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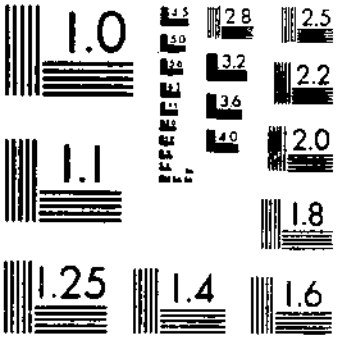

MICROCOPY RESOLUTION TEST CHART
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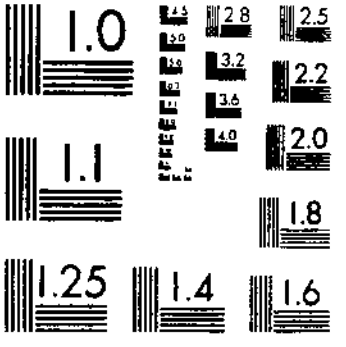

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BIOLOGICAL CONTROL OF THE ORIENTAL FRUIT FLY (Dacus dorsalis Hendel) AND OTHER FRUIT FLIES IN HAWAII

By
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and
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BIOLOGICAL CONTROL OF THE ORIENTAL FRUIT FLY (*Dacus dorsalis* Hendel) AND OTHER FRUIT FLIES IN HAWAII

By C. P. Clausen,[1] *professor of biological control and entomologist emeritus*, University of California, Riverside, D. W. Clancy, *entomologist, Entomology Research Division, Agricultural Research Service*, and Q. C. Chock,[2] *State entomologist*, Hawaii Department of Agriculture.

Two major fruit fly species have been present in Hawaii for more than 50 years. The first to gain a foothold there was the melon fly (*Dacus* (*Strumeta*) *cucurbitae* Coq.), discovered in 1895, which has inflicted heavy losses on vegetable crops grown for local consumption. The second is the better known Mediterranean fruit fly (*Ceratitis capitata* (Wied.)), first noted in the Islands in 1910, which quickly demonstrated its destructiveness to a wide range of fruits. The two species combined to place a severe check on the production of most fruits and vegetables and an added serious handicap on the development of export markets for certain of these crops.

The oriental fruit fly *Dacus* (*Strumeta*) *dorsalis* Hendel, first found in Hawaii in 1946, quickly spread throughout the Islands. It is recorded as a major fruit pest in India, Malaya, Indonesia, the Philippine Islands, Formosa, and the Mariana Islands, being native apparently to the Indo-Malayan Region. The discovery of the presence of this pest in the Islands, its rapid spread, and the exceedingly high rate of infestation that quickly developed in many fruits and vegetables, aroused great alarm, not only there but also in the continental United States. The development of air transportation with many flights daily from Hawaii to the Pacific Coast, greatly enhanced the risk of accidental carriage of adult flies and of immature stages in fruits and vegetables to the mainland. All three species are capable of establishing themselves and causing serious crop loss in some parts of the continental United States. It was, therefore, imperative that all possible methods of control be employed immediately, especially against the newly arrived oriental fruit fly, not only for the protection of the agricultural industry of Hawaii, but also to lessen the risk of establishment on the mainland.

The biological method of insect control has been more consistently successful in Hawaii than elsewhere, possibly because of its equable year-round climate. It is therefore understandable that this method of control, which had previously been attempted with only partial success in connection with the Mediterranean fruit fly and the melon fly, should be looked to with considerable hope for effective results against the newly arrived oriental fruit fly. Accordingly, the importation of natural enemies was undertaken, even prior to the development of research on other methods of control.

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[2] Retired.

While this latest program was directed against the oriental fruit fly, it was hoped that the collection of natural enemies of many fruit fly species from various parts of the world might yield also some parasites adaptable to the Mediterranean fruit fly and the melon fly to supplement those already established in the Islands.

EARLY WORK ON THE BIOLOGICAL CONTROL OF THE MEDITERRANEAN FRUIT FLY AND MELON FLY

Importation of natural enemies of the Mediterranean fruit fly was undertaken by the Hawaii Board of Commissioners of Agriculture and Forestry in 1912, when F. Silvestri, an Italian entomologist, was engaged to conduct a search for natural enemies. His investigations covered nearly 1 year, from July 1912, and the fields of search comprised West and South Africa and Australia (*30*).[3] As a result of his efforts, five species of parasites reached Hawaii alive, and three of them became permanently established. These were *Opius humilis* Silv.[4] from South Africa, *Dirhinus giffardii* Silv. from West Africa, and *O. tryoni* Cam. from Australia.

Upon his arrival in Honolulu on May 16, 1913, Silvestri had only 5 living specimens of *O. humilis* and 7 of *O. tryoni*. Rearing of the latter proved exceedingly difficult so that only 16 adults were released, 13 on the island of Hawaii. These, however, proved to be sufficient to establish the species. *O. humilis* was more amenable to insectary rearing, and 1,660 adults were released in the field by the end of 1913. Initial establishment of this species was effected through the release of 3 females and several males at Kona on the island of Hawaii. *Dirhinus* was reared very readily, and 16,185 were released during 1913. The few *Opius perproximus* Silv. that reached Hawaii alive failed to reproduce in the insectary, and no releases were made.

Psilus silvestrii (Kieff.) was reared and released in large numbers and persisted in Hawaii for some time but finally disappeared, so that establishment of the two species of *Opius* and *Dirhinus* constitutes Silvestri's major accomplishment. *O. humilus* was obtained originally from *C. capitata*, but *O. tryoni* had as its normal host *Dacus* (*Strumeta*) *tryoni* Frogg., though it had been recorded in Australia as attacking *C. capitata* also. The latter species is an introduced pest occurring in some parts of the country.

Silvestri's studies in West Africa had revealed a number of species of parasites of promise, which he unsuccessfully attempted to transport to Hawaii. A second effort to obtain them was made in 1914, when D. T. Fullaway and J. C. Bridwell, of the Hawaii Board of Commissioners of Agriculture and Forestry, went to West Africa and brought back living stocks of *Opius fullawayi* (Silv.) and *Tetrastichus giffardianus* Silv. (*16*). Both of these were successfully established in Hawaii. Their normal hosts in West Africa are several species of fruit flies, including *Ceratitis capitata*.

A third program for importation of natural enemies of the Mediterranean fruit fly was that by the U.S. Bureau of Entomology and Plant

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[3] Italic numbers in parentheses refer to Literature Cited p. 101.

[4] Fischer (*15*) recently concluded that *O. humilis* is a synonym of *O. concolor* Szepl., a common parasite of both the Mediterranean fruit fly and the olive fly *D. oleae* (Gmel.) in North Africa.

Quarantine in 1935–36. The investigations under this project were conducted in East and West Africa, Brazil, Malaya, India, and Ceylon, with importations also from Mexico. The area surveyed by R. H. Van Zwaluwenburg (*35*) and J. M. McGough in West Africa extended from Sierra Leone to Angola and the Belgian Congo. The Mediterranean fruit fly was very scarce in all countries of this region but other species of the genus and several species of *Dacus* yielded four or more species of *Opius*, of which 750 adults, representing three species, reached Hawaii alive. None of them became established.

The studies by Bianchi and Krauss (*5*) in Kenya, Tanganyika, and Zanzibar, East Africa showed that the Mediterranean fruit fly was rare in that region also, though found infesting a number of cultivated and wild fruits. Of the four species of *Opius* found there, two of them, *humilis* and *fullawayi*, were already established in Hawaii as a result of the earlier African importations by Silvestri and Fullaway. Because of shipping difficulties, no living parasite material from East Africa reached Hawaii alive.

The importations from Malaya, India, and Ceylon by F. C. Hadden (*20*) comprised principally six species of parasites, including three of *Opius*, reared mainly from *Dacus dorsalis* and *D. cucurbitae*. A total of 393 adults of the six species reached Hawaii alive. It is interesting to note that two of these species, then named *Opius longicaudatus* (Ashm.) and *O. persulcatus* (Silv.), the latter undoubtedly including *O. oophilus* Full. and *O. vandenboschi* Full., figured prominently in the later campaign against *D. dorsalis*.

The Brazilian material that was obtained by Fullaway (*18*) comprised *Opius cereus* Gahan and *O. bellus* Gahan, which apparently are restricted in their host preferences to the genus *Anastrepha*, though one generation of *O. cereus* was produced on Mediterranean fruit fly larvae in the insectary at Honolulu. Two staphylinid predators of the genus *Belonuchus*, which are of some importance in the field in Brazil, were imported and colonized in Hawaii, but did not become established.

The importations from Mexico comprised rather large numbers of adults of *Opius crawfordi* (Vier.), reared from *Anastrepha ludens* (Loew). This species failed to reproduce on either the Mediterranean fruit fly or the melon fly, and consequently did not become established.

The parasite and predator species imported and colonized against the two fruit fly species during the 1935–36 period did not result in a single establishment. The unexpected termination of the allotment of special funds at the end of the fiscal year 1935–36 necessitated the abrupt closing of the project before the areas had been fully explored, and the problems of shipment of material satisfactorily solved.

Biological control of the Mediterranean fruit fly in Hawaii prior to entry of *Dacus dorsalis* centered around the larval parasites *Opius humilis* and *O. tryoni*, imported by Silvestri in 1913 and, to a lesser extent, *O. fullawayi* and *Tetrastichus giffardianus*, established as a result of the efforts of Fullaway and Bridwell the following year. *O. humilis* was the first to be colonized in the field and quickly attained a high percentage of parasitization, but was then superseded by *O. tryoni*. The interrelation of these two species has been the subject of discussion for many years. Pemberton and Willard (*28*) asserted that *humilis* alone would probably have been more effective than the two species combined. This conclusion has since been questioned, but obvi-

ously any discussion of the subject must now be on purely theoretical grounds.

Detailed records of parasitization were taken by Back and Pemberton and following workers over a long period of years, with totals from all fruits ranging between 24.9 to 56.4 percent from 1914 to 1933 (*38*). *Opius humilis* attained its maximum parasitization in 1915 and *O. tryoni* in 1918, the latter species being dominant from 1916 onward. The highest percentage of parasitization has consistently been in coffee, as would be expected, because of the shallow pulp. The figures for larvae from this fruit range from 45.9 to 94.4 percent during the above-mentioned period. A substantial degree of control of the pest was obtained on that crop.

In other fruits, the percentage of parasitization has been much lower, as in guava 4.0–23.1 percent, mango 5.7–24.8 percent, and Chinese orange 3.5–12.8 percent, these figures in each case representing the yearly average over a 10-year period. There is thus a direct relationship between the depth of the pulp of the fruit and the extent of parasitization, but it is possible that other factors may have had an important influence in this respect.

One interesting and unexpected development was the complete disappearance of *Opius humilis* on the island of Oahu after it had persisted there for more than 20 years. The last specimen was found on the island in the late 1930's. It remains abundant in the Kona section of the Island of Hawaii, where after a period of years it equalled or exceeded *O. tryoni* in attack on larvae in coffee.

Biological-control activities against the melon fly were undertaken in 1915–16, when Fullaway (*17*) of the Hawaii Board of Commissioners of Agriculture and Forestry made collections of parasites in India and, on a smaller scale, in Ceylon, the Straits Settlements, Java, and the Philippine Islands. A larval parasite, *Opius fletcheri* Silv., that was found in all these countries except the last-named, was forwarded from India, released in considerable numbers in Hawaii, and quickly became established. Some reductions of the melon fly infestations resulted from the activities of *O. fletcheri*, and field parasitization at times averaged in the neighborhood of 50 percent. In general, however, the average parasitization has been appreciably less than this figure in recent years. An analysis of the incidence of parasitization in fruits of a wild cucurbit, *Momordica balsamina*, during 1950–51 by Newell, Mitchell, and Rathburn (*26*) reveals that successful attack by *Opius fletcheri* ranges up to a mean value of 34 percent during the winter months but declines sharply during June to September, when some collections show parasitization of 5 percent or less. The highest figure for any sample was 44.1 percent. During this period the fruit infestation seldom dropped below 90 percent.

COOPERATIVE PROJECT ON THE BIOLOGICAL CONTROL OF THE ORIENTAL FRUIT FLY

The initial effort toward importation of natural enemies of the oriental fruit fly had been made early in 1947, when the Hawaii Board of Commissioners of Agriculture and Forestry arranged, through L. B. Uichanco, dean of the College of Agriculture at Los Banos, Philippine Islands, for the forwarding of fruit fly puparia from that area. Through Uichanco's efforts, a total of 3,354 puparia were for-

warded during February to May of that year. Following this, entomologists of the Board collected and forwarded additional material from Luzon and Malaya (see pp. 8, 12). Then, in July 1948, the Bureau of Entomology and Plant Quarantine received an allotment of funds under the U.S. Department of Agriculture Research and Marketing Act for foreign exploration, and the quarantine handling and testing of the imported parasite material. D. W. Clancy was placed in charge of the domestic phase of this program.

In order to properly coordinate all phases of the biological-control project and to prevent duplication of effort by the increasing number of participating agencies, it was desirable to formalize the cooperation through a Memorandum of Understanding. Such a memorandum was drawn up and approved by authorized representatives of the cooperating agencies, and became effective September 30, 1948. The participating agencies were the U.S. Bureau of Entomology and Plant Quarantine, the Hawaii Agricultural Experiment Station, Board of Commissioners of Agriculture and Forestry of Hawaii (now Hawaii State Department of Agriculture), Hawaiian Sugar Planters' Association Experiment Station, and the Pineapple Research Institute of Hawaii.

In the general division of fields of work by the cooperators, major responsibility for foreign exploration, especially in Africa and India, was delegated to the Bureau, with the Hawaii Board of Commissioners of Agriculture and Forestry also participating, especially in the Pacific Area. The Bureau was also given responsibility for the quarantine handling of all imported material, and for the necessary studies on the parasites and predators to determine their exact relationships. The Division of Entomology and Plant Quarantine of the Hawaii Board of Commissioners of Agriculture and Forestry, under the direction of D. T. Fullaway and later of Q. C. Chock, had, in addition to its foreign exploration work, the rearing and colonization of all of the imported natural enemies, while the Department of Entomology of the Hawaii Agricultural Experiment Station, under the direction of H. A. Bess, undertook the field-recovery investigations and studies on evaluation of effectiveness of the different species of parasites and predators. That Station also provided the services of I. M. Newell for a 6-months' assignment on exploration work in India. The Hawaiian Sugar Planters' Association Experiment Station contributed the services of F. A. Bianchi for a period of 1 year. The Pineapple Research Institute made available an excellent quarantine insectary for the handling of the imported material, and various items of equipment, facilities, and services.

The inclusion of five agencies in the cooperative biological-control project made it essential that some overall supervision be provided on matters of policy relating to different phases of the project. At a meeting of representatives of these agencies on July 7, 1948, an advisory committee, under the chairmanship of Colin G. Lennox, president of the Board of Commissioners of Agriculture and Forestry, Territory of Hawaii, was named to deal with these matters.

The responsibilities of the Advisory Committee related to (1) assignment of the various areas of foreign investigation to the several cooperating agencies, (2) provision for and approval of quarantine facilities to be utilized in handling imported material, (3) responsibility for quarantine handling of imported material, and (4) approval

for field release from quarantine of parasite and predator species on recommendation of the unit responsible for studies on interrelations, or for their destruction if deemed undesirable.

One of the first problems confronting the Advisory Committee was methods to be employed in the importation of parasite material from foreign sources. Past experience, especially of the Mediterranean fruit fly expeditions sent out in 1935–36, had demonstrated the extreme difficulty of shipping only the adult parasites, as these, even when they arrived alive in Hawaii, were weakened and consequently unsuitable for laboratory propagation or field release. The Advisory Committee, as well as the various experienced entomologists consulted in the matter felt that, with the safeguards that could be set up for the quarantine handling of parasite material, the importation of host-fly puparia of any and all species was practicable and did not involve serious risk. This procedure was approved by the Board of Commissioners of Agriculture and Forestry, the agency responsible for enforcement of agricultural quarantine regulations in the Territory, and by the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture.

All of the known fruit fly parasites of consequence complete their development in and emerge from the host puparia, regardless of the stage in which oviposition takes place. The problems relating to the importation program consequently were greatly reduced.

Obviously, a "crash" program of this nature, designed for the importation of the maximum number of parasite species in a minimum of time, is subject to certain disadvantages. Perhaps the most important of these is that it provides little opportunity for the study of the habits of the parasites themselves in their native habitat, and of the role they play, if any, in the natural control of the different fruit flies in the countries of origin. The decision to include as many dacine fruit flies as possible in the importation program, rather than limit it to the oriental fruit fly alone, was influenced by earlier experience in work with the Mediterranean fruit fly, against which the most effective parasite was derived from another genus.

A substantial expansion of the biological control program took place in 1949 through an increase in Federal funds for research in Hawaii and through appropriation of funds by the State of California to its Agricultural Experiment Station for studies along several lines, including biological control, that were of particular interest to that State. These funds, both State and Federal, became available soon after July 1, 1949, and several necessary adjustments were immediately made in the biological-control project. The Memorandum of Understanding, previously referred to, that covered the cooperative program on biological control, was superseded on September 14, 1949, by a new memorandum embracing all phases of the fruit fly project.

The participation of the California Agricultural Experiment Station in the biological control program covered several phases, including foreign exploration. At the time that funds became available for this work by the State, its entomological explorers were already in the field in South China and Formosa in connection with other problems, mainly the California red scale. These explorers were consequently assigned the responsibility for assembling and forwarding fruit fly parasite material from those areas.

The studies on host and parasite nutrition, as well as on other problems, involved production of very large numbers of *Dacus dorsalis*, and a substantial portion of these flies were turned over to the Board of Agriculture and Forestry insectary for use in parasite production. In addition, a large part of the California efforts in Hawaii were on bioclimatic studies and on the development of methods for mass production, first of the host insects themselves and then of the more effective of the parasite species being released in Hawaii. Insect nutrition has a very important bearing upon rate of development, fertility, fecundity, et cetera, and advances in this study contributed substantially to more economical production of the insects involved. Thus, should the oriental fruit fly or other fruit flies become established at some future time in California, methods for mass production of parasites for use in control or eradication would already be known.

Another line of study was the determination of the effect of the various insecticides utilized in fruit fly control on the abundance and effectiveness of the parasites and predators. These chemicals would be extensively employed in case of any outbreak on the mainland, and their effect upon natural enemies would need to be known in order that biological control might supplement chemical control measures rather than be completely nullified by them.

Foreign Exploration for Natural Enemies

From 1947 to 1951 the search for fruit fly parasites was conducted in all of the major tropical and subtropical regions of the world with, of course, special emphasis on the areas in which the dacine Tephritidae are known to be abundant, and particularly the species of immediate concern—*Dacus dorsalis*. Clancy, Marucci, and Dresner (*11*) present a summary of the foreign work to September 1950.

In the course of these investigations 14 parasite collectors, representing three of the five cooperating agencies, participated in the search for natural enemies. They are listed below, with the countries in which each was engaged, and with their periods of service.

Foreign Parasite Collectors and Their Areas of Investigation

Territorial Board of Commissioners of Agriculture and Forestry:		
Q. C. Chock	Philippine Islands (Luzon).	July 1947–Jan. 1948
D. T. Fullaway	Philippine Islands (Luzon).	Jan.–Mar. 1948
N. L. H. Krauss	Malaya	May 1948–May 1949
	Australia	May–Sept. 1949
		Nov. 1949–Apr. 1950
	New Britain	Sept.–Nov. 1949
	New Caledonia	May–Aug. 1950
	Fiji	Sept. 1950
		Dec. 1950–May 1951
F. A. Bianchi (H.S.P.A. Expt. Sta., Coop.).	North India	Jan. 1949–June 1950
University of California:		
J. L. Gressitt	South China	July 1949–Sept. 1950
T. C. Maa	Formosa	July 1949–Oct. 1950

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Foreign Parasite Collectors and Their Areas of Investigation—Con.

Bureau of Entomology and Plant Quarantine:		
G. W. Angalet	Thailand	June 1950–Mar. 1951
	North Borneo	Mar.–July 1951
	Ceylon	Aug.–Oct. 1951
G. C. Beevor	South India	Feb. 1950–Apr. 1951
D. W. Clancy	Belgian Congo	Feb.–Apr. 1951
	Brazil	May–June 1951
T. C. Lawrence	South India	Feb.–July 1950
J. M. McGough	South, East, and West Africa.	Sept. 1948–Sept. 1951
I. M. Newell (Hawaii Agr. Expt. Sta., Coop.).	North India	Mar.–Sept. 1949
F. E. Skinner	South and East Africa	Sept. 1948–Sept. 1949
	Philippine Islands (Mindanao).	Sept. 1949–Sept. 1950
	North Borneo	Oct. 1950–Apr. 1951
N. D. Waters	India	Oct. 1949–Apr. 1951

All of these collectors deserve a great deal of credit for carrying out their investigations, often under extremely difficult conditions. In many countries, transportation was a major problem, as roads were exceedingly bad or almost nonexistant, living facilities were very poor and at times entirely lacking, and problems of health were a matter of constant concern. In spite of all of the handicaps that were encountered, they were able, in every case, to make substantial collections of a wide variety of fruits, rear out the fruit fly puparia, and ship them in a living condition to Hawaii.

The following account of the investigations in each of the different countries is a brief summary or compilation of the information contained in the quarterly reports submitted by the individual collectors or teams. The accumulated data are presented in this way in order to provide uniformity and continuity, as it has not seemed practicable to include summarized reports by the individual collectors because of overlapping of fields of work in some instances and the replacement of collectors in some areas before completion of the program.

Much of the African fruit fly material was identified by H. K. Munro and that from other areas by D. E. Hardy, and the many braconid parasite species encountered, a considerable number of which proved to be new, were identified mainly by D. T. Fullaway.

Philippine Islands

Investigations on the natural enemies of fruit flies in the Philippine Islands centered in Luzon and Mindanao, two quite widely separated islands having distinct differences in their flora and insect fauna. The work in Luzon in 1947 by the Hawaii Board of Agriculture and Forestry was the first effort to obtain natural enemies of the oriental fruit fly, and was completed prior to the setting up of the cooperative project, whereas that on Mindanao took place 2 years later. For these reasons, the studies on the two islands will be discussed separately.

The record of collections and shipments from both islands is given in table 1.

The search for natural enemies of the oriental fruit fly began in the Philippine Islands early in 1947, when entomologists of the Hawaii Board of Agriculture and Forestry arranged with Dr.

TABLE 1.—*Imports of fruit fly material from the Philippine Islands*

Host fruit	Period of collection	Dominant fruit fly species	Number of puparia shipped
LUZON			
Cananga odorata	Mar.–May 1947	*Dacus dorsalis* Hendel	1, 554
C. odorata and *Carica papaya.*	Feb. 1947	do	181
Carica papaya	Mar. 1947	do	200
Cucumis sativus	Mar. 1947	*D. cucurbitae* Coq	63
Eugenia javanica and *Garcinia venulosa.*	Feb. 1947	*D. dorsalis* Hendel *D. expandens* Walk	1, 356
Garcinia venulosa	Sept. 1947	*D. expandens* Walk	500
Psidium guajava	Aug. 1974–Jan. 1948	*D. dorsalis* Hendel	7, 905
Total			11, 759
MINDANAO			
Artocarpus heterophyllus.	Feb. 1950	*Dacus umbrosus* F	204
Averrhoa carambola	Feb.–Mar. 1950	*D. pedestris* (Bez.) *D. dorsalis* var. *occipitalis* (Bez.).	1,779
Citrullus vulgaris	Aug. 1950	*D. cucurbitae* Coq	62
Cucumis spp	Dec. 1949–Feb. 1950 Aug. 1950	do	4, 360
Cucurbitaceae sp	Feb. 1950	*Euphranta* sp	98
Dracontomelum dao	Dec. 1949-Sept. 1950	*Dacus limbiferus* (Bez.)	42, 007
Luffa cylindrica	Sept. 1950	*D. hageni* Meij	195
L. acutangula	Feb.–Mar. 1950	*D. cucurbitae* Coq	1, 778
Momordica charantia	Feb.–Sept. 1950	*Dacus* n. sp. near *hageni* Meij. *D. cucurbitae* Coq	1, 554
M. cochinchinensis	Feb. 1950	*Dacus* n. sp. near *hageni* Meij.	338
Psidium guajava	Feb.–Mar. 1950	*D. pedestris* (Bez.) *D. dorsalis* var. *occipitalis* (Bez.).	1, 470
Trichosanthes sp	Dec. 1949	*D. hageni* Meij	428
Total			54, 273

Uichanco, dean of the College of Agriculture at Los Banos, to assemble and forward fruit fly material from that area. Through Dr. Uichanco's efforts, six shipments of puparia, totaling 3,354, mainly of *Dacus dorsalis* from Java apple (*Eugenia javanica*) and ylang-ylang (*Cananga odorata*), were forwarded during February to May of that year.

Following this, the work on Luzon was taken up on a more extensive scale by Q. C. Chock of the Territorial Board during the period July 1947 to January 1948, and by D. T. Fullaway during January–March 1948. Mr. Chock was provided with laboratory facilities at Manila and much assistance in the field work through the courtesy of Dr. G. Merino, Director of the Bureau of Plant Industry of the Department of Agriculture.

Local conditions made it difficult to conduct extensive field investigations at that time; consequently, surveys were necessarily limited to the immediate vicinity of Manila, the Agricultural College at Los Banos, the Lipa Citrus Experiment Station in Batangas Province, and the Citrus substation at Lamao on Bataan. Also, the food situation in the Islands was critical at this time and the normal supply of fallen ripe fruits was not available, as the crops, even of the wild fruits, were thoroughly harvested, usually while still quite green. Because of this shortage of infested fruit, it was possible to obtain only 8,405 puparia for shipment to Hawaii.

The fruits of guava were heavily infested by *Dacus dorsalis* and fair numbers of larvae were obtained from ylang-ylang and Java apple. The degree of attack was quite low in mango, jackfruit, and citrus. Mangosteen (*Garcinia venulosa*) was found to be heavily infested by *Dacus cxpandens*, and cucumbers by *D. cucurbitae*, of which a high percentage were parasitized by *Opius fletcheri*.

In all fruits, the rate of parasitization of *Dacus dorsalis* by what were then designated as *Opius persulcatus* and *O. longicaudatus* was very low. It was found later that the true *O. persulcatus* does not occur in the Philippine Islands or Malaya, and that the material identified under that name comprised two species, since named by Fullaway as *vandenboschi* and *oophilus*. A staphylinid beetle, *Thyreocephalus albertisi* (Fauvel), was noted to be a common predator on fruit fly larvae in decaying fruit on the ground. Both adults and larvae attack the fruit fly maggots. From August 1947 to January 1948, 522 adult beetles, 5 larvae, and 55 eggs were obtained by Chock and shipped to Hawaii.

The field survey and collection program in Mindanao was started by F. E. Skinner early in September 1949, after his transfer from East Africa, and was continued through September of the following year. Headquarters were first set up near Cagayan, capital of Misamis Province, in the north-central part of the island, where living accommodations and travel facilities were made available through the Philippine Packing Corporation at Del Monte. The field work here was handicapped throughout by difficulties of transportation, and the base of operations was consequently transferred, early in January 1950, to Davao City, the capital of Davao Province, in the southeastern part of the island.

The most promising area in the north was the narrow strip of coastal vegetation between the sea and the grass-covered hills. There is virtually no commercial fruit-growing on the island and in this coastal area, as elsewhere, what little fruit that is produced, either wild or cultivated as on dooryard trees, is picked long before it ripens. Any that escape this premature harvest and ripen or fall to the ground, are very quickly disposed of by bats, birds, ants, rats, and domestic pigs and chickens. One fortunate exception is the fruit of *Dracontomelum dao*, a commercial timber tree, which is about 1 inch in diameter and contains a large seed. These apparently are disliked by animals and humans alike, and consequently could be obtained in quite large quantities throughout most of the year.

A trip during November to Lake Lanao (elevation 2,300 ft.) and surrounding area yielded almost no fruit. The market at Dansalan, capital of the province, revealed only a very few fruits, the most common

being that of *Lansium* sp., but the total quantity obtained was less than a bushel.

Mango trees seldom set fruits in the Davao area, but in February and March of 1950 a few weeks of dry weather were followed by abundant fruiting. However, this fruit production contributed little to obtaining fruit fly material, as the crop was harvested when less than half-grown. Mangoes sold on the local market at the equivalent of 25 cents each, twice the price of imported oranges and apples.

Guava is usually an excellent source of fruit fly larvae. A planting of 30 trees was found near Davao—the largest orchard seen in Mindanao. Arrangements were made with the owner to have the fruit of five trees left to ripen. In spite of evry care, the bulk of the fruit was taken by local residents, fruit bats, crows, et cetera. In the end, 2 gallons of fallen fruit fragments were obtained, and these yielded only a few puparia. This experience was typical of many other efforts to obtain material from cultivated fruit. In a period of 5 months only 50 gallons of guavas were obtainable from all sources.

A survey was made at the end of April in the vicinity of Zamboanga, at the western end of the island, and infested fruits of pummelo, jackfruit, ampalaya (*Momordica charantia*), smooth patola (*Luffa cylindrica*), and several other cucurbits were found in very small numbers. Here, as in other parts of the Orient, fruits and vegetables are often protected from fruit fly attack by being enclosed in paper bags.

In mid-April, a week was spent at Dumaguette, on the island of Negros, but here also fruit was scarce. Small quantities of infested *Luffa* and *Momordica* yielded fruit fly puparia that proved to be free of parasites.

A week was spent at Cebu, on the island of that name, during midsummer, to investigate possible sources of fruit fly material. Cebu is a center of mango culture and much of the fruit is shipped to other islands. A search through all producing areas quickly revealed the almost complete absence of infestation in this fruit.

Each fruit is enclosed in a paper bag while still very green, and the presence of many pigs, chickens, and ants insured the immediate and complete elimination of fallen fruit that otherwise might have served for the production of fruit flies. In this same area, fruits of ampalaya and tambis (*Eugenia aquea*) were examined, of which the latter proved to be infested with *Dacus* sp., but the larvae proved not to be parasitized.

Most of the fruit fly puparia collected in Mindanao were reared from *Dracontomelum dao*, and these were all *Dacus* (*Strumeta*) *limbiferus*, which apparently is restricted to that host. Muskmelon and watermelon were infested only by *D. cucurbitae*, and it was the dominant species obtained from ampalaya, cucumber, and patola (*Luffa acutangula*). *Dacus* (*Strumeta*) *pedestris* was the most abundant species in carambola and guava, and emerged in small numbers from *Luffa acutangula* also. *Dacus* (*Zeugodacus*) n. sp. near *hageni* was dominant in *Momordica cochinchinensis* and present also in *Luffa* spp. and ampalaya. *D.* (*Zeugodacus*) *hageni* was the only species reared from *Luffa cylindrica* and *Trichosanthes* sp., and was associated with *Dacus* n. sp. near *hageni* in *Momordica cochinchinensis*. Jackfruit (*Artocarpus heterophyllus*) was infested only by *D.* (*Strumeta*) *umbrosus*.

The true *Dacus dorsalis* did not appear in the collections, though the variety *occipitalis* was present, in association with *D. pedestris*, in carambola and guava.

Other fruits that were examined and found to be infested with larvae of *Dacus* but not sufficiently abundant for collection in quantity were breadfruit, pummelo, orange, grapefruit, cashew (*Anacardium occidentale*), chayote (*Sechium edule*), squash (*Cucurbita maxima*), gourd (*Lagenaria leucantha*), and star apple (*Chrysophyllum cainito*). Fruits found to be free from infestation at the time of examination were avocado, banana, coffee, papaya, fig, eggplant, sugar-apple (*Annona squamosa*), and sapodilla (*Achras zapota*).

The field parasitization of all species proved to be relatively low, as would be expected because of early harvesting of the fruits. In *Dracontomelum dao*, the total parasitization by three or more species of *Opius* was less than 1 percent during July but rose appreciably with advance of the fruiting season, and in late September, with few fruits remaining, it reached more than 60 percent at Lawayon. Several thousand puparia from guava, held for parasite emergence, yielded only 2 specimens of *Opius*, and some hundreds of *Dacus* puparia from jackfruit, ampalaya, and patola produced no parasites.

Malaya

The fruit-fly-collection program in Malaya was started by N. L. H. Krauss of the Hawaii Board of Agriculture and Forestry in May 1948, and continued until May of the following year. Because of the unsettled conditions on the peninsula, it was not possible to make extended surveys over the countryside, and collections were made only in limited areas about the cities and in certain outlying localities. Headquarters were established first at Kuala Lumpur, where laboratory and various other facilities were kindly provided at the Department of Agriculture, and it was possible to make collections at the Department's Experiment Station at Serdang, 15 miles away. The work here was interrupted from time to time by occasional survey trips to Penang, Malacca, Kuantan, Singapore, et cetera. Extensive shipments were made from June 1948, onward.

During April and May 1949, activities were centered at Singapore, where facilities for the rearing work were made available at the famous Botanic Gardens, through the courtesy of R. E. Holttum, Director.

Carambola (*Averrhoa carambola*) proved to be much the most productive of the host fruits available in Malaya, and quantity collections yielded 283,645 puparia of *Dacus dorsalis* for shipment to Hawaii. This was about four-fifths of the total from all sources. Next in order of abundance of *D. dorsalis* were *Solanum verbascifolium* and *Capsicum* sp. Other hosts of *D. dorsalis*, not sufficiently abundant for large-scale collections, were guava, lime, tomato, mangosteen (*Garcinia dulcis*), *Mangifera foetida*, and *Areca catechu*.

Dacus umbrosus was common in chempedak (*Artocarpus polyphema*), while large numbers of *D. cucurbitae* were obtained from various Cucurbitaceae, which yielded also a lesser number of *D. hageni*. Other fruit flies reared from native fruits were *Dacus* (*Paratridacus*) *expandens* Wlk. from mangosteen, *D. pedestris* (Bez.) from ylang-ylang (*Cananga odorata*) and *D.* (*Strumeta*) *megregori* (Bez.)

from spinach jointfir (*Gnetum gnemon*). The data relating to shipments to Hawaii are given in table 2.

TABLE 2.—*Imports of fruit fly material from Malaya*

Host fruit	Period of collection	Dominant fruit fly species	Number of puparia shipped
Artocarpus polyphema	June 1948–Jan. 1949	*Dacus umbrosus* F	8, 158
Averrhoa carambola	do	*D. dorsalis* Hendel	283, 645
Capsicum sp	do	do	6, 427
Cucumis sativus	do	*D. cucurbitae* Coq *D. hageni* Meij	2, 110
Cucurbitaceae (mixed)	Jan.–May 1949	*D. cucurbitae* Coq *D. hageni* Meij	23, 851
Eugenia sp	July 1948–Mar. 1949	*D. dorsalis* Hendel	1, 086
Lagenaria vulgaris	Nov. 1948	*D. hageni* Meij	989
Luffa cylindrica	Dec. 1948	*D. cucurbitae* Coq *D. hageni* Meij	359
Mangifera indica	Nov. 1948–Jan. 1949	*D. dorsalis* Hendel	251
Solanum verbascifolium	June 1948–Jan. 1949	do	12, 216
Total			339, 092

The field parasitization of *Dacus dorsalis* by the several species of *Opius* was consistently low, with those comprising the "*persulcatus* complex" predominating. Inasmuch as these and *Opius longicaudatus* var. *malaiensis* were found to be established in Hawaii late in 1948, the emphasis in the collection program in Malaya was shifted during 1949 to the chalcidoid parasites, several of which were known to be present in that region. Large numbers of fruit fly larvae and puparia were exposed to their attack in the field before shipment to Hawaii. These parasites comprised mainly *Aceratoneuromyia indicum*, *Pachycrepoideus vindemmiae*, *Tachinaephagus* sp., and *Spalangia* sp.

South China and Formosa

The investigations on fruit flies and their natural enemies in South China and Formosa were conducted by the University of California under the immediate direction of J. L. Gressitt, with Chien-chi Wu and Y. W. Djou assisting in South China and Tsing-chao Maa in Formosa. This work was on a part-time basis in conjunction with studies on natural enemies of the red scale and red mites for importation into California.

A summary of the data covering the shipment of fruit fly parasite material from these two areas to Hawaii is given in table 3.

During the last half of 1949 and early 1950, very intensive collections were made of a wide variety of fruits in the Canton area of South China to determine the presence or absence of *Dacus dorsalis* in that region. These fruits included guava, carambola, citrus, mango, banana, papaya, loquat, and persimmon, among them being several that were known to be favored hosts of that pest. Not a single specimen of *D. dorsalis* was obtained from these collections or from later collections in other areas of South China. This is especially surprising in view of

TABLE 3.—*Imports of fruit fly material from South China and Formosa*

Host fruit	Period of collection	Dominant fruit fly species	Number of puparia shipped
SOUTH CHINA			
Cucurbitaceae spp.	July–Sept. 1950	*Dacus cucurbitae* Coq. + *D. nubilus* Hendel	3, 465
Luffa spp.	July 1950	*D. cucurbitae* Coq.	625
Lycopersicon pimpinellifolium.	June 1950	*D. latifrons* (Hendel)	209
Momordica charantia	July–Sept. 1950	*D. cucurbitae* Coq. + *D. nubilus* Hendel	435
Solanum spp.	Mar.–July 1950	*D. latifrons* (Hendel)	41, 121
Total			45, 855
FORMOSA			
Eugenia javanica	Aug. 1949–Oct. 1950	*Dacus dorsalis* Hendel	16, 574
Eugenia spp., *Mangifera indica*, and *Clausena lansium* (mixed).	Aug. 1950	do	5, 898
Luffa sp.	Aug. 1950	*D. cucurbitae* Coq. + *D. nubilus* Hendel	1, 700
Mangifera indica	July 1950	*D. dorsalis* Hendel	6, 239
Psidium guajava	Oct. 1949–Nov. 1950	do	171, 937
P. cattleianum	Sept.–Oct. 1950	do	20, 397
Total			222, 745

the general occurrence of the species on the Asiatic mainland from Thailand to India, and its abundance in Formosa, only a short distance from the South China coast.

In addition to the Canton area, surveys were made during August and September on the Luichow Peninsula, the most southern area of mainland China, and in Kiangsi, Kiangsu, Hupeh, and Shantung provinces during the early summer of 1950. Fruit was scarce in all of these areas, with very few fruit flies obtained from collections on the Peninsula and almost none in the provinces mentioned above.

About 90 percent of all fruit fly puparia obtained in South China for shipment to Hawaii proved to be *Dacus* (*Strumeta*) *latifrons*, which develops in fruits of *Solanum* spp., especially those of *S. torvum*. The fruits of *Luffa* sp. yielded only *D. cucurbitae*, and those of ampalaya (*Momordica charantia*), while infested with the latter species, yielded also a considerable number of *D.* (*Zeugodacus*) *nubilus*. The only other host fruit that yielded more than a single species was the oriental pickling melon (*Cucumis melo* var. *conomon*), which, while predominantly infested with *D. cucurbitae*, produced a fair number of *D. nubilus* and an occasional *D. latifrons*.

An unidentified species of Staphylinidae of the genus *Philonthus* was noted to be a common predator on larvae of fruit flies in melon

fields. Both adults and larvae participate in this attack, but do not limit their feeding to fruit fly larvae. In suitable locations they feed extensively on house fly and other larvae. Shipments of this beetle, totaling 102 pupae, were forwarded to Hawaii. In addition, 650 adult hymenopterous parasites, comprising several species, were included in the consignments of material from South China.

The studies on fruit flies and their natural enemies in Formosa were started by Dr. Maa in July 1949, and continued until October 1950. The oriental fruit fly has been established on the island for a long period, and is the most destructive member of the family Tephritidae occurring there. The fruits of red and white pummelo and "mikan" are usually infested in excess of 50 percent, while oranges are only lightly infested. Other fruits that are heavily infested, and which provided the bulk of material for shipment to Hawaii, are guava (*Psidium guajava*), strawberry guava (*P. cattleianum*), Java apple (*Eugenia javanica*), mango (*Mangifera indica*), *Eugenia littoralis*, Surinam cherry (*E. uniflora*), and Chinese wampee (*Clausena lansium*). The main areas of collection were Yilan on the northeast coast, which is the most important producing area for guava and plum, Tainan on the southwest coast, and Arisan and Chia-yi on the central western slope of the mountain range. The infestation in guava at Yilan was exceedinglyg high, especially in August and September, towards the end of the fruiting season, the yield being approximately 20 puparia from each pound of fallen fruit.

The first shipments of puparia were made to Hawaii in August 1949, and continued to the end of the 1950 season. The bulk of the material was obtained from guava, and this and other tree fruits were infested solely by *D. dorsalis*. *Luffa* sp. yielded mainly *D. cucurbitae*, with a small number of *D. nubilus*. The *D. dorsalis* puparia were parasitized by five species of *Opius*, of which the most important in the field were *O. formosanus* and *O. arisanus*, the latter being most abundant in the subalpine region during the late summer and autumn. Field parasitization was the highest in larvae from *Eugenia littoralis*, amounting to about 30 percent by *O. formosanus*, and 13 percent in Surinam cherry. It was found that *O. formosanus* undergoes protracted diapause in the host puparium during the winter, a valuable adaptation for survival through winter periods during which temperatures may approach freezing.

In addition to the shipments of puparia that yielded hymenopterous parasites, two consignments of a parasitic mite, *Tyroglyphus* sp., which attacks fruit fly larvae and pupae in the soil, were forwarded to Hawaii for testing.

Thailand (Siam)

G. W. Angalet arrived in Thailand early in June 1950, and his surveys and collections there continued without interruption until the latter part of March 1951. Immediately after arrival, arrangements were made, through Mr. G. S. Quate, agricultural attaché at the American Embassy, to meet the higher officials of the Thailand Ministry of Agriculture. Mr. B. Balenkura, chief entomologist, was assigned as advisor in the investigations and proved to be exceedingly helpful in arranging for various facilities and in planning travel to distant parts of the country. Excellent laboratory facilities were provided at the Bangkok Noi Fruit Station and the staff of that station

provided a great deal of assistance in the assembling of fruits of many kinds and in rearing out the fruit fly puparia. Early surveys with methyl eugenol traps quickly demonstrated the presence of *Dacus dorsalis* in considerable numbers in all fruit-producing areas. During the 10 months covered by the survey practically all of the main agricultural areas were visited, though some were reached from Bangkok with considerable difficulty.

The rainy season came to an end in October and field studies were thereafter much more readily accomplished. In that month, two visits were made to the towns of Songkla and Haad Yai in the southern part of the country. Most of November was spent at Chantaburi and Rayong in southeast Thailand, the largest citrus-producing area in the country, where many other fruits are grown in quantity. Later in that month, and in February also, trips were taken to northern Thailand, where observations and collections were made from Chingmai to the Burma border. This is a forested, mountainous area, but considerable quantities of wild fruits were available, especially in the vicinity of Muang Fang.

A survey in central Thailand in December, centering around the towns of Nakom Pathon and Bang Pong, revealed an abundance of mango and *Eugenia* trees, which would provide an excellent source of fruit fly material in late spring.

During the latter part of February 1951 an extended trip of 2,000 miles was made by jeep to the northeastern part of the country in company with the agricultural attaché and the air attaché from the Embassy. This area in general did not appear to be promising for the collection of fruit fly material, but there were indications of abundant production of wild fruit in the vicinity of Lopburi, and between the towns of Korat and Ban Phai.

The survey as a whole yielded fairly adequate sources of supply of a large variety of cultivated and wild fruits. The details of the shipment of material to Hawaii are given in table 4.

By far the most abundant fruit, and the one that yielded the bulk of fruit fly puparia, was the jujube (*Zizyphus jujuba*), which occurs throughout the country and ripens during the late autumn and winter. The native variety is only lightly infested by fruit flies, usually yielding only about 5 larvae per pound of fruit, whereas another variety imported from India is invariably heavily infested, with a yield up to 50 per pound. Unfortunately, plantings of this variety were not common, so that main reliance had to be placed on the native variety. The great majority of flies from this host proved to be *Carpomyia vesuviana*, with a fair number of *Dacus dorsalis*, and an occasional *D. latifrons*. The handling of jujube fruit to obtain puparia was complicated by heavy infestation of a lepidopterous pest. Often half of the fruits contained the caterpillars, and such fruits never yielded fruit fly larvae. *Carpomyia* and *D. dorsalis* were obtained in about equal numbers from *Chickrassia velutina*, and the first was also reared in small numbers from fruits of *Eugenia* spp., eggplant (*Solanum melongena*), carambola (*Averrhoa carambola*), and guava.

Guava is generally considered to be one of the favored hosts of *Dacus dorsalis*, and is very heavily infested in many countries, so that this fruit was expected to provide a good supply of puparia for shipment. Two small orchards were rented and the fruit obtained from an additional 80 trees near Bangkok. The outcome was exceedingly

TABLE 4.—*Imports of fruit fly material from Thailand*

Host fruit	Period of collection	Dominant fruit fly species	Number of puparia shipped
Artocarpus polyphema	Oct. 1950	*Dacus dorsalis* Hendel	220
Averrhoa carambola	do	do	1,070
Chickrassia velutina	do	*Carpomyia vesuviana* Costa. *Dacus dorsalis* Hendel	1,320
Citrullus vulgaris	Feb. 1951	*D. cucurbitae* Coq *D. nubilus* Hendel	162
Eugenia spp.	Nov. 1950–Mar. 1951.	*D. dorsalis* Hendel	7,500
Lycopersicon esculentum.	Feb. 1951	*D. nubilus* Hendel *D. latifrons* (Hendel)	86
Momordica charantia	July 1950	*D. cucurbitae* Coq	1,720
M. cochinchinensis	Aug. 1950	*D. nubilus* Hendel *D. dorsalis* Hendel *D. cucurbitae* Coq	400
Psidium guajava	Nov. 1950	*D. dorsalis* Hendel *D. nubilus* Hendel *Carpomyia vesuviana* Costa.	60
Randia dumetorum	Mar. 1951	*Dacus* sp.	200
Solanum spp.	Aug. 1950–Mar. 1951.	*D. latifrons* (Hendel)	9,387
Zizyphus jujuba	July 1950	*Carpomyia vesuviana* Costa. *Dacus dorsalis* Hendel	135,734
Total			157,859

disappointing, as only about 20 puparia were obtained from each 100 bushels of fruit, and only a portion of these were *D. dorsalis*. When this situation became apparent, collection of guavas was discontinued and attention centered on more productive sources.

Because of the abundance of its fruit, jujube was the main source of supply of *D. dorsalis*, though it represented only about one-sixth of the fruit fly population in the host. Fruits of several species of *Eugenia*, especially *E. malaccensis* and *E. javanica*, were infested almost exclusively by this species, but the portion infested was low, and the quantity of fruit available was small and expensive. Growers stated that the crop is usually heavily infested after the "mango" showers in March. The fruit of *Eugenia* proved difficult to handle in fruit fly rearing, as it decays within a week after picking. It was perhaps unfortunate that the work in Thailand was terminated before the mango fruiting season, as this host was expected to provide an abundance of *D. dorsalis*.

Fruits of carambola were obtained in limited quantity in southern Thailand but produced only a very few flies other than *D. dorsalis*. The few puparia obtained from *Artocarpus polyphema* were all of that species. The fruits of an unidentified wild *Solanum* encountered at Chantaburi were heavily infested, and several hundred pounds collected during February provided more than 7,500 puparia of *D. latifrons* for shipment. This species had also comprised practically all of the fruit fly yield from eggplant during the preceding summer.

It was noted that only the yellow-fruited varieties of eggplant were attacked by fruit flies, an observation also made in South India the preceding year.

One of the most common fruit flies, on the basis of variety of fruits infested, is *D. nubilus*. It was the dominant species in fruits of *Momordica cochinchinensis*, was present in about equal numbers with *D. latifrons* in tomato, and played a secondary role in ampalaya (*Momordica charantia*), watermelon, and guava. The melon fly, *D. cucurbitae*, was the most abundant species infesting the fruits of ampalaya and watermelon and was present in small numbers in *Momordica cochinchinensis* and tomato. The flies infesting the fruits of *Randia dumetorum*, obtained in small numbers, proved to be a new species of *Dacus*.

The puparia of *Carpomyia vesuviana* from *Zizyphus* appeared to be the most highly parasitized of all of the species encountered, and yet even here the field parasitization ranged up to a maximum of only 20 percent. Of the chalcidoid parasites, only *Spalangia* sp. was noted to be of general occurrence, but only in small numbers.

Ants are exceedingly abundant throughout Thailand and they undoubtedly play an important role in the natural control of fruit flies. In holding fruit for development and emergence of the larvae, extreme care was required to exclude ants from the trays holding the fruit, and the trays into which the larvae dropped for pupation.

Java

Investigations were not conducted in Java by personnel of the fruit fly project because of difficult working conditions on the island at that time, and also because of the belief that the important fruit flies and their parasites in this general area had already been obtained from Malaya. However, in July 1951, through the courtesy of Miss H. Vos of the Indonesian Ministry of Agriculture, a shipment of fruit fly puparia from Bogor was sent to Hawaii. This comprised 330 puparia of *Dacus dorsalis* from carambola and 225 from pepper (*Capsicum frutescens*).

Borneo

The investigations in North Borneo were started by F. E. Skinner at the end of October 1950, and continued through March of the following year, when G. W. Angalet took over the work. The officers of the Agriculture Department at Jesselton, and of the Forestry Department at Sandakan, were exceedingly helpful in providing information relating to fruit-producing plants and areas for their collection, and in arranging for facilities of many kinds. The details covering collection and shipment of material to Hawaii are given in table 5.

The collecting area in British North Borneo centered around Jesselton on the northwest coast. This is an area of lowlands that is intensively cultivated, with rubber and rice as the major crops. Most of the primary forest of the hill areas has been destroyed but there are large areas of secondary forest. The two main areas for the production of fruit and vegetables are Tamparuli, about 20 miles north of Jesselton, and Papar, about the same distance to the south. The area within reach by rail and road comprised several thousand square

TABLE 5.—*Imports of fruit fly material from Borneo, 1951*

Host fruit	Period of collection	Dominant fruit fly species	Number of puparia shipped
Artocarpus heterophyllus	Apr.–May	*Dacus umbrosus* F. *D. cucurbitae* Coq. *D. hageni* Meij.	3, 470
Averrhoa carambola	Jan.–May	*D. dorsalis* Hendel *D. dorsalis* var. *occipitalis* (Bez.).	7, 250
Baccaurea angulata	May	*D. dorsalis* Hendel *D. cucurbitae* Coq.	450
Carica papaya	Apr.–May	*D. dorsalis* Hendel	337
Cucumis sativus	Jan.–July	*D. cucurbitae* Coq *D. hageni* Meij.	9, 398
Cucurbita maxima	June	*D. cucurbitae* Coq.	105
Dracontomelum dao	do	do	350
Eugenia javanica	May	*D. dorsalis* Hendel *D. cucurbitae* Coq.	1, 000
Lagenaria leucantha	Apr.–July	*D. hageni* Meij. *D. cucurbitae* Coq.	540
Lufta acutangula	Jan.–July	*D. cucurbitae* Coq. *D. hageni* Meij.	20, 618
Mangifera indica	Apr.–July	*D. dorsalis* Hendel *D. cucurbitae* Coq.	23, 570
Momordica charantia	Jan.–May	*D. cucurbitae* Coq. *D. hageni* Meij.	1, 742
Psidium guajava	May	*D. cucurbitae* Coq. *D. dorsalis* Hendel	180
Solanum sp.	do	*D. dorsalis* Hendel	97
Unidentified fruits	June	*D. cucurbitae* Coq.	425
Total			269, 532

miles. Short trips were made to Sandakan on the east coast, where several days were spent in the Kabili Forest Reserve, and later, to the foothills of Mt. Kinabalu, the tallest mountain in Borneo. However, the wild fruits in the primary forests did not prove nearly so productive of fruit fly material as did those of the cultivated areas.

Cultivated cucurbits, especially patola (*Luffa acutangula*) were available in the field immediately after Mr. Skinner's arrival at the end of October, and proved to be quite heavily infested by *Dacus cucurbitae*, and to a lesser extent by *D. hageni*. *Opius* sp. and *Spalangia* sp. were reared in small numbers from the puparia of these fruit flies.

A greater variety of fruits became available for collection about the time Mr. Angalet took over the work late in March 1951, though *Luffa* still yielded the most fruit fly material. *D. cucurbitae* was by far the most abundant of the fruit flies encountered, and was the dominant species in all of the Cucurbitaceae and in dao dragonplum (*Dracontomelum dao*), guava, *Solanum* sp., and an unidentified fruit. It was also reared in smaller numbers from mango, carambola (*Averrhoa carambola*), jackfruit (*Artocarpus heterophyllus*), gourd (*Lagenaria leucantha*), *Baccaurea angulata*, and rather abundantly from Java apple (*Eugenia javanica*).

The oriental fruit fly was found to infest mangoes quite heavily, and was also the most abundant species in carambola, *Eugenia javanica*, *Baccaurea angulata*, and papaya, and was very nearly equal to *D. cucurbitae* in guava and *Solanum* sp. This slight dominance of *D. cucurbitae* over *D. dorsalis* in guava is much in contrast to the situation in other regions where studies were made. Large-scale collections of this fruit in India, Malaya, and Formosa, where both species occur in abundance, did not show infestation by *cucurbitae*. *D. dorsalis* var. *occipitalis* was found to be present only in the fruits of carambola.

D. hageni was reared from most of the fruits listed, though usually in rather small numbers, and it was the dominant species only in *Lagenaria leucantha*. *D. umbrosus* was the most abundant species in jackfruit and occurred in relatively small numbers in *Momordica* sp.

In general, the parasitization of fruit fly stages in North Borneo was low. For example, the melon fly never showed parasite attack in excess of 1 percent. *D. dorsalis* likewise was relatively lightly parasitized, much less than in other countries of tropical Asia.

India

At the beginning of the fruit fly biological-control program, India was considered to be one of the areas warranting immediate major attention. The oriental fruit fly was known to occur there; in fact, India is generally believed to fall within the general area comprising the native home of the fly, and several species of parasites were known to attack it in that country. A wide variety of fruits were known to be infested by fruit flies, many of them by several species. The country is so large and, with both the wild and cultivated vegetation, so different in the north compared to the south, that no single group of collectors operating from a common base could hope to give adequate attention to all areas during the anticipated period to be covered by the investigations. For that reason, the field of operation was divided into two: North India, with headquarters at Ranikhet, United Provinces (later transferred to Bareilly), and South India, with headquarters at Bangalore, Mysore. The observations and results attained in the two areas will be discussed separately.

The work in North India was started in late January 1949, when F. A. Bianchi arrived in Calcutta and shortly established headquarters at Ranikhet in the Kumaon District of the United Provinces. He was joined by I. M. Newell, to complete the team, at the end of March. Headquarters were transferred from Ranikhet to Bareilly in October. Dr. Newell returned to Hawaii at the end of September and was replaced by N. D. Waters, who arrived the following month. Mr. Bianchi continued the work in North India until the end of March 1950, and spent the months of April and May in South India with the team assigned to that area, before returning to Hawaii. Mr. Waters then continued alone until the completion of the program in October 1950.

The first search for infested fruit was at Calcutta during February and March. *Ficus* spp. and *Mimusops* were fruiting at that time but showed no infestation. Fruit in the market during this period included grapefruit, tangerine, papaya, guava, various melons, et cetera, but none of them showed evidence of attack. This, however, was not conclusive, as the fruit on the Calcutta stands at this time originated

at distant points, much of it from far south, and undoubtedly was carefully sorted before shipment.

Ranikhet, the town initially selected as headquarters for North India, is situated in the Himalayan foothills at an elevation of about 6,000 feet. The climate here is temperate, and the area that could readily be explored extended from Bhimtal, 31 miles in one direction, to Almora, 27 miles in the opposite direction. The elevation of this area ranges from 3,000 to 7,000 feet. The vegetation at the higher elevations was that of the temperate zone, with cultivated fruits comprising apple, pear, apricot, peach, plum, cherry, et cetera, and a wide variety of wild fruits. The lower elevations were subtropical and provided a range of fruits quite different from those growing at the higher elevations. The wild fruits available at this time included three species of fig, a wild pear, two species of chestnuts, a wild plum, a species of *Opuntia*, *Myrsine* spp., *Berberis* spp., *Crataegus* sp., *Mimusops* sp., *Ilex* sp., et cetera.

A few of the wild figs obtained at Ranikhet during April showed infestation by fruit fly larvae, while the fruits of Himalaya holly (*Ilex dipyrena*), available in small quantity during June, showed a high incidence of infestation. Barberry species (*Berberis aristata* and *B. vulgaris*), which reach the peak of the fruiting period during May and June, were abundant at elevations from 3,000 to 6,000 feet. At the lower elevations, the berries were heavily attacked by fruit flies, but near Ranikhet, at the higher elevation, the incidence of attack was very low, some collections yielding nothing at all. In all sections that were surveyed, fruit production by *B. vulgaris* was less than 1 percent of normal, due to heavy frost at blossoming time. Up to 161 collectors were engaged at one time in obtaining the berries of this plant.

During July to September, special attention was given to mango and guava because these two are favored hosts of the oriental fruit fly. August collections of mangoes from the hill areas proved to be only lightly infested. One lot of 1,500 that had been permitted to ripen on the trees and then piled beneath them for weekly collection of puparia yielded a total of only 635. During the 1950 season, which provided the bulk of the collections from mango, the infested fruit was obtained mainly from Mahliabad and Saharanpur.

Guava collecting was good during August and September 1949 in the Ranikhet and Bareilly areas, though the quantity available proved to be more limited than anticipated and the percentage of infestation was low except at Kohot, a small guava-producing area, where about 20 percent of the fruit was noticeably infested. At Izatnagar the infestation reached 90-100 percent in August 1949. Information obtained from several sources regarding fruit fly attack indicated that, in the Allahabad and Lucknow areas, the crop was very lightly infested in 1947 and 1948, whereas in 1949 it showed the greatest injury for many years. Unfortunately, collecting activities during that season were confined to other areas that proved to be not so productive.

All forms of *Citrus* appear to be free from attack by fruit flies in northern India. Large quantities of fruit were examined, both in the field and in the markets, and resulted in the finding of only 2 larvae in a single fruit of pummelo at Jubbulpore.

Of the cultivated deciduous fruits, peach appeared to be most subject to attack by fruit flies. Arrangements were made to purchase

the entire crop from nine trees at Bareilly, and these were guarded night and day to prevent theft. The fruit ripened normally on the trees, rather than being picked green, and proved to be about 95 percent infested by *Dacus* (*Strumeta*) *zonatus*. Pears were likewise heavily infested, especially the early portion of the crop. Arrangements were made during the summer of 1950 to have weekly shipments of infested apples and pears sent from Kashmir to Bareilly for examination and rearing out of the fruit fly material, but the extremely heavy floods of the Jehlum River in September completely covered the producing areas.

The fruits of a wild pear (*Pyrus pashia*) and a wild apple (*P. baccata*), which were approaching maturity in June, appeared promising as a source of material, though they showed no infestation at that time. The ripening fruit, when examined later, likewise showed no attack by fruit flies.

The fruits of jujube (*Zizyphus jujuba*) provided more than half of the total fruit fly puparia obtained for shipment to Hawaii. Several groves examined at Agra in December 1949 showed heavy infestation though the fruit was not yet ripe. About 70 gallons of fruit were obtained during the month, and later about 2,000 pounds from the same locality, and from Bareilly. The total yield of puparia exceeded 400,000.

Tomatoes were infested by *Dacus nubilus* in all areas in which observations were made, though usually the portion of the crop lost from this cause was not high. About 10 gallons of fruit per day were collected at Ranikhet during the late summer of 1950, which yielded 6,607 puparia for shipment.

The Cucurbitaceae, especially *Luffa* spp., watermelon (*Citrullus vulgaris*), muskmelon (*Cucumis melo* var. *utilissimus*), and ampalaya (*Momordica charantia*), proved to be excellent sources of fruit fly material. The extent of the infestation in *Luffa* may be judged from the rearings from about 700 pounds of fruit collected at Bareilly during October and November 1949. This comparatively small amount yielded more than 22,000 puparia. During the following summer, additional large quantities were obtained in that locality and at Agra, mostly from patola (*Luffa acutangula*) and small patola (*L. aegyptiaca*).

Watermelons were commonly infested in the Agra area, and collections during the late summer and autumn yielded large numbers of puparia, obtained mostly from melons left in the field after the crop had been marketed.

The large number of puparia from jujube shipped to Hawaii yielded only *Carpomyia vesuviana*, while those from *Berberis* spp. were exclusively *Rhagoletis* sp. (?). All other species that were contained in the shipments were found to develop in several host fruits. *Dacus zonatus* was the only species obtained from the large number of puparia from peach; it was the dominant species in mango, and was present also in small numbers in *Luffa* spp. Rather strangely, *D. dorsalis* was obtained only from mango and guava. While the guava material shipped to Hawaii yielded only *D. dorsalis*, this may be misleading, as rearings in India by Bianchi, with the flies identified by D. E. Hardy, indicated that the great majority were *D. zonatus*, and *D. dorsalis* was represented in the consignments only to the extent of about 10 percent.

Dacus (*Didacus*) *ciliatus* was the only fruit fly reared from ampalaya, and was the dominant species in watermelon, while it was secondary in abundance in muskmelon and *Luffa* spp. *D. cucurbitae* was dominant in the two last-named fruits and in cucumber (*Cucumis sativus*), and was present in small numbers in watermelon. Watermelon yielded, in addition to the species mentioned above, a small number of *Myiopardalis pardalina* Bigot. *Dacus nubilus* was the only fruit fly reared from tomato, but it was present in considerable numbers in association with other species in *Luffa* spp.

The details of the shipment of fruit fly material from North India to Hawaii are given in table 6. In addition, 9,033 adults of *Bracon fletcheri* were reared and forwarded in April 1950.

TABLE 6.—*Imports of fruit fly material from North India*

Host fruit	Period of collection	Dominant fruit fly species	Number of puparia shipped
Aegle marmelos	July 1950	Not identified	400
Berberis spp	May 1949–July 1950	*Rhagoletis* sp.(?)	16, 780
Citrullus vulgaris	May 1949–Oct. 1950	*Dacus ciliatus* Loew	28, 680
Coccinia indica	Oct. 1950	Not identified	245
Cucumis melo var. *utilissimus*.	Apr.–June 1950	*Dacus cucurbitae* Coq.–*D. ciliatus* Loew	35, 396
Cucumis sativus	June–Sept. 1950	*D. cucurbitae* Coq	539
Cucurbitaceae (mixed).	Sept. 1949–Oct. 1950	*D. ciliatus* Loew–*D. cucurbitae* Coq	11, 904
Ficus sp.	Feb. 1950	Not identified	34
Luffa spp	Oct. 1949–Oct. 1950	*Dacus cucurbitae* Coq.–*D. nubilus* Hendel–*D. ciliatus* Loew	172, 958
Lycopersicon esculentum.	Sept.–Oct. 1950	*D. nubilus* Hendel	6, 607
Mangifera indica	Sept. 1949–Aug. 1950	*D. zonatus* (Saund.)–*D. dorsalis* Hendel	22, 457
Momordica charantia	May–Oct. 1950	*D. ciliatus* Loew	11, 745
Prunus persica	June–July 1950	*D. zonatus* (Saund.)	62, 609
Psidium guajava	Aug. 1949–Nov. 1950	*D. dorsalis* Hendel	19, 117
Zizyphus jujuba	Dec. 1949–Nov. 1950	*Carpomyia vesuviana* Costa.	401, 965
Total			791, 436

Very little can be said regarding the field parasitization of the fruit flies in northern India. One sample of 223 puparia obtained from beneath a pile of guava fruits in the field at Bareilly yielded 45 adult *Opius*, the host presumably being *Dacus dorsalis*. This was an unexpectedly high parasitization, as the Indian entomologists had indicated that the maximum previously recorded was about 2 percent. Field observations indicated also that parasitization of species developing in cucurbits is quite high late in the season.

At the completion of the collection program in North India in late October 1950, Mr. Waters spent about one month en route to Coonor in the south, where he was to join Mr. Beevor. At this time he was able to make some observations at various points in Central India upon several fruit fly hosts and the extent of infestation. At this season,

however, the number of hosts with ripening fruit was at a minimum and infestations, as would be expected, were usually light.

Between Jansi, United Provinces, and Saugor, Central Provinces, great numbers of *Zizyphus jujuba* were seen growing wild over the rolling hills. The fruits of this plant were small and immature at the time of observation, but at the proper season would provide unlimited quantities for collection. The custard apple, *Annona squamosa*, grows abundantly on the rocky foothills about Jubbulpore, but the fruit appeared to be free from fruit fly attack. At Bilsapur, an area famous for the production of guavas, fruit was abundant but, as elsewhere in India during 1950, fruit fly attack was very light. Nagpur is a center of citrus production, and tons of fruit of mandarin and tangerine oranges were seen and examined in the wholesale market. No evidence of fruit fly injury was seen, either in the markets or in the field. These observations are in accord with the findings of Bianchi the preceding winter. Even this far south the winter temperatures may be sufficiently low to prevent fruit fly activity. At Poona, in the Bombay Presidency, guavas were abundant, but it was possible to obtain only a small quantity of lightly infested fruits.

The fruit fly parasite-collection program in South India was initiated more than a year later than that in North India. G. G. Beevor and T. C. Lawrence arrived there in February 1950 and established headquarters at Bangalore, Mysore. Bangalore is situated at an elevation of 3,000 feet, with excellent rail and road connections with other provinces, and is the site of the Mysore State College. This college has a large and well-staffed agricultural department and research institute, and the chief entomologist, B. Krishnamurti, was exceedingly helpful in providing assistance in every way possible. Likewise, through the courtesy of L. S. Dorasami, economic botanist of the Mysore State Department of Agriculture, the facilities of the Fruit Research Station at Hessarghatta were made available to the fruit fly workers. This research station is situated 15 miles north of Bangalore, and a large assortment of tropical and subtropical fruits and vegetables are grown there in abundance.

Mr. Bianchi of the North India team arrived at Bangalore at the beginning of April 1950 and remained through May. He was of substantial assistance in the development of improved methods of handling the fruit fly material, based on his experience in the north during the preceding year. Mr. Beevor transferred his headquarters in midsummer to Coonor in the Nilgiri Hills, about 150 miles south of Bangalore, at an elevation of 6,000 feet. Mr. Waters arrived from North India in December and soon thereafter established his own base of operations at Kodaikanal in the Madras Presidency. The investigations in South India extended to May 1951.

Table 7 gives a summary of the fruit fly rearings and shipments of puparia from South India to Hawaii during 1950–51.

During the early months of the survey the work was confined to the general area about Bangalore. The 600-acre Palace Gardens, belonging to the Maharaja of Mysore, were made available for study and field experimentation. These gardens include 57 acres of fruiting trees (of which 20 acres are fine old mango trees) and extensive acreages of various vegetables, and provided exceptional opportunity for field observations and collections.

TABLE 7.—*Imports of fruit fly material from South India*

Host fruit	Period of collection	Dominant fruit fly species	Number of puparia shipped
Aegle marmelos	May 1951	Not identified	380
Coffea robusta	Mar. 1950	*Dacus incisus* Wlk. / *D. nigrotibialis* (Perk.)	152
Coccinia indica	May 1950–Jan. 1951	*D. ciliatus* Loew / *D. cucurbitae* Coq	54, 254
Citrus reticulata	Mar. 1950–Mar. 1951	*D. incisus* Wlk	130, 605
Cucurbitaceae (mixed).	Mar.–May 1950	*D. cucurbitae* Coq	9, 833
Eugenia jambos	May 1950	*D. correctus* (Bez.)	2, 707
Ficus sp	Mar. 1950–Mar. 1951.	*D. incisus* Wlk	421
Luffa acutangula	Jan. May 1951	*D. cucurbitae* Coq	1, 806
Mangifera indica	May–July 1950	*D. dorsalis* Hendel / *D. zonatus* (Saund.)	86, 256
Momordica charantia	Apr. 1951	Not identified	2, 128
Solanum auriculatum	June 1950–Apr. 1951	*Dacus dorsalis* Hendel	860, 384
S. sisymbrifolium	July 1950	*D. latifrons* (Hendel)	707
S. verbascifolium	Jan.–Apr. 1951	*D. dorsalis* Hendel	10, 753
Solanum sp	Mar. 1950–Apr. 1951	*D. latifrons* (Hendel)	3, 810
Trichosanthes palmata	Jan.–Feb. 1951	*D. nubilus* Hendel	12, 144
Zizyphus jujuba	Feb.–Mar. 1951	*Carpomyia vesuviana* Costa.	26, 678
Total			1, 203, 018

In the collection of fruit fly material, early attention was given to the various species of *Citrus*. The mandarin orange is widely grown in South India, and the fruit matures during the winter period. The early portion of the crop is only lightly infested, but attack by fruit flies increases as the season progresses. At Kodaikanal, the average infestation for the season is about 10 percent, but in some orchards, where the fruit is held until early February, 70–80 percent may be infested.

Coorg, a province on the west coast, is famous for its oranges, which are marketed throughout India. During the harvest period in March and April, fruit fly infestation was high. Large supplies of infested fruit could be obtained then, even in the markets of distant cities. Infested fruit that had fallen in the field did not prove to be a good source of supply of larvae, as these fruits soon became heated from exposure to the sun and all larvae that did not emerge quickly and enter the soil were killed. Other species and varieties of *Citrus* appear to be much less heavily infested than is *Citrus reticulata*.

Some observations were made during March on infestations in three species of coffee, *Coffea arabica*, *C. excelsa*, and *C. robusta*, at the Indian Coffee Board Experimental Farm at Balehonnur (elevation, 2,900 feet), 160 miles by road from Bangalore. The harvest of *C. arabica* was largely complete by then, but at nearby Mt. Ayapa, at an elevation of 4,060 feet, the fruiting was slightly later, and a few pounds of berries of *C. robusta* were obtained. These yielded a small number of puparia for shipment to Hawaii.

Guava fruits proved to be rather scarce in South India and the supply was not sufficient to provide material for shipment. Examination of a few fruits at Bangalore in March showed no infestation, which is suprising in view of the general occurrence of *D. dorsalis* in other fruits in this area, and its known preference for that fruit elsewhere.

A visit was made during May to Saklespur, about 150 miles northeast of Bangalore, at an elevation of 2,900 feet, following reports of heavy infestations in guavas in that area. The jungle contained many trees and bushes with immature fruits, but very few ripe fruits were found, and these were only lightly infested.

The mango crop was poor throughout India in 1950, but fortunately it was still possible to obtain sufficient fruit in Mysore for fly-rearing purposes. Culls and pieces of fruit under the trees in the Palace Gardens at Bangalore proved to be 100 percent infested. During May and from June 8 to 10, baskets of infested fruit could be obtained daily at the city markets, and these yielded a large number of puparia of *Dacus dorsalis* for forwarding to Hawaii.

Peaches and plums in the Coonor area were just beginning to ripen in late May. The few fruits examined by Bianchi at that time were practically all infested. Collections by Beevor the following month, however, showed very low infestation.

Most of the fruit fly puparia obtained in South India were derived from several species of *Solanum*, mainly *auriculatum*. This species and Mullein nightshade (*S. verbascifolium*) were heavily infested by *Dacus dorsalis*, and two others of the same genus by *D. latifrons*. *Solanum auriculatum* was first observed by Bianchi at Coonor in May and a small collection of fruits was made at that time. This is a treelike plant that grows 15 feet or more in height and produces clusters of fruit, each more than an inch in diameter. In June, Beevor found the fruits of this species in the same locality to be heavily infested, each containing up to 5 maggots. July collections of 160 pounds of fruit yielded 30,000 puparia.

During September, with day temperatures not above 70° F. and the night average about 56° F., the larvae showed a marked reluctance to leave the fruit, as a result of which the fruit had to be held in the trays up to 3 weeks, rather than the usual 10 days. The months of October and November provided the greatest production of puparia. An average of 2,000 pounds of fruit was held in the rearing trays during this period, with a resulting total production of 400,000 puparia. *Solanum auriculatum* alone provided 860,000 of the total of 1,203,000 puparia shipped from South India during 1950–51.

From all points of view, the Nilgiri Hills of South India proved to be one of the most productive areas encountered by the collectors in their search for natural enemies of the oriental fruit fly. Infested fruits, especially those of *Solanum auriculatum*, the preferred wild host of *Dacus dorsalis*, were available in abundance practically throughout the year, and the puparia from them showed an appreciably higher parasitization than those from other fruits. Females of several species of *Opius* were frequently observed ovipositing in infested fruits in the field. There was a marked decline in parasitization during January to March, the average at that time being less than 1 percent.

Solanum sisymbrifolium at Coonor in June was found to be only about 10 percent infested, only one maggot normally developing in each fruit.

Mr. Waters found *Solanum verbascifolium* 100 percent infested at Kodaikanal during January to March. The shipments of that period, comprising about 10,000 puparia, were obtained from the fruit of only 43 plants, distributed over an area of 15 square miles.

Observations were made on several additional species of *Solanum* that were not sufficiently abundant for large-scale collections. Eggplant (*S. melongena*) at Coonor is of several varieties, and it was interesting to note that only the yellow-fruited variety was infested by fruit flies, and this only lightly.

The fruit of jujube (*Zizyphus jujuba*) was not as abundant or as readily obtained as had been anticipated, but about ½ ton was obtained at the village of Manappairi, near Trichinopoly, in February. Also, it was found that the loose dirt beneath the piles of fruit, where they were assembled by the wholesalers when delivered from the outlying villages, was a productive source of larvae and pupae. Three sacks of this loose dirt were taken and this, with the fruit mentioned above, yielded more than 26,000 puparia for shipment.

Melons of various kinds did not prove to be as heavily infested by *Dacus cucurbitae* as had been expected. More than 7,000 puparia were obtained from a quantity of mixed melons obtained in April from the Fruit Research Station at Hessarghatta. Later, five baskets of damaged fruit were assembled from fields near the village of Veidyanathapura, in the Shimsha River bed, but unfortunately most of the larvae in these melons were dead, apparently killed by the intense heat that prevails at this season.

Ivy gourd (*Coccinia indica*) proved to be a productive source of supply of two species of fruit flies. The fruits of this plant are small, yellow and green striped, becoming red when mature, and resemble a miniature cucumber. During May, 150 pounds were obtained in the market at Bangalore, and a quantity also from the village Sonalipur, 19 miles away. These proved to be heavily infested and yielded more than 54,000 puparia.

Several species of *Eugenia* were common, and fruit was available in quantity during the summer period. They were not sufficiently infested, however, to warrant large-scale collections. Tomatoes, even when dead ripe in the field, appeared to be free from infestation.

Reference to tables 6 and 7 shows a marked difference in the fruit fly hosts available for collection in North and South India, as well as in the dominant species of fruit flies themselves. The bulk of the material from North India was obtained from *Zizyphus jujuba*, with relatively large numbers also from Cucurbitaceae, especially *Luffa* spp., watermelon, *Cucumis* and *Coccinia indica*, and from peach, mango, and guava. In the South, on the contrary, three-fourths of the total collections were from species of *Solanum*, a genus not represented at all in the material assembled in the north. Oranges and tangerines were next in productiveness and these, likewise, were not represented in the large collections in the northern area. Only small numbers of infested Cucurbitaceae other than *Coccinia indica* were obtained in this area. Only mango and jujube were obtained in abundance in both sections of the country.

Among the fruit fly species obtained from the collections in South India, *Dacus dorsalis* was much the most abundant because of the large quantity of *Solanum auriculatum* and *S. verbascifolium* it was possible to obtain. It was the only species reared from these fruits, while *Solanum sisymbrifolium* produced only *D. latifrons*, and *Solanum* sp. produced predominantly *D. latifrons* and a few *D. dorsalis*. The latter species was also dominant in mango, in association with a considerable number of *D. zonatus* and a few *D.* (*Strumeta*) *correctus*. This latter species, in turn, was the only one reared from rose apple (*Eugenia jambos*) and in very small numbers from coffee.

Dacus (*Strumeta*) *incisus* was the only fruit fly obtained from Mandarin orange and *Ficus* sp. It was the dominant species in coffee, and was obtained occasionally from Cucurbitaceae. *D. nubilus* was the major species reared from fruits of *Trichosanthes palmata*, and was associated with a small number of an undescribed species of the same genus. It was also present in small numbers in *Coccinia indica*.

Only the melon fly, *Dacus cucurbitae*, appeared in rearings from paroła (*Luffa acutangula*); it was the dominant species obtained from rather large lots of mixed Cucurbitaceae, and also appeared in the rearings from *Coccinia indica*. *D. ciliatus* was the dominant species infesting the latter fruit, and it was also taken from mixed Cucurbitaceae. *D.* (*Strumeta*) *nigrotibialis* was reared only from coffee, though in much smaller numbers than *D. incisus*. The large numbers of fruits of *Zizyphus jujuba* yielded only *Carpomyia vesuviana*. It may be noted that mango is a favored host of two species of *Dacus*, with *dorsalis* dominant in the south and *zonatus* in the north.

One of the objectives of the South Indian expedition was to study and obtain for shipment, if possible, the small chalcidoid parasite recorded by George Compere (*12*) as attacking the eggs of various fruit flies, including those infesting tree fruits as well as melons, in the Poona and Nagpur areas. Specimens of the parasite were not obtained and identified, but he concluded that the egg parasite was the most effective of the natural enemies of fruit flies in the areas in which observations were made. Unfortunately, the collectors engaged on this project in India during 1949–51 were unable to find any trace of true egg parasites. The eggs of the fruit flies are deposited in clusters just beneath the skin of the fruit and are certainly within reach of parasites of this type. Such a parasite, if it could be found, would be a valuable addition to the parasites now known, all of which, whether ichneumonoid, chalcidoid, proctotrupoid, or cynipoid, emerge from the puparium, regardless of the stage in which the egg is deposited.

Ceylon

The survey and collection of fruit fly material in Ceylon was conducted by G. W. Angalet immediately following completion of the program in North Borneo and covered the months of August to October 1951. Excellent laboratory facilities were made available at the agricultural experiment station at Peradeniya through the courtesy of the Ceylon Department of Agriculture.

The fruiting season for most fruit fly host plants had passed at the time this work was undertaken, so that quantity collections were pos-

sible only of two cucurbits, edible snakegourd (*Trichosanthes anguina*) and ampalaya (*Momordica charantia*). The fruit of these two plants yielded about 90 percent of the puparia forwarded to Hawaii. *Dacus cucurbitae* is the dominant fruit fly pest in Ceylon, and heavily infests many kinds of vegetables. At certain times the loss of some crops exceeds 50 percent. The only control measure practiced by the farmers is bagging of the individual fruits, and this is done only by the small producers. In the larger-scale plantings it is the practice to collect and destroy all infested fruits and vegetables. This permitted the collection of large quantities of material for rearing of fruit fly puparia at little cost.

Dacus dorsalis was the dominant fruit fly in a small lot of fruits of *Averrhoa* sp., and was accompanied by a small number of *D. cucurbitae*. The scarcity of oriental fruit fly in the collections of August to October should not be taken as an indication of the true status of that pest in Ceylon. None of the host fruits listed above yielded *D. dorsalis* in India, where it is abundant in other fruits. Collections during the late spring and early summer, when the favored host fruits of *D. dorsalis*, such as mango, *Eugenia* spp., and *Solanum* spp., are ripening, would undoubtedly reveal a much different situation.

Opius fletcheri was found commonly as a parasite of *D. cucurbitae*, but with the percentage of parasitization ranging up to a maximum of only 10 percent in the four species of cucurbit hosts from which fruit fly larvae were obtained. *Spalangia* spp. were present in small numbers in practically all collections.

Shipments of fruit fly puparia from Ceylon during August and September 1951 comprised 128,400 *Dacus cucurbitae* from *Cucumis sativus*, *Luffa actangula*, *Momordica charantia*, *Trichosanthes anguina*, and mixed Cucurbitaceae; and 1,000 *D. dorsalis* from *Garcinia* sp.

Australia

Although *Dacus dorsalis* is not known to occur in Australia, that continent was considered to be a potentially fruitful source of parasites of the genus because of the large numbers of species known to occur there, and the wide range of fruits infested by them. The effectiveness of *Opius tryoni* (obtained from *D. tryoni* in that country in 1913) upon *Ceratitis capitata* in Hawaii, led to the hope that equally or more effective parasites might be obtained there for use against the oriental fruit fly.

The investigations in Australia by N. L. H. Krauss covered the periods May to September 1949, and November 1949 to April 1950. Headquarters were established at Cairns, in eastern Queensland, where laboratory facilities were made available at the Kamerunga Experiment Station, 8 miles from the city, through the courtesy of S. E. Stephens, horticulturalist of the Queensland Department of Agriculture and Stock. Frequent trips were made to nearby jungle areas at Deeral and to The Boulders near Babinda, as well as to Clump Point near Tully. During August, a week was devoted to a survey for fruits and fruit flies at Iron Range on Cape York Peninsula, and a few days on Thursday Island, just off the tip of the Cape.

The collections of infested fruits during April to July were mainly from the wild plants *Planchonella* sp., *Endiandra tooram*, and *Eugenia macrocarpa* along the Mulgrove River near Deeral, 30 miles

south of Cairns; and from nightshade (*Solanum auriculatum*) in the Atherton Tableland. Other fruits, available in small quantity, that yielded species of *Dacus* at this time were banana, carambola (*Averrhoa carambola*), guava, tomato, cucumber, pumpkin, ball kamani (*Calophyllum inophyllum*), and false kamani (*Terminalia catappa*). Unfortunately, *Planchonella* ceased fruiting in August, but a variety of other fruits were available during the late summer, though in rather small numbers. The most productive were *Beilschmiedia obtusifolia* and *Endiandra*. During the late winter period, the fruit of nightshade became abundant and yielded large numbers of *Dacus*.

From November 1949 to February 1950, the midsummer period, large quantities of fruits of cocky apple (*Careya australis*), a fibrous green fruit borne on small trees in the open forest near Cairns, *Castanospora alphandi*, and *Barringtonia calyptrata* were obtained, as well as smaller quantities of *Eugenia cormiflora*, and *Polyalthia nitidissima*, a very small reddish-orange fruit collected in the semirain forest near Hartley's Creek on the coast north of Cairns. Mangoes occasionally were found to be well infested.

The month of April was spent in New South Wales, with headquarters at Sydney. Wild fruits were scarce there at this season, but a search through the Botanic Gardens yielded small numbers of fruits of *Hemicyclia australasica*, *Eugenia* sp., and strawberry guava (*Psidium cattleianum*) that were infested by *Dacus*. At Gosford, fruits of feijoa (*Feijoa sellowiana*) were infested with *Dacus* and *Bioza*, and those of Chinese gooseberry (*Actinidia chinensis*) by *Dacus*. None of these was available in sufficient abundance to justify collections for shipment.

The collection program in Australia thus revealed a wide variety of fruits infested with fruit fly larvae. The most common was the well-known Queensland fruit fly *Dacus tryoni*, which was the only species reared from *Beilschmiedia*, carambola, *Solanum seaforthianum*, and mango, and was the dominant species in false kamani, *Eugenia cormiflora*, and river cherry (*E. tierneyana*). It was taken in about equal numbers with *D.* (*Afrodacus*) *jarvisi* from guava, and in smaller proportion from papaya.

Several varieties of *D. tryoni* were taken from wild fruits, *D.* (*Strumeta*) *melas* and *D.* (*Strumeta*) *tryoni sacrocephali* being about equally common in *Polyalthia nitidissima*, while *D.* (*Strumeta*) *neohumeralis* Hardy was reared in small numbers from guava.

Dacus jarvisi was the only species reared from *Careya australis* and, because of its abundance, comprised about half the total number of puparia shipped to Hawaii. It was the dominant species in papaya and was reared also from *Terminalia*, *Eugenia*, and *Semecarpus australiensis*.

Second in the number of puparia obtained for shipment was *D.* (*Strumeta*) *kraussi* from *Castanospora alphandi*, and this was the only species reared also from *Eugenia macrocarpa*. An occasional individual appeared in rearings from guava.

Dacus (*Strumeta*) *barringtoniae* (Tryon) was obtained in large numbers from fruits of *Barringtonia calyptrata*, in which it was the only fruit fly species, and in smaller numbers than *D. tryoni* in *Eugenia tierneyana*. *D.* (*Strumeta*) *endiandrae* was abundant in fruits of *Endiandra tooram*, and apparently is limited to that host. *D.*

laticaudus was restricted to *Planchonella* sp., *D.* (*Strumeta*) *pallidus* to *Sarcocephalus cordatus*, *D.* (*Gymnodacus*) *calophylli* to *Calophyllum inophyllum*, *D.* (*Strumeta*) *fagraeus* to *Fagraea* sp., *D.* (*Strumeta*) *cucuminatus* to *Solanum auriculatum*, and *D.* (*Strumeta*) *musae* to *Musa banksii*, a native, seedy banana obtained from Mossman Gorge, and other bananas. *D.* (*Daculus*) *murrayi* was the dominant species in *Semecarpus*, while *D.* (*Strumeta*) *mayi* Hardy appeared in very small numbers in rearings from guava. The details relating to shipments of material to Hawaii are given in table 8.

TABLE 8.—*Imports of fruit fly material from Australia*

Host fruit	Period of collection	Dominant fruit fly species	Number of puparia shipped
Averrhoa carambola	Sept. 1949–Feb. 1950	*D. tryoni* (Frogg.)	1, 353
Barringtonia calyptrata.	Dec. 1949–Jan. 1950	*D. barringtoniae* (Tryon).	35, 180
Beilschmiedia obtusifolia.	Nov.–Dec. 1949	*D. tryoni* (Frogg.)	15, 180
Calophyllum inophyllum.	Aug.–Sept. 1949	*D. calophylli* (P. & M.)	561
Careya australis	Dec. 1949–Feb. 1950	*D. jarvisi* (Tryon)	183, 493
Carica papaya	Feb. 1950	*D. tryoni* (Frogg.) *D. jarvisi* (Tryon)	101
Castanospora alphandi.	Dec. 1949–Jan. 1950	*D. kraussi* Hardy	38, 217
Endiandra tooram	June–Sept. 1949	*D. endiandrae* (P. & M.).	10, 987
Eugenia cormiflora	Dec. 1949–Jan. 1950	*D. tryoni* (Frogg.) *D. jarvisi* (Tryon)	2, 307
Eugenia macrocarpa	June–Sept. 1949	*Dacus kraussi* Hardy	4, 732
E. tierneyana	Feb. 1950	*D. tryoni* (Frogg.) *D. barringtoniae* (Tryon).	243
Fagraea sp	Sept. 1949	*D. fagraeus* (Tryon)	381
Mangifera indica	Nov. 1949	*D. tryoni* (Frogg.)	316
Musa spp	June 1949–Feb. 1950	*D. musae* (Tryon)	6, 156
Planchonella sp	June–July 1949	*D. laticaudus* Hardy	8, 535
Polyalthia nitidissima	Feb.–Mar. 1950	*D. melas* (P. & M.) *D. tryoni sarcocephali* (Tryon).	4, 935
Psidium guajava	do	*D. tryoni* (Frogg.) *D. jarvisi* (Tryon)	19, 162
Sarcocephalus cordatus.	do	*D. pallidus* (P. & M.)	1, 974
Semecarpus australiensis.	Dec. 1949–Jan. 1950	*D. murrayi* (Perk.) *D. jarvisi* (Tryon)	370
Solanum auriculatum	June–Dec. 1949	*D. cucuminatus* (Hering).	17, 211
S. seaforthianum	Mar. 1950	*D. tryoni* (Frogg.)	385
Terminalia catappa	Jan. 1950	do	3, 126
Total			354, 905

Field and laboratory observations during the survey and collection program revealed an abundance of *Opius* spp., as well as chalcidoid and cynipoid species. Conspicuously absent from the list of parasites is *Opius tryoni*, which was collected from *Dacus tryoni* in Australia

by Silvestri in 1913 and successfully established on *Ceratitis capitata* in Hawaii. Silvestri's collections comprised only about 50 puparia of *D. tryoni* from fruits of *Schizomeria ovata* at Gosford, N.S.W., a short distance north of Sydney. Although this is a more temperate area than Queensland, it would be expected that the parasite would tend to follow the distribution of its host. Mr. Krauss made small collections of fruit of several kinds at Gosford during April, from which fruit flies emerged, but no specimens of *Opius*. No material from this area was shipped to Hawaii.

Pacific Islands

Importations of fruit fly parasite material have been made into Hawaii from New Britain, New Caledonia, Fiji, and Saipan. The summarized data regarding these shipments are given in table 9.

The investigations in New Britain by N. L. H. Krauss covered the period September to November 1949, with Rabaul as the base of operations. En route from Australia he had made short stops at Port Moresby and Lae, on New Guinea, but opportunities for collection of fruits were very limited at these places. Even at Rabaul the number of fruits available was quite small. The best for fruit fly collection proved to be the Tahitian chestnut (*Inocarpus edulis*), which produces a nut that is eaten by the natives. These nuts provided the main source of fruit fly material on the island, being infested by *Dacus* (*Strumeta*) *frauenfeldi*, the larvae of which were parasitized by several species of *Opius*.

A small supply of mango yielded the same fruit fly species, while *Artocarpus* sp. was infested with *Dacus umbrosus*. There was a heavy crop of carambola (*Averrhoa carambola*), but surprisingly, in view of its heavy infestation in other areas, the fruit was practically free from fruit fly attack. A fine area of virgin jungle at Keravat yielded very little fruit and none of it was infested.

The survey and collection of fruit flies and their parasites in New Caledonia were conducted by N. L. H. Krauss during May to August 1950. Laboratory facilities at the Institut Francais d'Oceanie at Noumea were provided through the courtesy of the Director, Dr. F. Bugnicourt.

There was relatively little in the way of possible fruit fly hosts in the forests during the period mentioned, these fruits being most abundant from December to February or March. Fortunately, a fairly good crop of guavas was available, which were well infested with larvae of *Dacus* (*Strumeta*) *psidii*, and these provided the bulk of the puparia forwarded to Hawaii. This fruit fly was also reared from strawberry guava (*Psidium cattleianum*). The puparia yielded several species of *Opius* and a few *Spalangia*. The fruiting season for guava came to an end in August, coincident with the completion of the collection program.

The fruits of Brazilian nightshade (*Solanum seaforthianum*) and of several undetermined plants yielded *Dacus* (*Strumeta*) *curvipennis*, as did those of an introduced tree, *Ochrosia elliptica*. *Ochrosia* and guava were also infested to a lesser extent by *Dacus* n. sp. near *facialis*. A fourth species, *Dirioxa pornia* (Wlk.), was also present in very small numbers in guava. Only *D. psidii* had previously been recorded from the island.

TABLE 9.—*Imports of fruit fly material from Pacific Islands*

Host fruit	Period of collection	Dominant fruit fly species	Number of puparia shipped
NEW BRITAIN			
Artocarpus sp.	Oct. 1949	*Dacus umbrosus* F.	92
Inocarpus edulis	Oct.–Nov. 1949	*D. frauenfeldi* Sch.	3,487
Mangifera indica	do	do	398
Total			3,977
NEW CALEDONIA			
Ochrosia elliptica	June–July 1950	*Dacus curvipennis* (Frogg.). *D.* n. sp. near *facialis* Coq.	606
Psidium guajava	May–Aug. 1950	*D. psidii* (Frogg.)	64,714
Unidentified fruits	May 1950	*D. curvipennis* (Frogg.). *D. psidii* (Frogg.)	3,709
Total			69,029
FIJI			
Artocarpus altilis	Mar. 1951	*Dacus passiflorae* (Frogg.).	2,035
Barringtonia edulis	Jan.–Mar. 1951	*D. xanthodes* (Brown). *D. passiflorae* (Frogg.).	23,261
Cerbera sp.	Apr. 1951	do	152
Chrysobalanus icaco	Mar.–May 1951	do	1,099
Gnetum gnemon	May 1951	*D.* n. sp. near *facialis* Coq.	30
Inocarpus edulis	Jan.–May 1951	*D. passiflorae* (Frogg.).	8,766
Ochrosia sp.	May 1951	do	341
Pometia pinnata	Jan.–Feb. 1951	do	4,513
Psidium spp.	Jan.–May 1951	do	6,265
Total			46,462
SAIPAN			
Aglaia mariannensis	July 1949	*Dacus ochrosiae* Mall.	125
Total			125

The month of September 1950 was spent in Fiji by N. L. H. Krauss in a preliminary survey of fruit fly hosts, while the collection program extended from December 1950 to May 1951.

The September collections were not at all productive, as both cultivated and forest fruits, with the exception of banana and rough lemon, were very scarce and these were not infested with fruit flies. How-

ever, an abundance of guava, mango, *Eugenia*, and several other native plants, especially *Inocarpus* and *Pometia*, was noted, with the fruiting period from December onward. The collection program was therefore postponed until that time.

With the resumption of activities in late December, laboratory quarters were set up at the Fiji Department of Agriculture headquarters at Suva, and at the Plant Introduction and Quarantine Station at Nandaruloulou, 17 miles east of Suva. These facilities were made available through the courtesy of Messrs. B. E. V. Parham and B. A. O'Connor of that Department.

The most productive area for fruit collections proved to be in the vicinity of the town of Nausori. Here, a variety of fruits were available, with those of *Barringtonia edulis* by far the most abundant and well infested with *Dacus* (*Notodacus*) *xanthodes* and *D.* (*Strumeta*) *passiflorae*. About half of the fruit fly puparia shipped to Hawaii from Fiji were from this fruit. The guava crop was very poor but yielded a considerable number of *D. passiflorae*. The fruits of Tahitian chestnut (*Inocarpus edulis*), especially the secondary crop in May, were heavily infested with the same species, and yielded also a small number of *D. xanthodes*. *Gnetum gnemon*, *Cerbera* sp., and *Ochrosia* sp. were quite heavily infested, but the amount of fruit that could be obtained was very small. *Gnetum* yielded only *Dacus* (*Strumeta*) n. sp. near *facialis*, while the remaining two produced only *D. passiflorae*.

Collections of smaller numbers of puparia from *Pometia pinnata*, breadfruit (*Artocarpus altilis*), coco plum (*Chrysobalanus icaco*), and strawberry guava proved to be entirely of *D. passiflorae*. This species is certainly the dominant one of the family in Fiji, encountering competition only with *D. xanthodes* in *Barringtonia* fruits.

Four temporary field stations were set up in order to obtain greater numbers of the chalcidoid parasites. Two of these were stocked with infested guavas, one with *Barringtonia edulis* and *Pometia pinnata*, and the fourth with breadfruit. The latter two were soon discontinued because of lack of fruit, but the guava stations were continued for several months. The dominant parasite was *Aceratoneuromyia indicum*, an introduced species of Indian origin that had been imported from Australia in 1938. *Spalangia endius*, another imported species, was present in small numbers.

A predaceous lygaeid bug, *Germalus pacificus* Kirk., feeds on the eggs of fruit flies in Fiji. Shipments totaling 43 nymphs and 94 adults were forwarded to Hawaii for laboratory testing during the early part of 1951. While this predator appears to be of some value against fruit flies, its omnivorous habits probably preclude serious consideration of its release in Hawaii.

In July 1949, N. M. Ross of the Bureau of Entomology and Plant Quarantine forwarded to Hawaii 125 puparia of *Dacus* (*Strumeta*) *ochrosiae*, which had been obtained from the fruits of *Aglaia mariannensis* collected on Mount Popagehau on Saipan. This proved to be a new host and a new geographic record for that species. The larvae were lightly parasitized by *Opius* sp.

Africa

The investigations on fruit flies and their parasites in Africa were started by J. M. McGough and F. E. Skinner, who arrived in South

Africa in September 1948. Mr. Skinner continued on the work in South and East Africa until his transfer to the Philippine Islands in September 1949, and thereafter, Mr. McGough carried on alone except during late February to April 1951, when he was joined in the Belgian Congo by D. W. Clancy.

Africa had been considered to be a potentially productive region for research on natural enemies of fruit flies, not only because of the many species of dacine Tephritidae recorded from the continent, but also because of the many species of promising parasites reported by Silvestri (*40*) as a result of his trip to the west coast in 1912–13, by Fullaway and Bridwell in 1914, and by the Bureau expeditions to East and West Africa in 1935–36.

The route followed by the expedition was from Capetown through the Union of South Africa to Lourenco Marques in Mozambique, thence northward through Southern and Northern Rhodesia and Tanganyika to Nairobi, Kenya, British East Africa, where an extended stay was made. Following this, a return trip was made to Natal in South Africa and finally came the trip westward from Nairobi through equatorial Africa to the west coast. The route followed for this portion of the journey was first northwest above Lake Victoria, across the southern portion of Uganda, across the Belgian Congo by way of Stanleyville and into French Equatorial Africa at Bangui. From this point, travel was continued to Yaoundi in the Cameroons, terminating at Douala, on the Gulf of Guinea. The airline distance from Capetown to Nairobi is more than 2,500 miles, and from Nairobi to Douala, about 2,000 miles.

A summary of the data relating to the rearing of fruit fly puparia from different fruits and shipments to Hawaii from the different regions of Africa, is given in table 10.

Messrs. McGough and Skinner arrived at Johannesburg on September 4, 1948, and immediately met with American consular representatives to arrange for meetings with officials of the South African Department of Agriculture. Pretoria was visited a few days later and here the Agricultural Attaché at the American Legation, J. L. Dougherty, was exceedingly helpful in providing much useful information regarding agricultural conditions throughout the Union, and the areas in which the principal fruit and vegetable crops are grown.

The chief of the Division of Entomology of the South African Department of Agriculture, T. J. Naude, was of very great help in setting up plans for the field work and provided laboratory facilities and automobile transportation pending arrival of the party's own car. Arrangements were made for the identification, by H. K. Munro of that Division, of the fruit fly species encountered during the course of the investigations. Dr. Munro is a recognized authority on the identification and classification of the Tephritidae, and his cooperation and assistance were invaluable. R. A. Dyer, chief of the Division of Botany and Plant Pathology, kindly agreed to identify the many species of plants, the fruits of which were hosts of the different fruit fly species. On a continent such as Africa, with an extremely varied flora and many genera and species unknown elsewhere, this assistance in identification contributed greatly to the value and accuracy of the

TABLE 10.—*Imports of fruit fly material from Africa*

Host fruit	Period of collection	Dominant fruit fly species	Number of puparia shipped
UNION OF SOUTH AFRICA			
Chrysophyllum sp.	Apr.–May 1949	*Ceratitis capitata* (Wied.)	[1] 2, 200
Cucurbitaceae, cultivated.	do	*Dacus* sp.	[1] 12, 500
Total			14, 700
KENYA			
Cucurbitaceae, cultivated.	Aug. 1949–June 1950	*Dacus ciliatus* Loew *D. bivittatus* var. *cucumarius* Sack	153, 078
Chrysophyllum pruniforme.	June 1950	*Pardalspis* sp.	5, 000
Coffea arabica	Oct. 1949–Jan. 1950	*Ceratitis capitata* (Wied.)	7, 551
Olea chrysophylla	Aug.–Oct. 1949	*Dacus oleae* (Gmel.)	80, 000
Drypetes sp.	June 1950	*Pardalaspis* sp. (?) *Carpophthoromyia dimidiata* Bez.	5, 000
Strychnos reticulata	Aug. 1949–June 1950	*Pterandrus rosa* (Ksh.)	198
S. usambarensis	Oct. 1950	*Trirhithrum queritum* Mro.	41, 620
Warburgia ugandensis	Aug. 1949–Feb. 1950	*Pardalaspis contramedia* Mro.	60, 969
W. ugandensis and cultivated cucurbits, mixed.	Dec. 1949	*Pardalaspis contramedia* Mro. *Dacus ciliatus* Loew *D. cucurbitae* Coq.	1, 567
Unidentified fruit	June 1950	*Trirhithrum queritum* Mro.	5, 000
Do	do	*Ceratitis capitata* (Wied.).	150
Total			361, 033
BELGIAN CONGO			
Chrysophyllum pruniforme.	Dec. 1950–Feb. 1951	*Pardalaspis ditissima* Mro.	24, 715
Coffea robusta	Mar. 1951	*Trirhithrum coffeae* Bez.	5, 300
Pancovia laurentii	do	*Pterandrus anonae* (Grah.).	17, 430
Sapotaceae	Dec. 1950–Mar. 1951	*Pardalaspis ditissima* Mro.	45, 140
Terminalia catappa	Dec. 1950–Feb. 1951	*Pterandrus anonae* (Grah.).	32, 600
Tridesmostemon claessensi.	Jan.–Feb. 1951	*Pardalaspis ditissima* Mro.	10, 077
Total			135, 532

See footnote at end of table.

TABLE 10.—*Imports of fruit fly material from Africa*—Continued

Host fruit	Period of collection	Dominant fruit fly species	Number of puparia shipped
FRENCH CAMEROONS			
Myrianthus arboreus	Aug. 1951	*Pterandrus anonae* (Grah.).	58, 200
Cucurbitaceae, cultivated.	do	*Dacus bivittatus* var. *cucumarius* Sack.	1, 950
Unidentified fruits	do	Not identified	580
Total			60, 730

[1] Shipped to the Bureau of Entomology and Plant Quarantine station at Hoboken, N.J., where the parasites were reared out and forwarded to Hawaii.

host records assembled by the expedition. The botanists of the several universities in South Africa also provided many plant identifications.

With the seasons reversed, as compared with the Northern Hemisphere, September and the following months represent the late winter and early spring, and, consequently, few fruits and vegetables were yet available for observation or for infestation by fruit flies. A field of pumpkin near Pretoria showed a light infestation by *Dacus ciliatus*, whereas at Nelspruit, at a considerably lower elevation than Pretoria, only very light infestations were found in the small portion of the cucurbit crop then remaining. These comprised *D. ciliatus* and *D. cucumarius*.

Information provided by various entomologists indicated an almost complete lack of records of *Dacus* infestation in citrus, peach, and apple in the Union of South Africa. The infestations of cucurbits, however, are usually low in the spring and build up to virtually 100 percent towards the end of the season. These species pass the winter in the adult stage and are found in swarms in nearby trees. Dissections of larvae failed to reveal the presence of any species of *Opius*, though puparia yielded a few *Tetrastichus* spp. and *Dirhinus giffardii*. Infested cucurbits placed in piles in the field to give maximum opportunity for parasitization produced 4,970 puparia, but not a single parasite emerged from this lot of material.

The months of November, December, and early January were spent at Stellenbosch and Capetown. Here also the cucurbits are heavily infested by fruit flies; so much so, that the growing of these crops is restricted to the early portion of the growing season. Some cultivated fruits are attacked by the Mediterranean fruit fly and the Natal fruit fly (*Pterandrus rosa*), while the wild olive yielded large numbers of *Dacus* (*Daculus*) *oleae*, which proved to be parasitized to the extent of 50 percent or more by two species of *Opius* and several Chalcidoidea and Proctotrupoidea.

Collections were made in South Africa of a considerable number of fruits that were not available in sufficient quantity for rearings

for shipment to Hawaii, but the flies from these were reared out and indentified by Dr. Munro, as follows:

HOST FRUIT	FRUIT FLIES REARED
Aberia caffra	*Ceratitis capitata* (Wied.)
Asclepias physocarpa	*Dacus (Daculus) brevistriga* Wlk.
Capparis citrifolia	*Ceratitis capitata* (Wied.)
Capparis tomentosa	*Pardalaspis bipustulata* Bez.
	Themaricera laticeps (Loew)
Carissa bispinosa	*Pardalaspis bipustulata* Bez.
C. grandiflora	*Pterandrus rosa* (Ksh.)
Conopharyngia sp.	*Pardalaspis punctata* (Wied.)
Cucurbitaceae, cultivated	*Dacus bivittatus cucumarius* Suck
	D. ciliatus ciliatus Loew
	D. (Didacus) frontalis Beck.[1]
Maerua triphylla	*Pardalaspis melanaspis* Bez.
Mimusops caffra	*Ceratitis capitata* (Wied.)
Momordica involucrata	*Dacus ciliatus ciliatus* Loew
Passiflora coerulea	*Ceratitis capitata* (Wied.)
	Dacus ciliatus Loew
Psidium sp.	*Ceratitis capitata* (Wied.)
	Pterandrus rosa (Ksh.)
Rawsonia lucida	Do.
Sclerocarya caffra	*Pardalaspis cosyra* (Wlk.)
Sideroxylon inerme	*Ceratitis capitata* (Wied.)
Solanum auriculatum	*Pterandrus rosa* (Ksh.)
Strychnos spinosa	Do.
	Pardalaspis cosyra (Wlk.)
Voacanga dregei	*P. punctata* (Wied.)

[1] According to Munro, 1960, this may be the same as *D. duplex Mro.*, or *vertebratus* Bez.

After leaving Stellenbosch, field observations were made at Grahamstown, Port Alfred, Hogsback, Umtata, Port St. John, and Durban, but aside from infestation records in various cultivated and wild fruits, no promising leads to effective natural enemies were discovered. Pietermaritzburg was reached early in March and here, as well as at Eshowe, extensive surveys were undertaken. The fruit fly situation in Natal differed very little from that in the areas of South Africa already visited. Large-scale rearing of Natal fruit fly material yielded no parasites. Various cultivated and wild cucurbits were collected in quantity, and while the parasitization was known to be low, three consignments, comprising 12,500 puparia of *Dacus* from cultivated cucurbits and 2,200 of *Ceratitis capitata* from *Chrysophyllum* sp., were forwarded to the Bureau laboratory at Hoboken, N.J., where the parasites were reared out and forwarded to Hawaii.

Inasmuch as the survey in South Africa, covering more than eight months, had been exceedingly unproductive in parasites and predators of fruit flies, it was decided to move the base of operations to East Africa, which the 1935–36 Mediterranean fruit fly expedition had shown to be a promising area for further study.

En route from South Africa to Kenya in June 1949, and on the return trip the following year, it was possible to make some hasty observations on fruit flies and their hosts in southern Mozambique, Southern and Northern Rhodesia, and Tanganyika. The area about Laurenco Marques was scouted for several days. Fruits of *Strychnos* sp. and of an unidentified species of Asclepiadaceae were found in small numbers and proved to be infested, as well as a few wild Cucurbitaceae. The produce in the city markets was examined, but at this

season (midwinter) the bulk of the melons and squash offered for sale are not produced locally but shipped in from the Transvaal.

Samples of fruit collected for rearing yielded *Pardalaspis pedestris* Bez. from *Strychnos* sp. and *Dacus bivittatus cucumarius*, *D.* (*Dacus*) *punctatifrons* Ksh., and *D. ciliatus ciliatus* from wild cucurbits. In the Rhodesias, loquats were found to be infested, but no adult flies were obtained. Dissections showed that a few of the larvae were parasitized by *Opius*.

The limited observations and collection of fruit fly material by Bianchi and Krauss (*5*) in Kenya in 1935–36 had indicated the occurrence of several potentially valuable parasites in that region, and the vastly improved facilities for air shipment at the time of the current investigations gave promise that shipments would reach Hawaii in living condition.

The investigations in Kenya began early in July 1949, with the arrival at Nairobi from South Africa of Messrs. McGough and Skinner. Field studies and collections were continued until early February of the following year, when they were temporarily interrupted by a trip to South Africa, which extended to the latter part of May. A few weeks of collecting at Nairobi was then followed by a 3-months' trip to Hawaii by McGough, after which studies in Kenya were renewed for 1 month and completed early in October, with the base of operations then shifted to the Belgian Congo. Mr. Skinner was transferred to the Philippine Islands early in September 1949, and thereafter the survey and collections were made by McGough alone.

Immediately after arrival at Nairobi, the Department of Agriculture was visited, and later the Scott Agricultural Laboratories, where Dr. R. LePelley was entomologist. Dr. LePelley had been engaged in biological-control work on coffee mealybug and other problems for many years, and was thoroughly familiar with the insect pest problems of British East Africa. Because of this, his advice and suggestions were exceedingly helpful throughout the investigations. For fruit fly studies, he recommended Limuru, about 20 miles west of Nairobi, at an elevation of 7,800 feet, and Naivasha on the lake of the same name, 50 miles northwest of Nairobi, elevation 6,200 feet, as being the most promising localities in which to make an initial survey.

Dr. L. P. S. Leakey, director of the Coryndon Museum, and Mr. E. Pinhey, entomologist, were very helpful in naming insect material, and an excellent Tephritid collection in the Museum proved valuable in identifying local species of that family. P. O. R. Bally, botanist at the Museum, was of great assistance in naming the many plants from which fruit fly material was reared.

During the July–September quarter, it was possible to make large-scale collections of wild olive, *Olea chrysophylla*, and approximately 100 gallons were obtained in the Nygobi Forest on the escarpment of the Rift Valley, either by collection or purchase, and these were set aside for rearing. Cultivated cucurbits were available in fair quantity, and 10–15 gallons each of fruits of greenheart (*Warburgia ugandensis*), kei apple (*Aberia caffra*), and *Strychnos* sp. were also obtained. The latter were collected mainly from the City Park in Nairobi, after severe competition with the monkeys for the available supply. The 100 gallons of wild olives were heavily infested and yielded more than 76,000 fruit fly puparia for shipment.

Much difficulty was experienced at this time in making shipments by air eastward to Hawaii, as the air lines refused to accept the consignments unless advance clearance had been obtained from the different countries in which transshipment would be made en route. Because of this requirement, the second shipment, comprising 23,600 puparia, was sent instead to the Bureau station at Hoboken, N.J., where the parasites were then reared out and sent on to the final destination. Later shipments were consigned directly to Hawaii via New York, as the time required in transit proved to be much less than by way of India and the Pacific.

The ripening period for fruits and vegetables in the Nairobi area covered a wide range, as there are usually two rainy periods each year, in April–May and November–December. In addition to the fruits above mentioned, about 6 gallons of coffee berries were obtained for examination in early August, but these proved to contain mostly fruit fly eggs and very young larvae. When set aside for rearing, they yielded only *Ceratitis* spp., the puparia of which were parasitized to the extent of about 25 percent by *Opius africanus*. Sample rearings were made from 22 additional lots of fruit during this period, most of which were not available in sufficient quantity for shipment.

The October to December period was most productive in material from cultivated and wild Cucurbitaceae. The 19 shipments forwarded during the quarter included 66,774 puparia from these fruits. Most of these were collected in the Nairobi area, with a small portion from Mombasa. In addition, the last of the wild olive crop yielded 3,825 puparia. Fruits of *Warburgia ugandensis* became more abundant, and 38,576 puparia were obtained from them. Coffee was still available only in small quantities.

The season's work in Kenya was completed early in February 1950. Shipments to Hawaii from the first of the year comprised 43,391 puparia from cucurbits, 22,255 from *Warburgia*, and 6,835 from coffee. The two first-named fruits appear to be heavily infested throughout the year.

During late May and early June, following a period of collecting in South Africa, the assembling of material in the Nairobi area was renewed. As usual, Cucurbitaceae provided the bulk of the material. The last shipment was carried to Hawaii by Mr. McGough, and included 3,000 infested fruits of *Strychnos reticulata*, 3,000 fruits of *Chrysophyllum pruniforme* and 5,000 puparia from same, 5,000 puparia from *Drypetes* spp., 3,000 fruits of an unidentified plant and 150 puparia from same, 25,000 puparia from cultivated cucurbits, and 29 adult *Opius* spp.

The third and final collecting period in Kenya extended from early September to early October 1950. Efforts were concentrated upon *Strychnos usambarensis* during this time as the fruits were abundant and adequate quantities of puparia from other common fruits had already been forwarded. In a short collecting period it was possible to rear out and forward a total of 41,620 puparia from this source.

A considerable variety of fruit fly species was found to be represented in the collections from the different fruits in Kenya. The heavily infested wild olives yielded only *Dacus oleae*, while in coffee, *Ceratitis capitata* predominated, with a few *Pterandrus rosa* and *Trirhithrum coffeae* appearing in the rearings. *T. queritum* was also present in small numbers in *Drypetes* fruits and was the only species

infesting *Strychnos usambarensis*. The shipments of *Strychnos reticulata* yielded only *Pterandrus rosa*, on the basis of identifications after emergence in Hawaii, though specimens reared from this fruit in Kenya and examined by H. K. Munro were identified as *Pterandrus curvatus* Mro., *Pardalaspis lobata* Mro., and *Ceratitis capitata*. *Pardalaspis contramedia* was the dominant species in *Warburgia ugandensis*, accompanied by a smaller number of *P. cosyra*. From *Drypetes* sp. the principal species were *Pardalaspis* sp. (?) and *Carpophthoromyia dimidiata*.

Rearings from mixed Cucurbitaceae produced *Dacus ciliatus ciliatus* and *D. bivittatus cucumarius* in nearly equal numbers, and relatively few *D. cucurbitae*. The melon fly is of relatively recent establishment in East Africa. One rearing of this species was from Mombasa and others probably, but not certainly, were from the Nairobi area.

In addition to the species mentioned above, that were present in some numbers in the material shipped to Hawaii, there were other fruits collected in small numbers in Kenya that yielded Tephritidae, named by Dr. Munro as follows:

HOST FRUIT	FRUIT FLIES REARED
Aberia caffra	*Pterandrus rosa* (Ksh.)
Acokanthera friesiorum	*Pardalaspis simi* Mro.
Conopharyngia johnstoni	*Pardalaspis* sp.
Cucumis aculeatus	*Dacus* (*Daculus*) *vertebratus* Bez.
Eriobotrya japonica	*Ceratitis capitata* (Wied.)
Euclea sp.	*Dacus oleae* (Gmel.)
Landolphia florida	*Pardalaspis cosyra* (Wlk.)
Psidium sp.	*Pterandrus rosa* (Ksh.)
Solanum spp.	*Xanthorrhachista alata* (Beck.)

In Kenya field parasitization was noted for *Dacus oleae* in wild olive, which was attacked by *Opius africanus* to the extent of about 25 to 35 percent, and less frequently by several other species of that genus. *O. phaeostigma* Wilk. was present in *Dacus ciliatus ciliatus*, *D. bivittatus cucumarius*, *Pardalaspis contramedia*, and *Trirhithrum queritum*, and several other species appeared in smaller numbers as parasites of the same genera.

Of the chalcidoid parasites reared from the pupae, the most abundant were *Tetrastichus giffardianus*, *T. dacicida*, and *T. giffardii*, which were found to attack practically all species. *Dirhinus giffardii* appeared to be common only in puparia of host species developing in *Cucurbitaceae*. *Spalangia* spp., *Pachycrepoideus*, and *Psilus* sp. were noted in only very small numbers.

The trip westward by Mr. McGough from Kenya to the Belgian Congo was started early in October 1950. The route followed was via Kisumu to Kampala, Uganda, and thence into the Belgian Congo by way of Fort Portal. En route through southern Uganda it was possible to make some observations on fruit fly infestation in a number of fruits. At the Kowanda Experiment Station near Kampala, tomato, cultivated cucurbits, papaya, coffee, and *Annona* sp. were found to be infested, while in the Mabiro Forest area at Namataba the same was true of pumpkin, a wild species of Passifloraceae, the fruits of which contained many eggs but no larvae, and wild Cucurbitaceae. At Fort Portal, little fruit could be found and very few of these were infested. The citrus fruits that were seen were free from maggots. A few flies were obtained from *Melothria maderaspatana* and from cultivated cucurbits.

No material was assembled in Uganda for shipment to Hawaii because of the small amount of fruit that could be collected. Samples of the following fruits, obtained mainly at the Kawanda Experiment Station and forest areas near Namataba, showed infestation. The flies were reared out and identified by Dr. Munro, as follows:

HOST FRUIT	FRUIT FLIES REARED
Coffea robusta	*Trirhithrum coffeae* Bez. *Ceratitis capitata* (Wied.)
Cucurbita pepo	*Dacus* sp.
Cucurbitaceae, cultivated	*D. bivittatus cucumarius* Sack
Cucurbitaceae, wild	*D. punctatifrons* Ksh.
Lycopersicon esculentum	*D. bivittatus cucumarius* Sack
Melothria maderaspatana	*D. (Dacus) bivittatus* Big.

Two trips were made to Ituri and Bwamba Forests, about 40 miles to the west of Fort Portal. These forests extend westward into the Belgian Congo. Pygmies served as guides through the Bwamba Forest and were familiar with the fruiting plants of the area. Very little was found at this time, and they indicated that most forest fruits ripen during December to March.

A base for the work in the Belgain Congo was established at Yangambi, situated about 80 miles west of Stanleyville, on the north side of the Congo River. Here also are the headquarters of the Institut National Pour L'Etude Agronomique au Congo. This locality is less than one degree from the Equator, and the elevation is about 1,600 feet.

L. Soyer, Director-General, and E. J. Buyckx, entomologist, of the Institut, provided every facility, including one section of an insectary, and were exceedingly helpful in many ways. Considerable difficulty was experienced in forwarding parasite material from Yangambi, inasmuch as the Customs Service required that each shipment be packed in the presence of an official of that Service, necessitating a trip to Stanleyville with each consignment. Later, authorization was obtained for packing the material at Yangambi, provided that each consignment was accompanied by a certificate stating that an officer of the Institut had supervised the final preparation.

During December, collections of fruit fly material were limited to false kamani and mixed Sapotaceae, and totaled 24,650 puparia. The following quarter was more productive of a variety of material, and fruits of an additional 20 kinds of trees, shrubs, and vines were obtained for observation. The fruits of 16 of these proved to be infested with fruit fly maggots to a varying extent, but only *Chrysophyllum pruniforme*, *Tridesmostemon claessensi*, *Terminalia catappa*, *Pancovia laurentii*, *Coffea robusta*, and several unidentified Sapotaceae were available in sufficient numbers for large-scale collection. *Pancovia* has a fruiting season of only about 2 weeks in late February and early March, and *Chrysophyllum* was available only until the end of February. Shipments from the Belgian Congo totaled 135,532 puparia, the bulk of which came from *Terminalia*, *Chrysophyllum*, and *Pancovia*.

As the dry season advanced it was found that an increasing portion of the maggots remained in the fruits for pupation, thus greatly reducing the yield for shipment. This problem was solved, to a considerable extent, by occasional heavy sprinkling of the fruit with water, simulating heavy rain.

The above collections yielded very little variety in species of fruit flies. *Pardalaspis ditissima* was the only species reared from *Chrysophyllum*, *Tridesmostemon*, and the large collections of mixed Sapotaceae. Fruits of *Terminalia* sp. yielded mainly *Pterandrus anonae* and a few *Pardalaspis cosyra* (?), but no *P. ditissima*. *Pancovia* fruits produced only *Pterandrus anonae*. *Trichithrum coffeae* was obtained only from *Coffea robusta*, and this was the only fruit fly found attacking the berries of that plant.

One sample of puparia of *Pardalaspis ditissima* from *Chrysophyllum* yielded 71 fruit flies, 68 *Opius* spp., and 32 colonies of *Tetrastichus dacicida*, thus showing a field parasitization of about 58 percent. The puparia of *Pterandrus anonae* from *Terminalia* yielded very few *Opius*, but were parasitized to the extent of more than 50 percent by *Tetrastichus*. The sample of *Pardalaspis* from *Tridesmostemon* was also heavily parasitized, nearly 50 percent by *Tetrastichus* and 17 percent by *Opius*. A later collection of *Pterandrus anonae* from *Pancovia* showed a combined parasitization of 15 percent by four species of *Opius*.

Miscellaneous fruit fly material reared from other fruits in the Belgian Congo but not sufficient for shipment was as follows:

HOST FRUIT	FRUIT FLY SPECIES REARED
Adenia lobata	*Dacus* (*Dacus*) *purus* (Curr.)
Cucurbitaceae, cultivated	*D. bivittatus* (Big.)
Drypetes sp.	*Pterandrus anonae* (Grab.)
Erythrophleum guineense	*Aethiothemara fallaciosa* (End.)
Eugenia uniflora	*Pterandrus anonae* (Grab.)
Momordica charantia	*Dacus* (*Dacus*) *momordicae* Bez.
Panda oleosa	*Pterandrus anonae* (Grab.)
Psidium sp.	Do.
Tabernanthe sp.	*Pardalaspis* sp.

The studies in the French Cameroons were undertaken during May to early September 1951. Some shrubs of *Myrianthus* were seen in the forests between Bangui and Yaounde, but the fruit was small and green, while a species of *Strychnos* also bore immature fruits. Scouting was extended to the Kribi area during the latter part of May and continued into early July, but this area did not prove productive and Yaounde again became the scene of operations; then to Mbalmayo, about 30 miles southwest of Yaounde. The Ottotomo Forest, about 30 miles west of this locality, and at an elevation of about 2,300 feet, provided fruits of a number of forest trees, shrubs, and vines.

The first collections for shipment were from fruits of *Myrianthus arboreus*, which were available in unlimited quantity in the Forest during July and August. More than 58,000 puparia of *Pterandrus anonae* were obtained from this fruit. A sample of 333 puparia yielded 27 adults of 2 species of *Opius*, 56 colonies of *Tetrastichus giffardii*, and 112 adult flies.

Cultivated cucurbits were very heavily infested by *Dacus bivittatus cucumarius* but could not be obtained in large quantities because the native owners, as soon as they became aware of the demand for infested fruit, named a prohibitive price for them. These cucurbits yielded only the above species, and field aggregate parasitization averaged about 10 percent by 2 species of *Opius* and by *Tetrastichus*.

Other fruits found to be infested, but not available in sufficient numbers to permit collections for shipment, were ripe bananas, avo-

cado, guava, coffee, *Conopharyngia*, *Adenia lobata* (?), *and Pycnanthus kombo*.

Observations were made on infestations in fruit of a number of additional plants for which identification could not be obtained. Cultivated gourds, one used only for the making of liquid containers and another produced only for its seeds, were infested with *Dacus* larvae, which were parasitized by *Opius* sp. to the extent of about 6 percent. The fruits of what was possibly *Cola mirabilis* and another species of that genus were also infested. Small numbers of puparia were obtained from five of these undetermined plants. Unfortunately, these, and about 20,000 puparia from *Myrianthus* and cultivated cucurbits that were included in the last shipment, were lost in transit to Hawaii.

Brazil and Mexico

A number of species of the tephritid genus *Anastrepha* are common pests of a variety of fruits in Brazil and other South American countries, and are parasitized by several species of *Opius*, principally *cereus* Gahan, *anastrephae* (Vier.), and *bellus* Gahan. Early tests with these parasites against the Mediterranean fruit fly in Hawaii (see p. 3) had shown them not to be adapted to that host, a conclusion in accord with absence of attack on that fruit fly in the field in Brazil. Importation of the natural enemies of *Anastrepha* was again undertaken on the chance that they might be adaptable to the oriental fruit fly.

On his return from West Africa in May 1951, D. W. Clancy spent that month and the early part of June in the vicinity of Rio de Janeiro with the object of securing the above natural enemies, and others that might be found. This period was unfavorable for collection, however, it being early winter, and the fruiting season of most plants was past. Eventually, large quantities of the small yellow fruit of hog plum (*Spondias mombin*) were found, and these proved to be heavily infested with *Anastrepha mombinpraeoptans* Sein, the larvae of which were heavily parasitized by *Opius cereus* and *O. anastrephae*. Other infested fruits obtained in smaller quantity were carambola, *Citrus* spp., Surinam cherry (*Eugenia uniflora*), *Spondias dulcis*, and *Lucuma caimito*. A total of 23,332 puparia of *A. mombinpraeoptans* and *A. serpentina* (Wied.) were obtained for shipment to Hawaii. Unfortunately, because of the adverse season, the two staphylinid predators of the genus *Belonuchus* known to occur there could not be found.

The most common of the fruit flies attacking mango, citrus, and other fruits in Mexico is *Anastrepha ludens* (Loew), which is parasitized by *Opius crawfordi* (Vier.). This species had also been tested against the Mediterranean fruit fly in Hawaii in 1936. In October 1949, through the cooperation of W. E. Stone of the Bureau's fruit fly laboratory at Mexico City, a consignment of 323 adults of *O. crawfordi* was forwarded to Hawaii for testing upon the oriental fruit fly.

Summary of Fruit Fly Shipments to Hawaii

During the years 1947 to 1951, covered by the foreign exploration program of the fruit fly project, more than 60 species of Tephritidae were collected from a wide range of host fruits in many tropical and

subtropical countries and shipped to Hawaii. Of the total number of puparia that were shipped to Hawaii, the species most strongly represented was, of course, *Dacus dorsalis*, which comprised more than 1½ million, followed by *Carpomyia vesuviana*, 544,000, and the melon fly *D. cucurbitae*, 400,000 puparia.

Number of puparia forwarded from each country or geographic area

Africa:		Java	555
South Africa	14, 700	Pacific Islands:	
Kenya	361, 033	Fiji	46, 462
Belgian Congo	135, 532	New Caledonia	69, 029
French Cameroons	60, 730	New Britain	3, 977
Australia	354, 905	Saipan	125
Borneo	269, 532	Philippine Islands:	
Brazil	23, 332	Luzon	11, 759
Ceylon	128, 400	Mindanao	54, 273
Formosa	222, 745	South China	45, 855
India:		Thailand	157, 859
North	791, 436		
South	1, 203, 018	Total	4, 294, 349
Malaya	339, 092		

Details of the rearing in Hawaii of the different species of parasites from the imported puparia are given in a following section (p. 48).

In addition to the shipments of fruit fly puparia listed above, a number of parasites and predators were forwarded in their free-living stages to Hawaii. These included 9,033 adults of *Bracon fletcheri* reared from *Carpomyia vesuviana* in North India; 323 *Opius crawfordi* from Mexico; 102 pupae of *Philonthus* sp., a staphylinid predator on the larvae, and 650 miscellaneous Hymenoptera, presumed to be parasitic on fruit flies from South China; 522 adults, 5 larvae, and 55 eggs of *Thyreocephalus albertisi* from the Philippine Islands; 94 adults and 43 nymphs of *Germalus pacificus* Kirk., a lygaeid predator of rather general habits, from Fiji; and an unrecorded number of a parasitic mite, *Tyroglyphus* sp., that attacks fruit fly larvae and pupae in the soil in Formosa.

Methods of Collecting, Rearing, and Shipping Fruit Fly Material

As the foreign collection program was initially set up on the basis that any and all fruit fly puparia that could be obtained were to be shipped in that stage, the problems confronting the foreign explorers were much simplified, comprising mainly (1) the finding and collection of infested fruits, (2) the holding of these fruits until completion of feeding and pupation by the fruit flies, and (3) the shipment of the puparia to Hawaii.

Despite this reduction of the program to its bare essentials, a great many problems were encountered by the parasite collectors in the different countries in the course of their investigations, and a great deal of ingenuity and improvisation were involved in solving them. The mere collection of fruit, which at first glance would appear to be a comparatively simple matter, often became a major problem. In many areas all available fruit was harvested by the natives long before it was suitable for fruit fly attack. The few fruits that were not thus

harvested were greedily eaten by monkeys, birds, bats, et cetera if still on the tree, and by pigs, rats, chickens, and other animals if on the ground. As a result, ripe or nearly ripe fruit, either on the tree or on the ground, was often exceedingly scarce and difficult to obtain. In some cases, to obtain sufficient quantities of infested fruit, it was necessary to purchase in advance the crop of a specified number of trees and then have them guarded night and day until the fruit was ready for harvest.

Rearing of the fruit fly larvae from infested fruit is a simple matter where insectary facilities and equipment are available, but in many of the areas where these investigations were conducted even the simplest equipment was unavailable and rearing boxes, trays, covers, et cetera, had to be improvised from whatever material was at hand. The 5-gallon oil tin, which can be found almost everywhere, proved very useful, and on one occasion in Central Africa, 50-gallon wine barrels, cut in half, served satisfactorily as rearing containers.

Infested fruits usually need to be held about 2 weeks in order to obtain the full-grown larvae. This period permits the partly grown larvae to complete their development, and it is then the general habit of the family for the larvae to leave the fruits and to enter the soil for pupation. Certain fruits, such as those of *Eugenia*, decay very rapidly, so that they can be held in the trays not to exceed 1 week, and consequently only larvae are obtained that are practically full-grown at the time the fruit is collected.

The general practice in the handling of fruit was to place it in trays or baskets over sand, so that the larvae, as they leave the fruit, drop onto the sand, burrow into it, and pupate.

Bianchi found, in North India, that a cloth receiving tray, without sand, yielded the best results with the oriental fruit fly, yet this method, when tested with the same fly species in South India, proved unsatisfactory. In his collections of fruits of *Dracontomelum dao* in Mindanao, Skinner found that best results were obtained when the fruits were first held in cloth sacks for 3 to 4 days and then spread on wire trays over moist sand. The larvae died without pupating if held in dry sand or on cloth.

McDough, in dealing with infested fruits of *Trichesmostemon* during the dry season in Central Africa, found that the larvae of *Pardalaspis discissura* showed a pronounced tendency to pupate in the fruit. This difficulty was solved by subjecting the fruit to heavy sprinkling with water, simulating a heavy rain.

In all rearing programs, the protection of the infested fruit and pupation trays from ants proved to be absolutely essential, otherwise a virtually complete mortality of the larvae inevitably ensued. This protection was provided by equipping the trays with legs and banding them with cloth saturated with mercuric chloride, or by the use of a heavy automobile lubricating grease. Another alternative was to have the legs standing in tins of oil.

Trays of fruit held in the open, either for emergence of fruit fly larvae or to obtain higher parasitization, had to be protected against birds, rats, monkeys, and other predators. This was accomplished by the use of heavy screen covers, or covers of split bamboo with a 1-inch mesh that could be made on the spot. Trays needed to be protected also

against the heavy downpours that frequently occur in the Tropics during the rainy season. These temporary shelters provided protection against strong sunlight as well.

The method described above for the handling of fruit fly material was satisfactory insofar as it insured that braconid parasites of the genus *Opius* would be present in the puparia to an extent approaching natural parasitization in the field. These species normally attack their hosts in the egg or early and middle larval instars. However, puparia obtained in this way would not yield appreciable numbers of the chalcidoid, cynipoid, and prototrupoid parasites that were known to attack practically all fruit fly species. They oviposit into the fully-grown larvae as they are about to leave the fruit for pupation, or directly into the puparia. These parasites were obtained by exposing the rearing trays in the open at sites where natural populations of these parasites were present, enabling them to oviposit in the emerging full-grown larvae or in already-formed puparia. This procedure provided sufficient parasitized puparia for shipment, though it did not reflect in any way the extent of parasitization in the field.

In forwarding the fruit fly puparia by air mail or air express from the different countries, they are placed loose in double cloth bags, with shredded soft paper, each bag securely tied, the whole then packed in a strong wooden box having a screened aperature at each end for ventilation. Several thousand puparia could thus be shipped in a parcel weighing only 1 or 2 pounds. Air shipments from the most distant countries usually reached Hawaii in 7 to 10 days. Since the pupal period of many of the fruit flies is about 2 weeks under tropical temperatures, shipment from the more distant countries had to be made fairly soon after pupation. On the other hand, Skinner found that the puparia of *Dacus limbiferus* must remain in moist soil or sand for several days after pupation; otherwise, they die very quickly. The margin of time available was, therefore, not great and consignments that were much delayed in transit contained only a mass of dead flies and parasites upon arrival.

There were wide and unexplainable differences in the condition of the shipments of fruit fly material upon arrival at Honolulu, even when there was no apparent delay in transit. The most probable cause of this very high mortality in some consignments was exposure to high temperatures while the planes were grounded at airports en route. During such stops, which may cover several hours, the cooling system of the plane is not in operation and the mail and express compartments, as well as the passenger cabins, may become heated to such a degree that the insects are killed. Also, the insecticidal aerosol treatment to which airplanes in international movement are usually subjected may have a harmful effect upon parasite material shipped by air mail or express.

The very large numbers of puparia dealt with by the several expeditions precluded the employment of refined techniques such as might have been used with smaller numbers. The flies emerging after arrival at Honolulu represented a very small portion of the total shipped, and this was true also of the parasites, judging from those cases where the approximate extent of parasitization of the material was known.

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Quarantine Rearing of Natural Enemies

All incoming shipments from the foreign explorers were received and held for rearing in Honolulu under strict quarantine to prevent the escape of any fruit flies and hyperparasites, or of various contaminants contained in them. Those received prior to January 1949 were handled in the quarantine room of the Hawaii Board of Agriculture and Forestry; thereafter, all shipments were received by Bureau personnel in the Pineapple Research Institute quarantine building on the University of Hawaii campus.

Upon receipt, the packages were opened in a special glass-topped receiving box with cloth sleeves in order to confine any adult fruit flies that had emerged in transit. The fruit fly puparia enclosed in cloth bags were emptied into wide-mouth fruit jars of various sizes, organdie tops were secured by the regular screw-on metal rims, and the closed jars were removed and placed on shelves to await emergence. No moisture was added to the jars since it was found that emergence was not increased thereby and objectionable molds often resulted.

The emerging fruit flies and parasites were removed from the jars each day in a collecting hood with glass front facing a window, the operator's head and shoulders being inside the hood and beneath a black cloth curtain attached at the rear to force the insects toward the light and thus prevent their escape into the quarantine room. As an added precaution, the upper walls and ceiling of the room were painted with a strong solution of wettable DDT to kill any flies that might escape. When newly formed puparia are shipped at frequent intervals, most of the adult flies emerge before the parasites, thus simplifying their collection and preventing considerable parasite mortality that may otherwise result from "smothering" by numerous, damp, freshly emerged flies from puparia of various ages. Results were also improved by limiting the quantity of puparia per jar to a depth of three-fourths inch or less, and by providing small bits of loose excelsior through which the emerging parasites could crawl to help dislodge the clinging host puparia. The excelsior also afforded additional resting space, and increased the survival of parasites, which often had difficulty clinging to the glass walls of the jars.

Both fruit flies and parasites were collected by suction, piped to the collecting hood from an electric vacuum cleaner adapted for this purpose, or by mouth aspirators for small collections. The fruit flies were held in covered jars in the receiving box until they had properly hardened and colored, and were then killed by fumigation in a tight container and turned over to D. Elmo Hardy of the University of Hawaii for identification. The adult parasites were collected separately as to species, a fine streak of pure honey was placed in each vial for food, and the number and sex (where possible) of each species recorded daily on the emergence sheet. Since the late-emerging pupal parasites tended to remain at the bottom among the fly puparia, they were best collected by pouring the puparia into petrie dishes or shallow box tops at each examination. The emerged puparia and all wrapping and packing materials were thoroughly fumigated before being removed from the quarantine room for burning.

The parasite-rearing data are not indicative of natural field parasitization because of (1) the collection of host fruits before maximum exposure to natural infestation and parasitization, (2) different

methods of handling and rearing at points of origin, and (3) wide variations in larval and pupal mortality during shipment. Samples of puparia reared by several of the foreign explorers usually gave better parasite emergence than was obtained from the same collections after arrival in Honolulu. Furthermore, the reared pupal parasites were largely the result of incidental attack in the rearing containers prior to shipment and probably also of additional parasitization by early emerging adults en route and in the quarantine room. Since the small, gregarious larval parasites *Aceratoneuromyia indicum* and *Tetrastichus* spp. produce a variable number of adults per host, the recorded totals are not comparable with those of the solitary larval and pupal parasites.

Quarantine rearings from the foreign shipments are discussed according to country of origin, in the same order as covered under foreign exploration.

Philippine Islands

Detailed emergence records are not available for all of the Luzon shipments received in 1947, but so-called *Opius persulcatus* was the predominant parasite of *Dacus dorsalis*, with a recorded emergence of 101 adults (73 females). These were later found to be a mixture of *O. oophilus* and *O. vandenboschi* rather than *O. persulcatus*, the actual proportion of each species being unknown. The same shipments also produced a few adults of *O. longicaudatus* var. *chocki*, *O. incisi*, and *Aceratoneuromyia indicum*.

The 63 puparia of *Dacus cucurbitae* from cucumbers yielded 23 adults (8 females) of *Opius fletcheri*.

The predaceous staphylinid beetle *Thyreocephalus albertisi* was propagated and released in Hawaii for several years, and considerable information was obtained on the biology and laboratory culture of this predator (*25*).

About 80 percent of the 54,273 fruit fly puparia received from Mindanao were *Dacus limbiferus* infesting the fruits of the native forest tree *Dracontomelum duo*, and these produced 98 percent of the total parasite emergence listed below. The only species not obtained from these collections was *Opius makii*, which issued solely from *Dacus nubilus* infesting *Trichosanthes* sp.

Parasites reared	*Females*	*Total*
Opius longicaudatus (Ashm.) var.?	1,403	2,804
Opius skinneri Full.	573	1,101
Opius fletcheri Silv. var.?	44	80
Opius makii Sonan	15	20
Spalangia sp.	?	36
Psilus sp.	?	26
Pachyerepoideus vindemmiae (Rond.)	?	9
Eucyrtidae sp.?	?	5
Total	2,035	4,081

A possible color variety of *Opius longicaudatus* was easily the dominant parasite of *Dacus limbiferus*, with *O. skinneri* next in importance. The latter species is a very distinct large, black opiine not found in any other area. Twenty-two adults of *O. skinneri* were also reared from *Euphranta* n. sp. and 5 from the carambola collections, which produced mainly *D. pedestris*. *D. limbiferus* was also parasit-

ized by an apparent variety of *O. fletcheri*, only 3 adults issuing from *D. cucurbitae* infesting cucumbers. The relatively few pupal parasites emerged only from *D. limbiferus* and *D. cucurbitae*, the unidentified encyrtids from *D. limbiferus*.

Malaya

The final 39 of Mr. Krauss' 85 Malayan shipments were received by the Bureau when this phase of the cooperative project was transferred from the Territorial Board in January 1949. As shown in table 11, nearly 19,000 adult parasites of about 15 different species emerged from the 339,092 fruit fly puparia received by both organizations during the course of these investigations.

Ninety-three percent of the *Dacus dorsalis* puparia comprising the bulk of these shipments were obtained from the fruits of carambola, and these collections also furnished the vast majority of adult parasites. Those of the *Opius persulcatus* complex were consistently more numerous than all of the others combined, accounting for 81 percent of the *Opius* spp. reared from the oriental fruit fly. This complex was later found to consist of *O. oophilus* and *O. vandenboschi* rather than the true *O. persulcatus*, the majority of preserved specimens being *oophilus*. The actual ratio of these two species in the Malayan material is thus unknown, though *O. oophilus* was presumably the dominant parasite.

Opius incisi ranked second as a parasite of *Dacus dorsalis* infesting carambola but it actually outnumbered the *O. persulcatus* complex from the smaller fruits of *Solanum verbascifolium* and *Capsicum* sp. where it is able to reach more of the host larvae with its short ovipositor.

Opius longicaudatus var. *malaiensis* was the least numerous of the four Malayan oriental fruit fly opiines throughout the period of collection. It is interesting to note that, with the exception of *O. incisi*, these species have assumed about the same order of relative importance in Hawaii following their successful introduction from Malaya.

Aceratoneuromyia indicum and most of the *Tachinaephagus* spp. also issued from *D. dorsalis*, as did the majority of pupal parasites.

The cucurbit collections, consisting mainly of *Dacus cucurbitae*, produced a few *Opius fletcheri*, *Tachinaephagus* spp., and *Spalangia* spp., while *D. ambrosus* was very lightly parasitized only by several Cynipidae (including *Trybliographa daci*) and *Tachinaephagus* spp.

South China

The general scarcity of fruit flies and their natural enemies and the complete absence of *Dacus dorsalis* in the rather limited fruit collections obtained in south China have already been noted. Even the 41,121 puparia of *D. latifrons* from *Solanum* spp. in the Canton area produced only 2 adults of an unidentified *Opius* (possibly *O. arisanus* Sonan), 205 *Spalangia* sp., and 16 *Pachycrepoideus rindemmiae* (*dubius* Ashm.) upon arrival in Honolulu. An additional 97 *Spalangia* sp., 1 *P. rindemmiae*, and 1 *Dirhinus* sp. also issued from the smaller cucurbit collections infested by *D. cucurbitae* and *D. nubilus*.

Approximately 650 adult hymenopterous and dipterous parasites reared from various fruits at Canton were also shipped to Hawaii, of

TABLE 11.—*Parasites reared from fruit fly puparia imported from Malaya*

Fruit fly species	Number of puparia received	*Opius persulcatus* (Silv.)[1]	*Opius incisi* Silv.	*Opius longicaudatus malaiensis* Full.	*Opius fletcheri* Silv.	*Tachinaephagus* spp.[2]	*Aceratoneuromyia indicum* Silv.	*Pachycrepoideus vindemmiae* (Rond.)	*Spalangia* spp.[3]	Cynipidae[4]	*Psilus* sp.
Dacus dorsalis	303, 625	13, 905	2, 615	587	-------	442	299	625	189	19	7
Dacus cucurbitae	27, 309	-------	-------	-------	83	4	-------	-------	40	-------	-------
Dacus hageni											
Dacus umbrosus	8, 158	-------	-------	-------	-------	4	-------	-------	-------	33	-------
Total	339, 092	13, 905	2, 615	587	83	450	299	625	229	52	7
Number of females	-------	9, 399	1, 602	305	51	-------	-------	-------	-------	-------	-------

[1] Not the true *persulcatus*, but a complex consisting of *Opius oophilus* Full. and *O. vandenboschi* Full. An examination of reared specimens indicates that the majority were *O. oophilus*.

[2] Consists of two apparently undescribed species.

[3] Mostly *S. endius* Wlk., with a few *Spalangia* sp. near *simplex* Perkins.

[4] *Trybliographa daci* Weld, *Pseudeucoila* sp., and *Pilinothrix* sp.

which 259 were alive on arrival. However, the majority were *Bracon gelechidiphagus* (Ramak.), a known parasite of various Lepidoptera, which probably developed along with the others in a lepidopterous borer rather than in *D. latifrons*.

The 102 pupae of the staphylinid predator *Philonthus* sp., forwarded from South China, were all dead on arrival in Honolulu.

The almost complete lack of parasitization by species of *Opius* is in sharp contrast to the situation in other countries where most Tephritidae are attacked by one or more species of that genus. Although the melon fly, *Dacus cucurbitae*, was common in South China, its principal parasite, *O. fletcheri*, was never reared from these shipments.

Formosa

The 222,745 puparia of *Dacus dorsalis* shipped to Hawaii by T. C. Maa produced the following parasite emergence.

Parasites reared	*Females*	*Total*
Opius formosanus (Full.)	846	1,658
Opius arisanus Sonan complex	109	152
Opius makii Sonan	65	100
Tachinaephagus sp.	?	47
Spalangia sp.	?	21
Cynipidae	?	3
Pachycrepoideus vindemmiae (Rond.)	?	1
Total	1,020	1,982

Unfortunately, about one-third of these shipments, containing 70 percent of the fruit fly puparia, were either delayed in transit or the puparia were mostly dead and mouldy on arrival because of overcrowding. The parasites listed above emerged from collections comprising only about 58,000 puparia. These were all sent via airmail in the small water pine boxes used for shipping the parasites of citrus coccids (*19*). High mortalities resulted when the boxes were tightly sealed, or when too many puparia were included.

Five species of *Opius* issued from these shipments, about 87 percent of which were *O. formosanus*. This parasite apparently differs from *O. longicaudatus* only in its generally paler coloration, and was not obtained elsewhere. The mango collections showed the lowest parasitization of all, producing only 11 *O. formosanus* and 3 *Spalangia* sp. The *O. arisanus* complex (later found to include also *O. oophilus* and *O. vandenboschi*) was next in abundance from the common guava and mixed fruit collections, being largely replaced by *O. makii* in the same host infesting the smaller fruits of strawberry guava and *Eugenia javanica*. As in other areas where this species also occurs, *O. makii* seemed unable to parasitize many of the host larvae in larger fruits because of its very short ovipositor.

Tachinaephagus sp. and *Spalangia* sp. issued mainly from the common guava collections, only 7 adults of the former parasite being obtained from *D. dorsalis* infesting *Eugenia javanica*. This *Tachinaephagus* was identified as the same undescribed species imported earlier from Malaya.

No parasites emerged from the 1,700 puparia from *Luffa* sp., which produced mostly *Dacus cucurbitae* and a few *D. nubilus*.

The predaceous mites were not propagated as there was danger of their development on host and parasite-breeding stocks.

Thailand (Siam)

Although some 11 species of parasites, including 7 different *Opius*, were reared from the wide variety of collections obtained by G. W. Angalet in Thailand, about 73 percent of these were *Opius longicaudatus* var. *taiensis*, the great majority of which issued from the extensive *Zizyphus* collections comprising nearly 90 percent of the 157,859 puparia received at Honolulu. These 48 shipments produced the following parasites:

Parasites reared	*Females*	*Total*
Opius longicaudatus taiensis Full.	848	2,847
Opius makii Sonan	346	489
Opius incisi Silv.	46	72
Opius oophilus Full. complex	46	60
Opius vandenboschi Full.	9	9
Opius bianchii Full. ?	1	3
Spalangia sp.	?	310
Tachinaephagus sp.	?	81
Pachycrepoideus vindemmiae (Rond.)	?	11
Total	1,296	3,882

Dacus dorsalis and *Carpomyia vesuviana* were about equally numerous in the July to October collections from *Zizyphus jujuba*, which also yielded the majority of *Opius makii*. *O. incisi*. *O. oophilus*, and *O. vandenboschi*. Those listed as *O. oophilus* also included a few adults, later identified as *O. arisanus*. However, *C. vesuviana* far outnumbered *D. dorsalis* in the much larger winter collections from the same host plant, which produced most of the *O. longicaudatus* var. *taiensis* listed above. The latter parasite thus seemed able to develop in both species of fruit flies while the other opiines probably parasitized only *D. dorsalis*. Twenty-one *O. longicaudatus* var. *taiensis* also emerged from *D. latifrons* infesting *Solanum* sp. Only a few scattered *Opius* spp. were reared from several other collections containing *D. dorsalis*.

Interesting differences were noted concerning the fruit fly and parasite fauna of *Zizyphus jujuba* in Thailand as compared with that encountered in India, where the fruits are apparently attacked only by *C. vesuviana*, which is parasitized by *Bracon fletcheri* in the north and by *Opius carpomyiae* in the south, yet neither parasite was reared from the same host in Thailand.

Seventy-six adults of the small encyrtid larval parasite *Tachinaephagus* sp. were obtained from the puparia of *Dacus latifrons* infesting eggplant, and an additional 5 adults emerged from the extensive *Zizyphus* collections. The common pupal parasites *Spalangia* sp. and *Pachycrepoideus vindemmiae* issued from various puparia without apparent preference, the former being most numerous especially in the *Zizyphus* material, though Dresner (*13*) was able to breed the Thailand *Spalangia* in puparia of *D. dorsalis* but not in those of *C. vesuviana*.

Java

All of the 555 puparia of *Dacus dorsalis* from Java were parasitized as no fruit flies emerged and the unhatched puparia all contained dead stages of *Opius*. The 330 puparia from *Averrhoa carambola* produced 221 (129 females) *O. vandenboschi*, and the 225 puparia from *Capsicum fructescens* produced 164 (76 females) of *O. makii*. Since

O. makii has a very short ovipositor, it was apparently able to reach fruit fly larvae only in the small fruits of *Capsicum*.

A small box of dead parasite specimens reared from the oriental fruit fly in Java, kindly loaned by J. van der Vecht of the Indonesian Ministry of Agriculture, also contained a few *Opius oophilus*, *Tetrastichus dacicida*, *Aceratoneuromyia indicum*, and *Bracon* sp., thus adding considerably to the known distribution of these species.

Borneo

The majority of the 269,532 fruit fly puparia imported from British North Borneo were of *Dacus cucurbitae*, obtained largely from various Cucurbitacae, though *D. dorsalis* was also reared in abundance and *D. hageni* in smaller numbers from a wide variety of host fruits. However, since most of these collections contained two or more different species of fruit flies, the exact host relations of the emerging parasites were often obscured. Total parasite emergence is thus listed below, followed by a discussion of the probable hosts attacked by each species.

Parasites reared	*Females*	*Total*
Opius longicaudatus (Ashm.)	169	331
Opius oophilus Full	171	251
Opius vandenboschi Full	75	155
Opius angaleti Full	39	142
Opius incisi Silv	63	80
Spalangia sp.	?	1,156
Aceratoneuromyia indicum Silv	?	82
Pachycrepoideus vindemmiae (Rond.)	?	42
Trybliographa daci Weld	?	12
Encyrtidae sp.?	?	10
Total	517	2,261

The cucurbit collections produced most of the *Spalangia* sp. and all of the adult *Opius angaleti* listed above, in addition to a few *O. vandenboschi*, *Aceratoneuromyia indicum*, *Pachycrepoideus vindemmiae*, and *Trybliographa daci*. Parasitization was very low, and nearly all of these parasites were obtained from the extensive *Luffa* collections, which comprised about 82 percent of the Borneo shipments. They also issued only from the earlier January-to-April collections, and were absent in puparia reared during the period from May to July. Since an estimated 87 percent of the fruit flies from *Luffa* were *Dacus cucurbitae*, the emerging parasites probably developed largely in that host, though *D. hageni* and *Callantra smieroides* Wlk. cannot be entirely ruled out. The well-known melon fly parasite, *Opius fletcheri*, apparently does not occur in North Borneo.

The oriental fruit fly was lightly parasitized by *Opius longicaudatus*, *O. oophilus*, *O. vandenboschi*, and *O. incisi*, though in variable numbers, which indicates certain differences in relative importance, according to the sources of infestation. *O. longicaudatus* was the predominant larval parasite of *Dacus dorsalis* infesting mango, *Eugenia*, and *Baccaurea*, but was outnumbered by *O. oophilus* and *O. incisi* from carambola. The mango collections also yielded a large proportion of *O. oophilus*, all but 5 of the emerging adults of *O. vandenboschi*, and several *O. incisi*. Additional emergence included 75 *Aceratoneuromyia indicum* and 2 *Trybliographa daci* from the carambola material, while 10 encyrtids issued from the mango and *Baccaurea* collections.

North India

Although at least 19 different species of parasites issued from the 791,436 fruit fly puparia received from northern India, about half were *Bracon fletcheri* from *Carpomyia vesuviana* and another 40 percent were several species of the common pupal parasites *Spalangia*, *Dirhinus*, and *Pachycrepoideus* (table 12). Parasitization by *Opius* spp. was particularly low despite extensive collections from a wide variety of host fruits over a period of some 18 months. In all, parasites emerged from only about 2 percent of the total puparia received in Hawaii, and many of these species were already established there.

While rather high pupal mortalities occurred in many of these shipments, due to the inevitable delays in transit or exposure to high temperatures in the grounded planes prior to takeoff, low parasitization was also reported by the North India team.

Bracon fletcheri, the common Indian parasite of *Carpomyia vesuviana* infesting jujube fruits, was abundantly reared from the large pupal shipments of this tephritid, though in numbers indicating an average parasitization of less than 5 percent. Most of this material arrived during April 1950, one large shipment containing over 200,000 puparia of *C. vesuviana*. These collections also produced a few adults of *Opius carpomyiae*, *O. oophilus*, and an unidentified *Bracon* sp., in addition to moderate numbers of the common pupal parasites. *Dacus dorsalis* was not obtained from these fruits, as in Thailand and, except for the few *O. oophilus*, its parasites were also lacking.

The large quantities of puparia reared from various cultivated Cucurbitaceae were parasitized mainly by *Spalangia*, *Dirhinus*, and *Pachycrepoideus*, only 400 adult *Opius* of two species issuing from more than ¼ million puparia. Most of these were the new *O. watersi* that appeared largely in the *Luffa* collections, while only 17 adults of the well-known Indian melon fly parasite *O. fletcheri* emerged from the same source. The actual host of *O. watersi* in northern India cannot be definitely stated since these collections produced mixed populations of *Dacus cucurbitae*, *D. ciliatus*, and *D. nubilus*, but *D. cucurbitae* is indicated because of its ready propagation on that host in Hawaii. *Opius watersi* was absent in the April-to-July cucurbit collections, appearing only in those obtained during the period August to November.

The oriental fruit fly infesting guavas was lightly parasitized by *Opius incisi*, *O. longicaudatus*, and *O. vandenboschi*, the great majority of parasites being *O. incisi*, whereas only a few *O. longicaudatus* emerged from *Dacus* spp. infesting the mango collections, about three-fourths of which were *Dacus zonatus* and one-fourth *D. dorsalis*. A single *O. longicaudatus* issued from the much larger peach collections infested only by *D. zonatus*, indicating that these opiines were almost wholly specific on the oriental fruit fly. However, the dominant status of *O. incisi* and the recovery of several *O. oophilus* from *Carpomyia* but not from *D. dorsalis* is rather puzzling considering the status of these parasites in other areas.

Only a few adult flies, identified as *Rhagoletis!* n. sp., and four *Pachycrepoideus vindemmiae* issued from the extensive barberry collections, and these appeared several months after receipt. This fruit fly is obviously single-brooded, and all attempts to force emergence through periodic exposure to moisture and/or low temperatures were unsuccessful.

TABLE 12.—*Parasites reared from fruit fly puparia imported from North India*

Fruit fly species	Number of puparia received	Parasites reared												
		Bracon fletcheri Silv.[1]	*Opius incist* Silv.	*Opius watersi* Full.	*Opius longicaudatus* (Ashm.)	*Opius fletcheri* Silv.	*Opius vandenboschi* Full.	*Cratospila* sp.	*Spalangia* spp.[2]	*Dirhinus* spp.[3]	*Pachycrepoideus vindemmiae* (Rond.)	Cynipidae	*Psilus* sp.	*Trichopria* sp.
Carpomyia vesuviana	401, 965	[4] 9, 526	------	------	------	------	------	------	456	2	83	1	----	----
Dacus cucurbitae	267, 829	------	------	383	1	17	------	1	2, 537	1, 375	915	21	1	1
Dacus ciliatus														
Dacus nubilus														
Dacus zonatus	62, 609	------	------	------	1	------	------	------	282	988	97	----	----	----
Dacus zonatus	22, 457	------	------	------	19	------	------	------	110	1, 018	209	----	----	----
Dacus dorsalis														
Dacus dorsalis	19, 117	------	687	------	21	------	2	------	82	18	2	2	----	----
Rhagoletis? n. sp	16, 780	------	------	------	------	------	------	------	------	----	4	----	----	----
?	[5] 679	------	------	1	------	------	------	------	------	28	------	----	----	----
Total	791, 436	9, 526	687	384	42	17	2	1	3, 467	3, 429	1, 310	24	1	1
Number females	------	6, 070	479	227	28	9	2	1	------	------	------	----	----	----

[1] Subsequent studies showed that these rearings also contained a few *Opius carpomyiae* (Silv.), *O. oophilus* Full., and an unidentified *Bracon* sp.

[2] Includes *S. afra* Silv. and *S. endius* Wlk.

[3] Includes *D. luzonensis* Roh. and *D. giffardii* Silv.

[4] An additional 9,033 adults of *B. fletcheri* (only 35 still alive) reared from similar collections at Bareilly were received in April 1950.

[5] Comprises 400 puparia of unknown species from *Aegle marmelos*, 245 from *Coccinia indica*, and 34 from *Ficus* sp., none of which produced adult fruit flies.

South India

The South India shipments provided an exceptional number and variety of fruit fly parasites, some 48,000 adults of 27 different kinds being reared from nearly 1¼ million puparia received in Honolulu (table 13). These included about 29,000 *Aceratoneuromyia indicum*, nearly 12,000 *Opius* of 6 species, about 6,000 pupal parasites of the genera *Spalangia*, *Dirhinus*, and *Pachycrepoideus* (7 species), and smaller numbers of a wide variety of other parasites.

Of particular interest were the large collections of *Dacus dorsalis* comprising about three-fourths of the total puparia shipped, the great majority being obtained from the fruits of *Solanum auriculatum* at Coonor. While *Aceratoneuromyia indicum* was the predominant parasite in these collections, the large number recorded in table 13 probably issued from less than 2,000 puparia, because of the gregarious larval development of this species. Many of these parasites undoubtedly were also the progeny of females which attacked host larvae in the rearing containers rather than in the field. *A. indicum* did not appear in these shipments until October, becoming most numerous from November to February and declining rapidly thereafter. It was absent in collections of this host infesting mango and *Solanum verbascifolium* but was reared occasionally from *D. incisus?* and *D. nubilus*.

What is apparently the true *Opius persulcatus* was obtained only from South India where it was the most numerous opiine parasitizing *Dacus dorsalis* at Coonor, but the least abundant of five *Opius* spp. from the same host infesting *Solanum verbascifolium* at Kodaikanal. It was also the predominant opiine parasite of *D. incisus?* infesting citrus at Coorg during March and April. *O. persulcatus* was most active at Coonor (elevation 6,000 feet) in the fall and early winter despite relatively low temperatures, indicating that it is particularly effective in the extreme Temperate Zone range of *D. dorsalis*, and would thus merit particular attention should the oriental fruit fly ever become established in the continental United States.

Opius oophilus was second only to *O. persulcatus* as a parasite of the oriental fruit fly at Coonor, and ranked first in the same host from *Solanum verbascifolium* at Kodaikanal. A few adults were also reared from *Dacus latifrons* infesting another *Solanum* sp. and from *D. incisus?* out of citrus. In southern India, *Opius longicaudatus* was replaced by the very similar *O. compensans*, which issued almost entirely from *D. dorsalis*, collected at both localities. *Opius incisi* and *O. manii* were also reared from the same shipments in smaller numbers, the former being most abundant at Coonor and the latter at Kodaikanal. Only *O. vandenboschi* was conspicuously absent from these shipments. Strangely enough, however, only two *O. persulcatus* and a few pupal parasites emerged from the large mango collections obtained at Bangalore, which produced *D. dorsalis* and *D. zonatus*.

Even the ubiquitous pupal parasites were represented by a larger number of species than usual, though none of them issued from *Carpomyia vesuviana* or from *Dacus dorsalis* collected at Kodaikanal.

About half of the large citrus collections infested by *Dacus incisus?* came from Coorg during April 1950, the others being obtained at Kodaikanal in January and February 1951. Most of the parasites from this host listed in table 13 issued from the earlier Coorg ship-

TABLE 13.—*Parasites reared from fruit fly puparia imported from South India*

Fruit fly species	Number of puparia received	Parasites reared													
		Opius persulcatus (Silv.)[1]	*Opius oophilus* Full.	*Opius compensans* (Silv.)	*Opius incisi* Silv.	*Opius manii* Full.	*Opius carpomyiae* (Silv.)	*Acerataneuromyia indicum* (Silv.)	*Spalangia* spp.[2]	*Dirhinus* spp.[3]	*Pachycrepoideus vindemmiae* (Rond.)	*Trichopria* sp.	Cynipidae[4]	*Psilus* spp. (2)	Others
Dacus dorsalis	871, 137	5, 698	4, 668	773	222	110	----	28, 653	1, 770	463	1, 250	419	47	8	[5] 47, [6] 20
Dacus dorsalis	86, 256	2	----	----	----	----	----	----	31	281	122	----	----	----	----
Dacus zonatus															
Dacus incisus?	131, 026	167	28	3	8	----	----	34	15	334	194	21	229	----	[6] 2
Dacus ciliatus	54, 254	----	----	----	2	----	----	----	235	469	61	----	----	19	----
Dacus cucurbitae									43	185	260	----	----	----	----
Dacus cucurbitae	11, 639	----	----	----	----	----	----	----	----	----	2	3	----	----	[7] 43, [8] 2
Dacus nubilus	12, 144	----	----	3	1	----	----	378	----	----	10	----	----	----	----
Dacus latifrons	4, 517	1	23	1	----	----	----	----	5	203	----	----	----	----	----
Dacus correctus	2, 707	----	----	----	----	----	----	----	----	1	----	----	----	----	----
Dacus incisus?	152	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Dacus nigrotibialis															
Carpomyia vesuviana	26, 678	----	----	----	----	----	75	----	----	----	----	----	----	----	----
?	2, 508	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Total	1, 203, 018	5, 868	4, 719	780	233	110	75	29, 065	2, 099	1, 936	1, 899	443	276	27	114
Number females	----	3, 528	2, 600	357	149	57	50	----	----	----	----	----	----	----	----

[1] Apparently the true *O. persulcatus* of Silvestri, since it best fits his meager description and is from the type locality.

[2] Identification of sample lots revealed the following species: *S. endius* Wlk., *S. afra* Silv., and *S. grotiusi* Gir.

[3] Identification of sample lots revealed both *D. giffardii* Silv. and *D. luzonensis* Roh.

[4] Identification of sample lots revealed the following five species: *Trybliographa daci* Weld, 2 *Pseudeucoila* spp., and 2 *Cothonaspis* spp.

[5] *Halticoptera* sp. (Pteromalidae).

[6] Unidentified Alysiidae (Braconidae).

[7] *Tachinaephagus* sp. (Encyrtidae).

[8] *Cratospila* sp. (Braconidae).

ments, while about three-fourths of the Kodaikanal puparia produced adult flies of the families Muscidae and Anthomyidae which bred in the rotting oranges. Parasitization of *D. incisus?* was thus very low in the latter material, except for the Cynipidae and Diapriidae which probably developed mainly in the muscoid Diptera. *D. incisus?* is apparently host to many of the same *Opius* spp. that parasitize *D. dorsalis*.

The few *Opius* spp. listed from *Dacus ciliatus*, *D. cucurbitae*, and *D. nubilus* were probably accidental inclusions from other sources. Even *O. watersi* and *O. fletcheri* failed to issue from the sizeable South India cucurbit collections. The small larval parasites *Aceratoneuromyia indicum* and *Tachinaephagus* sp. were, however, obtained from *D. nubilus* infesting *Trichosanthes palmata*, this being the only record of *Tachinaephagus* sp. in India.

Carpomyia vesuviana was lightly parasitized only by *Opius carpomyiae* in South India, the common North India parasite *Bracon fletcheri* being absent from the limited collections of this fruit fly obtained at Manappairi in February 1951.

A few of the oriental fruit fly opiines were also reared from the puparia of *Dacus latifrons* infesting an unidentified *Solanum* sp. at Coorg, but the smaller collections from several other host fruits, including *Eugenia* and coffee, were almost devoid of parasites.

Ceylon

Various cultivated Cucurbitaceae were about the only source of material in Ceylon during the months of August to October 1951, and these produced a total of 128,400 puparia of *Dacus cucurbitae* for shipment to Hawaii. An additional 1,000 puparia, principally of *D. dorsalis*, were obtained from the fruits of *Garcinia* sp. These shipments produced the following parasites:

Host species	*Parasites reared*	*Females*	*Total*
Dacus cucurbitae	*Opius fletcheri* Silv.	139	181
	Opius watersi Full.	2	4
	Spalangia sp.	?	588
	Psilus sp.	?	1
Dacus dorsalis	*Aceratoneuromyia indicum* (Silv.)	?	9
	Spalangia sp.	?	4
Total		141	787

The very low parasitization of *Dacus cucurbitae* was rather surprising in view of its abundance and the presence of both *Opius fletcheri* and *O. watersi*. The nine *Aceratoneuromyia indicum* probably issued from a single puparium of *D. dorsalis*, and there was no evidence of any *Opius* attacking this host in the limited Ceylon collections.

Australia

Although very little was previously known concerning the fruit fly and parasite fauna of northeastern Queensland, this region provided an unusual abundance and variety of both host and parasite species, the majority being new to science. As noted in table 14, we received 354,905 fruit fly puparia of 14 different species or varieties which produced 42,686 adult parasites of 13 species, including nearly 27,000 adults of five different *Opius*.

TABLE 14.—*Parasites reared from Queensland fruit flies*

Fruit fly species	Number of puparia received	Parasites reared										
		Opius kraussii Full.	*Opius deeralensis* Full.	*Opius fijiensis* Full.	*Opius perkinsi* Full.	*Opius froggatti* Full.	*Tryblliographa daci* Wald	*Spalangia* spp. [1]	*Pachycrepoideus vindemmiae* (Rond.)	*Dirhinus giffardii* Silv.	*Halticoptera ? daci* Silv.	*Psilus* sp.
Dacus jarvisi	183, 493	7, 422	507	123			14, 776	156				4
Dacus tryoni	20, 360	677	161	1, 147	190	75	5		36		17	
Dacus tryoni var. *melas*	4, 935	513	62	438	19		218	1				
Dacus tryoni var. *sarcocephali*												
Dacus jarvisi	21, 570	680	773	1, 121	1		569	33				
Dacus tryoni												
Dacus kraussii	42, 949	[2] (3, 613)	705	2, 605	149	2	8	11		10		
Dacus barringtoniae	35, 180	76	3, 120	2								
Dacus cacuminatus	17, 211	612			2			3	1	13		
Dacus endiandrae	10, 987		907	2				10	1	13		
Dacus laticaudus	8, 535		202	432	18	166			1	5		
Dacus musae	6, 156		60	5					10			
Dacus pallidus	1, 974	23	49	25								
Dacus calophylli	561											
Dacus fagraeus	381		5	3								
Dacus murrayi	370	35	38	17								
Dacus jarvisi												
Dacus tryoni	243	1					2					
Dacus barringtoniae												
Totals	354, 905	10, 039	6, 589	5, 920	379	243	15, 578	214	49	41	17	4
Number of females		[2] (3, 613) 4, 038	3, 717	3, 324	193	104						

[1] Mostly *S. afra*, but some *S. endius* and *S. grotiusi* also.
[2] Recorded as "*Opius* complex," but majority found later to be *O. kraussii*, with remainder *O. deeralensis*.

Trybliographa daci, *Opius kraussii*, *O. deeralensis*, and *O. fijiensis*, in that order of abundance, comprised about 98 percent of all the parasites reared from these collections. Adults of the cynipid larval parasite *T. daci* were indistinguishable from those of Malayan origin (*36*) and the primary larvae also appeared to be identical when compared under high magnification. Whereas this species was obtained mainly from *Dacus jarvisi*, the three predominant opiines issued in good numbers from puparia of most of the Queensland fruit flies. *Opius perkinsi* and *O. froggatti* failed to appear in the large collections of *D. jarvisi* from the fruits of *Careya australis*, and are apparently more host-specific than the other opiines.

Seven species of pupal parasites, including three identified species of *Spalangia*, also issued from many of the Australian collections, but in very small numbers.

New Britain

Only 54 adults of three parasite species emerged from the small collections obtained by Mr. Krauss in the vicinity of Rabaul, and these issued from the 3,487 puparia of *Dacus frauenfeldi* infesting the fruits of *Inocarpus edulis*, as follows:

Parasites reared	*Females*	*Total*
Opius longicaudatus (Ashm.) var.?	5	30
Opius fijiensis Full	6	14
Opius deeralensis Full. var.?	8	10
Total	19	54

Both *O. longicaudatus* and *O. deeralensis* showed slight color differences which may be of varietal significance.

New Caledonia

Twenty-five shipments containing 69,029 puparia of three *Dacus* spp. were received from New Caledonia, and these produced the parasites shown in table 15.

TABLE 15.—*Parasites reared from New Caledonia fruit flies*

Fruit fly species	Number of puparia received	Parasites reared				
		Opius longicaudatus novacaledonicus Full.	*Opius fijiensis* Full.	*Opius froggatti* Full. var.	*Spalangia endius* Wlk.	*Pseudeucoila* sp.
Dacus psidii	64,818	647	273	4	82	2
Dacus curvipennis	3,605	236	9			
Dacus curvipennis	606	39	2		9	
Dacus sp. near *facialis*						
Total	69,029	922	284	4	91	2
Number of females		568	179	2		

A color variety of *Opius longicaudatus* described as *novacaledonicus* was the predominant parasite reared from both *Dacus psidii* and *D. curvipennis*, the same hosts also producing smaller numbers of *O. fijiensis*. However, the latter species showed an apparent preference for *D. psidii* infesting the fruits of common guava. Only four adults of a third *Opius* representing a possible color phase of *D. froggatti* issued from *D. psidii*. The common pupal parasite *Spalangia endius* also emerged in fair numbers, while the two small cynipids (*Pseudeucoila* sp.) probably developed in *Drosophila* rather than *D. psidii*, as recorded.

Fiji

Parasitization of the 46,492 fruit fly puparia received from Fiji was quite low despite the emergence of 3,241 adults of five different parasite species. As shown in the following list, about 94 percent of these were *Aceratoneuromyia indicum*, which normally produces from 10 to 25 or more adults per host.

Parasites reared	*Females*	*Total*
Aceratoneuromyia indicum Silv.	?	3,036
Opius hageni Full.	29	66
Opius fijiensis Full.	12	29
Opius oophilus Full.	5	8
Spalangia endius Wlk.	?	102
Total	46	3,241

The four larval parasites were reared from the puparia of *Dacus passiflorae* infesting several host fruits, though 678 *A. indicum* and 38 *O. hageni* also issued from the large *Barringtonia* collections, which produced nearly equal numbers of *D. passiflorae* and *D. xanthodes*. Common guava was the best source of *A. indicum*, nearly two-thirds of the total emergence coming from these collections, with the remaining 28 *O. hageni* also issuing from *D. passiflorae* in the small *Ochrosia* collections. *Opius fijiensis* has a very short ovipositor and was obtained mainly from *D. passiflorae* infesting the smaller strawberry guava, in which the larvae are more accessible. The eight adults of *Opius oophilus* emerged from the same host infesting common guava. It is interesting to note that the two predominant species, *A. indicum* and *Spalangia endius*, were both introduced into Fiji, the others being apparently endemic.

Simmonds (*31*) recorded *O. fijiensis* as *Opius* sp. and *O. hageni* as *Biosteres* sp., also listing the lygaeid bug *Germalus pacificus* Kirk. as an important egg predator of *D. passiflorae* in wild guavas. However, the 43 nymphs and 94 adults of this predator received from Mr. Krauss were destroyed in quarantine because of its known omnivorous feeding habits.

Saipan

Only 8 adults (3 females) of an apparent color variety of *O. longicaudatus* emerged from the 125 puparia of *Dacus ochrosiae* received from Saipan. This parasite has also been reared from the same host on the Island of Guam.

South Africa

The 14,700 fruit fly puparia shipped to Hoboken, N.J., produced 97 *Opius* spp. and 128 *Tetrastichus giffardianus*, of which 84 *Opius* and 66 *T. giffardianus* were alive on arrival in Honolulu. Later identification of the *Opius* by C. F. W. Muesebeck showed that about half were *O. humilis* and the remainder, two undescribed species of that genus. Although the actual hosts are unknown, since the puparia were apparently combined prior to emergence, these were probably parasites of *Ceratitis capitata*.

Kenya

Various cultivated Cucurbitaceae infested by *Dacus ciliatus*, *D. bivittatus cucumarius*, and *D. cucurbitae* provided the greatest and most constant source of puparia during the Kenya investigations. These were lightly parasitized by three species of *Opius*, two of *Tetrastichus*, and three different pupal parasites (table 16). *O. caudatus* (Szep.) not Wesm. was reared only from these collections, which also produced the majority of *O. phaeostigma* and a few *O. giffardii*. Other larval parasites of the genus *Tetrastichus* were largely *dacicida* though *giffardianus* also appeared in the later collections. Since an average of about 10 adults develop per host, the actual parasitization by *Tetrastichus* was considerably lower than indicated in table 16. *Dirhinus giffardii* was the most abundant pupal parasite and issued only from the cucurbit-infesting flies. The host species actually attacked by these parasites could not be determined as both *D. ciliatus* and *D. bivittatus cucumarius* emerged in nearly equal numbers. *D. cucurbitae* was probably unparasitized since it appeared in very few collections, and comprised only about three percent of the total fruit fly emergence.

The large shipments of *Dacus oleae* from wild olives were well parasitized by several very small species of *Opius* resembling *O. concolor*, *O. fransburgi*, and *O. africanus*, as described from this host in several parts of Africa by Silvestri (30). However, these specimens did not entirely agree with the original descriptions, so there is some doubt as to their true identities.

Next in size were the extensive pupal collections of *Pardalaspis cruentata* from *Warburgia*, which yielded all but 7 of the total *Opius giffardii*, a few *O. phaeostigma*, *Tetrastichus* (apparently *dacicida*), and 6 adults of the pupal parasites *Psilus magnificus* and *Pachyneuron pulchrum vindemmiae*. Total parasitization was extremely low. The mixed puparia from *Warburgia* and cucurbits produced only a few *O. phaeostigma* and *Tetrastichus*.

The only parasites obtained from extensive collections of *Trirhithrum quadrum* infesting *Strychnos usambarensis* and an unidentified fruit were *Opius phaeostigma*, *O. berisi* (?), and *Tetrastichus* (sp.?), all but the last in comparatively small numbers.

The Mediterranean fruit fly in coffee was apparently parasitized by *Opius africanus*, and by *Tetrastichus giffardii* and *Braeon celer* in an unidentified fruit, the coffee puparia also producing a few *Trirhithrum coffeae*. The fruits of *Dryptes* sp. were infested mainly by *Pardalaspis* sp. (?) and *Carpophthoromyia dimidiata*, the 5,000 puparia from this collection yielding only a few *O. phaeostigma* and *Tetrastichus* (sp.?). The 5,000 puparia of *Pardalaspis* sp. from

TABLE 16.—*Parasites reared from fruit fly puparia imported from Kenya, British East Africa*

Fruit fly species	Number of puparia received	*Opius* spp.[1]	*Opius phaeostigma* Wlk.	*Opius giffardii* (Silv.)	*Opius caudatus* (Szep.)	*Opius africanus* Szep.	*Opius bevisi* Brues?	*Opius perproximus* Silv.	*Opius* sp.	*Bracon celer* Szep.	*Tetrastichus* spp.[2]	*Dirhinus giffardii* Silv.	*Psilus* spp.[3]	*Spalangia afra* Silv.	*Pachycrepoideus vindemmiae* (Rond.)
Dacus ciliatus	153, 978		763	7	56						[4] 9, 520	953	39	23	
Dacus bivittatus cucumarius															
Dacus oleae	80, 000	[5] 8, 211									473		5		1
Pardalaspis contramedia	60, 969		8	173					22		33				
Pardalaspis sp.	5, 000														
Pardalaspis contramedia											9				
Dacus ciliatus	1, 567		16												
Dacus cucurbitae															
Trirhithrum queritum	46, 620		[6] 22				14				[6] 1, 278				
Ceratitis capitata	7, 551					63									
Trirhithrum coffeae															
Ceratitis capitata	150									[6] 3	[6] 19				
Pardalaspis sp. (?)	5, 000		26								39				
Carpophthoromyia dimidiata						1		[6] 3			32				
Pterandrus rosa	198														
Total	316, 033	8, 211	835	180	56	64	14	3	22	3	12, 403	953	44	23	1
Number of females		4, 394	432	110	46	40	9	3	12	3					

[1] Two or three unrecognized species, including apparent color varieties of *O. concolor* Szep. and *O. lounsburyi* Silv.

[2] Includes three species identified as *T. giffardianus* Silv., *T. dacicida* Silv., and *T. giffardii* Silv., the latter being least numerous.

[3] *Psilus silvestrii* Kief. was reared from *Dacus* spp. in cultivated cucurbits and *P. magnificus* (Nixon) from *Pardalaspis contramedia*.

[4] An additional 72 adults (58 alive) reared from similar collections were received from the Bureau's Hoboken, N.J., laboratory.

[5] An additional 2,419 adults (1,560 alive) reared from similar collections were received from the Bureau's Hoboken, N.J., laboratory.

[6] Includes emergence from approximately 12,600 fruits of *Strychnos* spp. and two unidentified plants brought to Honolulu with the puparia.

Chrysophyllum pruniforme produced only 22 adults of an unidentified *Opius* and 33 *Tetrastichus*. A single *O. africanus*, 3 *O. perproximus*, and a few *T. giffardianus* issued from *Pterandrus rosa* infesting the fruits of *Strychnos reticulata*.

Belgian Congo

Many of the same parasites obtained in Kenya also issued from the Belgian Congo collections, though mostly from different tephritid hosts, while several other species found here were not recorded in Kenya. Some 13 species of fruit fly parasites were reared from the Belgian Congo shipments, including 8 different *Opius*, 4 chalcidoids, and one cynipid (table 17).

In the Congo, *Opius phaeostigma* showed an apparent preference for *Pardalaspis ditissima* and was reared from *Pterandrus anonae* only in the *Pancovia* collections. *O. fuscipennis* was second in total numbers (not recovered in Kenya), emerging almost entirely from *P. ditissima* as did *O. giffardii*, the third most abundant opiine. In Kenya, *O. giffardii* developed primarily in the related *P. contramedia*. *Opius* "*caudatus*" was also obtained from both areas, parasitizing mainly *Dacus* spp. in cultivated cucurbits in Kenya, but issuing in variable numbers from all three of the Belgian Congo fruit flies, though largely as a parasite of *P. anonae*. *Opius concolor* var. (?) was the principal parasite of *Trirhithrum coffeae*, being second to *O.* "*caudatus*" only in *P. anonae* infesting *Pancovia*, but failed to issue from *P. ditissima*. A few *O. fullawayi* emerged from *P. anonae* and *T. coffeae*.

Large numbers of *Tetrastichus dacicida* were reared from the puparia of *Pardalaspis ditissima* and *Pterandrus anonae* but not from those of *Trirhithrum coffeae*. In Kenya, this species was an important parasite of *Dacus* spp. from cucurbits, and also occurred in several other hosts. A few *Tachinaephagus* sp. and *Trichopria* sp. issued from *P. anonae*, while the usually common pupal parasites were even fewer and did not include *Dirhinus* or *Psilus*.

Total parasitization was relatively high in the collections from various tree fruits but much lower in those obtained from coffee, in which *Ceratitis capitata* was absent.

French Cameroons

Collections were very limited in this part of Africa and two of the five shipments sent to Hawaii failed to arrive. The other three took 6, 16, and 23 days en route, and showed correspondingly wide variations in total parasite emergence. Thus, only 38,350 of the 60,730 puparia shipped actually reached Honolulu. These comprised 37,800 puparia of *Pterandrus anonae* from the fruits of *Myrianthus arboreus* and 550 puparia of *Dacus bivittatus cucumarius*.

The puparia of *Pterandrus anonae* produced 467 *Opius fuscipennis* (333 females), 86 *O. desideratus* (57 females), 3 females of *O. fullawayi*, and 6,765 adult *Tetrastichus giffardii*. A few of those recorded as *O. fuscipennis* were later found to be *O. desideratus*, which it closely resembles. The small cucurbit collection produced only 12 *O. phaeostigma* (3 females) and 19 *O. fuscipennis* (9 females).

TABLE 17.—*Parasites reared from fruit fly puparia imported from the Belgian Congo, Africa*

Fruit fly species	Number of puparia received	Parasites reared										
		Opius phaeostigma Wilk.	*Opius fuscipennis* (Szep.)	*Opius giffardii* (Silv.)	*Opius caudatus* (Szep.)[1]	*Opius concolor* Szep. var.?	*Opius fullawayi* (Silv.)	*Tetrastichus dacicida* Silv.	*Tachinaephagus* sp.	*Trichopria* sp.	*Spalangia afra* Silv.	*Pachycrepoideus vindemmiae* (Rond.)
Pardalaspis ditissima	80, 202	619	548	243	81	------	------	4, 464	------	------	1	4
Plerandrus anonae	50, 030	72	8	2	147	140	7	9, 459	10	8	7	------
Trirhithrum coffeae	5, 300	------	1	------	8	70	7	------	------	------	------	------
Total	135, 532	691	557	245	236	210	7	13, 923	10	8	8	4
Number of females	----------	423	382	91	184	182	3	------	------	------	------	------

[1] According to later identifications, these rearings also contained a few *O. desideratus* Brid., and an apparently undescribed *Opius* sp.

Brazil and Mexico

Opius cereus was the dominant parasite obtained from the 23,332 puparia of *Anastrepha mombinpraeoptans* and *A. serpentina* infesting various fruits in Brazil, a total of 2,310 adults (1,558 females) issuing from these collections. The same collections also produced 337 adult *Opius anastrephae*, of which 251 were females.

Of the 323 adults of *Opius crawfordi* reared from *Anastrepha ludens* in Mexico City, and shipped to Honolulu in October 1949, 157 females and 121 males were alive and in good condition upon arrival.

Distribution and Host Relations of the Major Parasites

The many species of Tephritidae and their parasites reared during these investigations came from three general regions, namely (1) Indo-Australasia, (2) Africa, and (3) Brazil and Mexico, the host and parasite fauna of each region being quite distinct from that of the others. The foregoing data covering foreign importations are therefore briefly summarized according to the region from which the various species were obtained.

1. Indo-Australasia

Exploration was concentrated mainly in the accessible areas of this large region since it is the home of both the oriental fruit fly and the melon fly. A great many additional dacine Tephritidae and their parasites were also obtained from these shipments, thereby vastly increasing our knowledge of the fruit fly and parasite fauna in this part of the world.

Opius longicaudatus (Ashm.) and Varieties.—The various members of this "complex" are widely distributed in the Indo-Australasian region as parasites of *Dacus dorsalis* and several related host species. The adults are remarkably similar except for slight local differences in general coloration, and some have been assigned varietal status. Several previously described species from the same region may also be no more than local varieties of *O. longicaudatus*.

Opius longicaudatus, as currently recognized, was the most numerous parasite of *Dacus dorsalis* in North Borneo and was second only to *O. incisi* from the same host in northern India. Of the described varieties attacking the oriental fruit fly in other areas, *taiensis* was the dominant parasite in Thailand, *chocki* was of minor importance in the northern Philippines, and *malaiensis* ranked fourth in the Malayan shipments. *O. longicaudatus* var. *taiensis* also parasitized *D. latifrons* and possibly *Carpomyia vesuviana* in Thailand. The variety *novacaledonicus* was the principal parasite of *D. psidii* and *D. curvipennis* in New Caledonia, while apparent though undescribed color varieties of *O. longicaudatus* were the predominant parasites of *D. frauenfeldi* in New Britain, *D. limbiferus* in Mindanao, and D. *ochrosiae* on Saipan. The very similar and closely-related species *O. formosanus* and *O. compensans* also ranked first and fourth in Formosa and South India as parasites of the oriental fruit fly.

Opius oophilus Full.—This egg-larval parasite (fig. 1) was also found to be widely distributed in most of the areas inhabited by *Dacus dorsalis*, where it occasionally attacked other host species as well. It was apparently the dominant oriental fruit fly parasite in Malaya, a

FIGURE 1.—A female of *Opius oophilus* Full. ovipositing in an egg cluster of the oriental fruit fly *Dacus dorsalis* Hendel beneath the skin of an infested papaya. (Photo by L. D Christenson.)

close second to *O. persulcatus* in South India, and to *O. longicaudatus* in northern Borneo, and ranked fourth from the same host in Thailand. A few specimens were also obtained from *D. dorsalis* in Formosa, *D. incisus* and *D. latifrons* in South India, *Carpomyia vesuviana* in North India, and from *D. passiflorae* in Fiji. It is known also to occur as a parasite of the oriental fruit fly in the northern Philippines, and in Java.

Opius vandenboschi Full.—First identified as *O. persulcatus* but later found to be a distinct though very similar species, as was *O. oophilus*, this parasite also attacks the oriental fruit fly over a rather wide area. It was the most abundant of two species received from Java, it ranked second only to *oophilus* in the large Malayan shipments, and was third as a parasite of *Dacus dorsalis* in Borneo. Only a few adults were reared from the same host obtained in Formosa, Thailand, the northern Philippines, and North India, but *O. vandenboschi* was strangely absent from the extensive South India collections. It thus appeared to be somewhat less important than *oophilus* in the region inhabited by *D. dorsalis*.

Opius incisi Silv.—This species was also one of the major oriental fruit fly parasites in Indo-Australasia, but varied widely in relative abundance in the areas explored. Although it was the dominant parasite in North India, it ranked fourth in South India and Borneo, and

third in Malaya and Thailand. *O. incisi* apparently occurs in the northern Philippines but not in Formosa or the Pacific islands.

Opius makii Sonan.—*O. makii* is smaller than *O. incisi* and has an even shorter ovipositor, but is otherwise very similar. It is apparently a major parasite of the oriental fruit fly in Java, as indicated by the large number of parasitized puparia received, was second in abundance from the Thailand shipments, and third in the Formosa rearings. A few adults were also obtained from *Dacus hageni* collected in Mindanao.

Opius fijiensis Full.—This parasite is similar to *O. fletcheri* and the two preceeding species but was obtained only from Queensland and the neighboring islands of New Britain, New Caledonia, and Fiji. It was found to parasitize nearly all of the endemic *Dacus* spp. in northern Queensland though ranking fourth among the five reared opiines from that area. *O. fijiensis* was the second most numerous of three *Opius* spp. parasitizing *D. frauenfeldi* in New Britain, *D. psidii* and *D. curvipennis* in New Caledonia, and *D. passiflorae* in Fiji.

Opius fletcheri Silv.—This well-known melon fly parasite, previously introduced into Hawaii from India in 1916, was surprisingly scarce over the wide area inhabited by its host, only 284 adults being obtained from at least ½ million puparia of *Dacus cucurbitae* during these investigations. They appeared only in the collections from Malaya, North India, Ceylon, and Mindanao, an additional 77 adults of an apparent variety of *fletcheri* also issuing from the puparia of *D. limbiferus* from Mindanao. *O. fletcheri* failed to appear in the melon fly collections from northern Borneo, South India, Thailand, Formosa, South China, and East Africa.

Other *Opius* Species.—Additional species of *Opius* obtained from the Indo-Australasian shipments are listed below according to host and country of origin.

Country and Parasite Species	*Host*
Mindanao:	
O. skinneri Full	*Dacus limbiferus, D. pedestris, Euphranta* n. sp.
Formosa:	
O. arisanus Sonan	*Dacus dorsalis*
South China:	
Opius sp., possibly *arisanus* Sonan	*Dacus latifrons*
Thailand:	
Opius sp., possibly *bianchi* Full	Probably *Dacus dorsalis*
O. arisanus Sonan	Probably *Dacus dorsalis*
Borneo:	
O. angaleti Full	Probably *Dacus cucurbitae*
North India:	
O. waterst Full	Probably *Dacus cucurbitae*
O. carpomyiae (Silv.)	*Carpomyia vesuviana*
South India:	
O. persulcatus (Silv.)	*Dacus dorsalis* and *D. incisus?*
O. manii Full	*Dacus dorsalis*
O. carpomyiae (Silv.)	*Carpomyia vesuviana*
Ceylon:	
O. waterst Full	*Dacus cucurbitae*
Queensland, Australia:	
O. kraussii Full	9 *Dacus* spp. and varieties
O. decraiensis Full	12 *Dacus* spp. and varieties
O. perkinsi Full	6 *Dacus* spp. and varieties
O. froggatti Full	3 *Dacus* spp.

Country and Parasite Species	*Host*
Fiji:	
O. hageni Full.	*Dacus xanthodes* and *D. passiflorae*
New Britain:	
O. decraiensis Full. var.	*Dacus frauenfeldi*
New Caledonia:	
O. froggatti Full. var.	*Dacus psidii*

Aceratoneuromyia indicum (Silv.=*philippinensis* Full.).—This small eulophid larval parasite was widely reared from the puparia of *Dacus dorsalis* and several other host species during the present investigations. It was the most numerous oriental fruit fly parasite in South India, but probably ranked third in actual parasitization, being reared also from *D. incisus* and *D. nubilus*. *A. indicum* was easily the dominant parasite of *D. passiflorae* and possibly of *D. xanthodes* in the collections received from Fiji. This species had been introduced previously from India via Australia. It also issued in smaller numbers from the puparia of *D. dorsalis* obtained in Malaya, Ceylon, and Borneo, and a single adult identified as this species was included in a box of mounted oriental fruit fly parasites received from Java.

Tryblographa daci Weld.—*T. daci* was the most numerous and widespread of several Cynipidae which issued from these collections. It was the dominant fruit fly parasite in northern Queensland, emerging in large numbers from the puparia of *Dacus jarvisi* and *D. tryoni*, though only a few adults were obtained from *D. dorsalis* and *D. umbrosus* collected in Malaya, *D. dorsalis* and *D. incisus?* in South India, and from *D. cucurbitae* and *D. dorsalis* in nothern Borneo. Its wide host range is also indicated by the experimental rearing of this parasite from two species of *Drosophila* and from all three of the Hawaiian fruit flies. It is obviously attracted to rotting fruits, as are other Cynipidae that parasitize larval Diptera.

Tachinaephagus sp.—One or more undescribed species of this encyrtid genus occurred as a minor parasite of several *Dacus* spp. in Malaya, South India, Formosa, and Thailand. The majority of adults issued from the puparia of *D. dorsalis* collected in Malaya, a few also being recorded as parasites of *D. umbrosus* and *D. cucurbitae* or *D. nubilus* in the same shipments. Other host records include *D. nubilus* from South India, *D. dorsalis* from Formosa, and both *D. latifrons* and *D. dorsalis* from Thailand.

Pupal parasites.—Since these parasites will attack only host puparia, and most of the Tephritidae received in Honolulu had been collected as larvae in infested fruits, the reared pupal parasites were thus largely the progeny of adults that had been attracted to the rearing containers. Consequently, these figures do not reflect the extent of field parasitization. Although very little information is available concerning the importance of fruit fly pupal parasites in the areas explored, they are generally assumed to be of minor value and have shown no evidence of giving effective control when introduced into new areas. Their ability to develop as secondary parasites through *Opius* spp. would also limit their usefulness.

The small pteromalid *Pachycrepoideus vindemmiae* (Rond.) (*dubius* Ashm.) is a nearly cosmopolitan parasite of many Diptera, and was recovered throughout Indo-Australasia except Ceylon and the Pacific islands of New Britain, New Caledonia, and Fiji, being most numerous in the collections from North and South India. As with the other pupal parasites, it is apparently nonspecific, developing

with about equal readiness in the puparia of most Tephritidae. It was successfully introduced into Hawaii from Australia as a dung-fly parasite in 1914, and was also found to be capable of developing as either a primary or secondary parasite of *Ceratitis capitata* (*29*).

The genus *Spalangia* was represented by three described species—*endius*, *afra*, and *grotiusi*—and possibly others that could not be positively identified, the first two apparently being more widely distributed and abundant than the others. *Spalangia* spp. were the most numerous of all the pupal parasites, failing to appear only from the small New Britain collections, but issuing in greatest abundance from the North and South India and Borneo shipments.

Two species of *Dirhinus*—*giffardii* and *luzonensis*—were also reared in large numbers from the puparia of most fruit fly species collected in North and South India, but only *giffardii* appeared in several of the Australian collections. A single adult identified as *Dirhinus* sp. issued from *Dacus cucurbitae* collected in the Canton area of South China. The genus *Dirhinus* was thus considerably more limited in distribution than either *Pachycrepoideus* or *Spalangia*. Both species of *Dirhinus* have long been present in Hawaii.

Only 66 adult *Psilus* were obtained from the Indo-Australasian shipments and none of these could be further identified, though several species were obviously involved. The majority issued from the South India and Mindanao collections, occasional adults also being reared from the Malaya, Australia, North India, and Ceylon shipments.

An unidentified species of *Trichopria* and another diapriid of undetermined genus also issued from the South India shipments, but their actual host relations are unknown since they may have developed in the puparia of *Drosophila* or other small Diptera included with those of the Tephritidae.

2. Africa

The African importations have already been listed and discussed in considerable detail, and will therefore require only brief summarization. Fruit fly infestations are characterized by many species of the endemic genera *Ceratitis*, *Pardalaspis*, *Pterandrus*, and *Trirhithrum* which attack the fruits of native forest trees and certain cultivated varieties as well, while the Cucurbitaceae are largely infested by *Dacus ciliatus* and *D. bivittatus cucumarius*. The melon fly is a recent introduction found only in the coastal area of Kenya. The oriental fruit fly does not occur in Africa.

The parasite fauna is also very different from that of Indo-Australasia, consisting largely of many endemic species of *Opius* and several *Tetrastichus* not found elsewhere. Most numerous were parasites of the latter genus, more than 30,000 adult *Tetrastichus* being obtained from the majority of African Tephritidae during these investigations. These probably issued from about 3,000 host puparia. The Kenya shipments produced mostly *T. giffardianus* and *T. dacicida* with smaller numbers of *T. giffardii*, while identifications showed only *T. giffardianus* from South Africa, *T. dacicida* from the Belgian Congo, and *T. giffardii* from the French Cameroons.

Some 12 to 15 species of *Opius* also issued from the African shipments in variable numbers. The olive fly *Dacus oleae* was heavily parasitized by several small opiines in both South and East Africa,

over 10,000 of these parasites emerging from collections of infested wild olives made in Kenya. *Opius phaeostigma* was next in total abundance, more than 1,500 adults being obtained from a wide variety of hosts collected in East, Central, and West Africa. About 1,000 *O. fuscipennis* issued mainly from collections of *Pardalaspis ditissima* in the Belgian Congo and *Pterandrus anonae* in the French Cameroons, while nearly all of the 425 *O. giffardii* were obtained from two species of *Pardalaspis* originating in Kenya and the Belgian Congo. *Opius "caudatus"* parasitized only the cucurbit-infesting *Dacus* spp. in Kenya, but attacked most of the tephritid species collected in the Congo. *Opius desideratus* was a minor parasite of *P. anonae* in the Cameroons and was very scarce in the Congo. Several other *Opius* spp. were reared in small numbers from the various African shipments.

The Mediterranean fruit fly was found to be parasitized by *Opius humilis* and *Tetrastichus giffardianus* in South Africa and apparently by *Bracon celer*, *T. giffardii*, and *O. africanus* in Kenya, though most of the latter collections were obtained from coffee, which was also lightly infested by *Trichilhrum coffeae*. Both *B. celer* and *O. africanus* were originally recorded by Silvestri (*30*) only as parasites of the olive fly in South Africa. However, parasitization was very low in each case, and *Ceratitis capitata* was not contained in any of the Central or West African shipments.

The pupal parasites *Dirhinus giffardii* and *Spalangia afra* were originally described from West Africa (*30*), the first also being obtained from South Africa and Kenya, and the second from Kenya and the Belgian Congo, during these investigations. Two species of *Psilus* issued from the Kenya collections, but these and the Belgian Congo shipments produced only five adults of *Pachycrepoideus vindemmiae*. These were the only fruit fly parasites common to both Africa and Indo-Australasia.

3. Brazil and Mexico

A great many species of the genus *Anastrepha* are known to infest various fruits in Mexico, Central America, the West Indies, and South America, where several of them are attacked by endemic *Opius* spp. Three of the more common opiines from this region were accordingly sent to Hawaii to determine whether they might also parasitize the oriental, Mediterranean, or melon flies. These were: *Opius crawfordi* from Mexico, and *O. cereus* and *O. anastrephae* from Brazil. However, these species are apparently host-limited to the genus *Anastrepha* and could not be propagated on any of the dacine fruit flies.

Laboratory Testing of Introduced Parasites

In order to prevent the introduction of any harmful hyperparasites, the primary role of each species was first determined, either by rearing it through on parasite-free hosts, or by the dissection of empty fly puparia from which the parasites had emerged. The latter method was used when the species in question could not readily be propagated in the quarantine room. The parasites thus cleared from quarantine were then liberated by members of the Hawaii Board of Agriculture and Forestry or used in preliminary breeding tests at both

laboratories to determine their ability to develop as parasites of *Dacus dorsalis*, *Dacus cucurbitae*, or *Ceratitis capitata*. These tests also furnished important biological data, which often facilitated insectary production of the successful species.

Adult parasites of the species being tested were placed with infested fruits in glass cages made of large lamp chimneys or wide-mouth gallon mayonnaise jars from which the bottoms had been removed. The ends were covered with gauze, cheesecloth, or organdie fastened at the bottom with melted paraffin and temporarily secured with rubber bands at the opposite end. The cages were placed on their sides near a window which afforded strong light without direct sunshine, pure honey was streaked on the upper inside surface as food for the parasites, and the infested fruits were laid on paper toweling to absorb excess moisture. The number of parasites used depended on their availability, and the duration of each test depended on the condition of the host material; infested fruits were generally changed every 2 or 3 days. Dead parasites were replaced by newly-emerged adults of the same species, the male ratios being adjusted accordingly to encourage mating.

Oviposition was most readily obtained when the parasites were closely confined with infested fruits in this manner, particularly by species of *Opius* from hosts other than the Hawaiian fruit flies. Results were generally much poorer when tests were conducted in larger screen or cloth cages. Although oviposition was often "forced" under the conditions of these tests, they accomplished the primary purpose of determining the limits of host-parasite specificity. Subsequent breeding studies with the progeny of the surviving species soon indicated which ones were capable of continuous reproduction on one or more of the Hawaiian fruit flies.

The greatest difficulty experienced in the parasite-testing program was that of successful mating under laboratory conditions, as indicated by the predominantly male ratios shown in tables 18-20, since the unfertilized females of these parasites produce only male progeny. Different species were found to vary widely in this respect, and in most cases very little improvement was obtained, even with special techniques. This factor has greatly limited the breeding of many ichneumonoid parasites in particular, including various *Opius* spp. formerly introduced into Hawaii, cultures often "running out" after one or more laboratory generations. It is also known that the mated females of certain Hymenoptera have the ability to lay either fertilized or unfertilized eggs at will, depositing mostly infertile or male eggs on unnatural or otherwise less desirable hosts. Since the majority of imported species were parasites of fruit flies other than those occurring in Hawaii, this phenomenon may also have been involved in the frequent inability to establish laboratory cultures on the local fruit flies.

It was soon found that many of the common pupal parasites belonging to the genera *Spalangia*, *Dirhinus*, and *Psilus* would also develop readily as hyperparasites of *Opius* spp., in addition to their usual primary role. This immediately raised the question as to whether they should be released in Hawaii where the established Malayan opiines were already showing great promise. The Advisory Committee agreed that these parasites should be retained in quarantine until their habits had been studied in greater detail by dissecting numerous parasitized puparia, including those exposed previously to

Opius spp. in the larval stage. The results of these studies indicated that *Spalangia*, *Dirhinus*, and *Psilus* are not preferential hyperparasites but will develop with about equal readiness in either parasitized or unparasitized puparia attacked at random, though Dresner (*13*) found that *Spalangia* spp. exhibited some preference for the primary role under the same conditions. Since *Dirhinus giffardii* already occurs in Hawaii as a result of earlier releases, the Australian and African races of this species were approved for colonization. After considerable deliberation, the others were ordered destroyed to avoid any possible risk, as they had also shown no evidence of being effective fruit fly parasites in any of the areas where they occur. Many of the pupal parasites obtained from the imported material could be identified only to genus.

More than 1,800 separate rearing tests were conducted with the imported larval parasites on all three of the Hawaiian fruit flies, but progeny were obtained from only 53 percent of these combinations. The successful tests are summarized in table 18 for *Dacus dorsalis*, table 19 for *Ceratitis capitata*, and table 20 for *Dacus cucurbitae*. These do not include preliminary tests with the established opiines on their normal hosts or the pupal parasites which bred freely on all three fruit flies.

Although an attempt was made to conduct comparable tests with the reared parasites on each of the local fruit flies, this was sometimes impossible because of limited parasite emergence and variable host stocks. Efforts were necessarily concentrated on the more promising combinations in order to provide adequate breeding stocks for large-scale rearing and field colonization. Consequently, some of the yields might have been higher and the negative results fewer with more intensive testing, though it is doubtful whether breeding stocks of additional species could have been maintained, even with greater effort and larger importations.

Laboratory tests with all four of the established Malayan opiines showed that *Opius longicaudatus* var. *malaiensis*, *O. vandenboschi*, *O. oophilus* and *O. incisi* would also develop on *Ceratitis capitata* but not on *Dacus cucurbitae*, though they oviposited readily in both fruit flies. The immunity of *D. cucurbitae* to parasitization by the same species was later reported by Nishida and Haramoto (*27*). However, fewer progeny and lower female ratios were usually obtained on *C. capitata* than on *D. dorsalis*, the normal host.

The *Opius longicaudatus* varieties *noracaledonicus* and *taiensis* were readily propagated on the oriental fruit fly through several generations, and large breeding stocks were given to the Territorial Board for further increase and field colonization. The female ratios usually increased with each generation. Both parasites were also reared on *Ceratitis capitata* but not on *Dacus cucurbitae*.

Opius compensans and *O. formosanus* are very similar to other members of the *O. longicaudatus* "complex" and exhibited the same host relationships, breeding on *D. dorsalis* and *C. capitata* but not on *D. cucurbitae*, even though oviposition occurred in all three fruit flies. These parasites also seemed better adapted to *D. dorsalis* than to *C. capitata*, and large numbers were propagated on the oriental fruit fly to furnish breeding stocks for the Territorial Board insectary.

Particular attention was devoted to *Opius persulcatus* because of its dominant status as an endemic oriental fruit fly parasite in South

India, but with only partial success. Most of the adults emerging from the earlier shipments were very feeble and seldom lived more than a day or two. The tests were entirely negative, but with the onset of cool weather at Coonor, they issued from the later shipments in better condition, and females were frequently observed probing in the test fruits. However, there was little evidence of mating, and the numerous resulting progeny were nearly all males, but these individuals mated more readily with newly emerged females from the South India shipments. Although female ratios of subsequent generations showed some improvement, they seldom averaged more than 10 percent. A laboratory culture was thus maintained only with considerable effort.

Opius persulcatus is apparently similar to *O. oophilus* in its development as an egg-larval parasite, and the males of this species also require a premating period of 5 or 6 days. Most of the adults emerging from these tests and from the original shipments were turned over to the Territorial Board in order that *O. persulcatus* might be widely colonized in Hawaii. In further tests it was found to parasitize *Ceratitis capitata* but not *Dacus cucurbitae*.

Opius makii is an important parasite of the oriental fruit fly in Java, Thailand, and Formosa, and large numbers were propagated on this host in the quarantine room to furnish a breeding stock for the Territorial Board. However, female ratios were considerably lower than in the imported material, seldom averaging over 25 percent, even with continued breeding. Limited emergence was also obtained in tests with *C. capitata*, but not with *D. cucurbitae*.

Opius manii from South India produced only male progeny on *D. dorsalis* and *C. capitata*, and further reproduction was thus impossible. A few adults of the oriental fruit fly parasite *Opius arisanus* from Formosa also failed to reproduce on the Hawaiian fruit flies.

Some 13 species or varieties of *Opius* from the African shipments were tested on the local fruit flies, but only *O. phaeostigma* could be propagated for more than a single generation on *C. capitata*, and the colony eventually ran out because of low female ratios. Development was even less satisfactory as a parasite of *D. dorsalis*. Tests with *O. "caudatus," O. concolor* var.?, *O. desideratus, O. fuscipennis*, and *O. giffardii* produced limited numbers of male and occasional female progeny on *C. capitata*, but only 1 and 2 males of *O. "caudatus"* and *O. fuscipennis* developed on *D. dorsalis*. Negative results were obtained in similar tests with *D. cucurbitae*.

Although numerous tests were conducted with *Opius deeralensis, O. fijiensis, O. froggatti, O. kraussii*, and *O. perkinsi* from Australia, comparatively few progeny were obtained, and these were largely males, which developed only in *D. dorsalis* (table 18). However, *O. kraussii* was eventually propagated on *C. capitata* in papayas at the Territorial Board insectary. Smaller tests with *O. fijiensis* from New Britain, New Caledonia, and Fiji on both fruit flies gave negative results.

Brief tests with *Opius skinneri* and *O. fletcheri* var.? from Mindanao produced only a few male progeny on *D. dorsalis* and *C. capitata*.

Although a few progeny of the Brazilian *O. cereus* were obtained from *C. capitata* the three optime parasites of *Anastrepha* spp. in Brazil and Mexico were obviously unable to adapt themselves to the dacine fruit flies in Hawaii.

As noted in table 20, only three of the many imported *Opius* spp. (*angaleti*, *hageni*, and *watersi*) could be reared on the melon fly in Hawaii despite repeated attempts. Although the imported opiines apparently oviposited in all three fruit flies with about equal readiness, most of them were unable to develop in *D. cucurbitae*.

Opius angaleti is a previously undescribed species obtained only from North Borneo. Because of its apparent preference for *Dacus cucurbitae*, a total of 46 tests were conducted with the melon fly in an effort to establish a breeding stock. Although nearly 7,000 progeny were reared from these tests, only about 12 percent were females despite continued breeding through several generations. Emergence from the original shipments averaged only 27.5 percent females, perhaps indicating a normally low female ratio for this species. However, a sufficient number of both sexes were obtained to supply the Territorial Board with a large culture. *O. angaleti* also oviposited readily in cultures of *D. dorsalis* and *Ceratitis capitata*, but only male progeny issued from the latter host.

Limited breeding tests with *Opius hageni* from the Fiji shipments yielded a few progeny from all three of the Hawaiian fruit flies, but these were mostly males and further propagation was impossible.

It was soon found that *Opius watersi*, from North India and Ceylon, was well adapted to *Dacus cucurbitae* as a host though it was originally identified as *O. longicaudatus*, which it closely resembles and which cannot develop as a melon fly parasite. Reproduction of this species was at first rather limited, but the F_2 generation from an original 14 mated females totaled 562 progeny, of which 46 percent were females. One of these tests yielded a 20-fold increase with 55 percent females. The emerging adults were turned over to the Territorial Board in order that this promising new melon fly parasite might be increased and colonized in Hawaii at the earliest possible date. *O. watersi* failed to develop in *D. dorsalis* but a few progeny were obtained from *C. capitata*.

Biosteres dohrni from North India could not be propagated on any of the local fruit flies although oviposition was observed in the small fruits of *Bumelia buxifolia* infested by *D. dorsalis*. The following *Opius* spp. also failed to develop in *D. dorsalis*, *D. cucurbitae*, or *C. capitata*: *anastrephae* from Brazil, *crawfordi* from Mexico, *carpomyiae* from South India, and several unidentified species from South Africa, Kenya, and South China.

Several species of small larval parasites in the families Eulophidae, Cynipidae, and Encyrtidae, which issued in variable numbers from the foreign shipments, were also tested extensively on the local fruit flies in an effort to establish breeding stocks for colonization in Hawaii. Since these parasites usually enter the flesh of ripe and decaying fruits in search of host larvae which are attacked directly, tests were usually conducted with naked fruit fly larvae or agar cultures of the desired species, rather than with infested fruits.

Aceratoneuromyia indicum from South India was readily propagated in large numbers as a parasite of the oriental fruit fly. In the first trials with infested fruits reproduction was rather limited, but yields were considerably improved when the parasites were placed with naked host larvae. This parasite also developed to a limited extent in *C. capitata*, but not in *D. cucurbitae*.

Of the three species of *Tetrastichus* imported from Africa, *ducicida* was tested most extensively on the Hawaiian fruit flies because of its unusually wide host range. Development was readily obtained in the larvae of both *D. dorsalis* and *C. capitata*, and several thousand adults reared as parasites of the oriental fruit fly were supplied to the Territorial Board insectary. Although *T. ducicida* also oviposited with equal readiness in the larvae of *D. cucurbitae*, no progeny were obtained.

Since *Tetrastichus giffardianus* has long been established in Hawaii as a parasite of the Mediterranean fruit fly, the emerging adults were given to the Territorial Board after brief tests showed that this species would also develop in *D. dorsalis* but not in *D. cucurbitae*. *T. giffardii* was not identified until after the living emerged adults had been colonized in Hawaii with the other *Tetrastichus* spp.

The cynipid larval parasite *Trybliographa daci* was first reared from the Malayan shipments and initial tests showed that it would develop in all three of the local fruit flies. Development also occurred in *Drosophila* spp., but not in larvae of the house fly. Similar results were later obtained with adults from the Australian shipments, though female ratios were consistently low and yields were often reduced by superparasitism. Larval dissections showed 5 to 20 or more cynipid eggs and primary larvae per host from prolonged exposures to excessive numbers of parasites. However, results were considerably improved by using only 5 to 10 mated females per 100 late instar *D. dorsalis* larvae in agar-base media with a 2-day exposure period. The best of several tests with different combinations yielded 44 females and 32 male progeny (56 percent parasitization) from 4 mated females after a 4-day exposure. The parasites also oviposited more readily in larvae in the agar cultures than in naked host larvae.

Since *T. daci* was the only introduced larval parasite that developed with about equal readiness in each of the Hawaiian fruit flies, a large breeding stock was accumulated for further increase and liberation.

Brief tests with one or more undescribed species of the encyrtid genus *Tachinaephagus* from Malaya, Formosa, and Thailand yielded mostly male progeny from *D. dorsalis* only, and continued breeding was thus impossible. Similar results were obtained with several unidentified encyrtids from the Mindanao and North Borneo shipments.

A number of very small unidentified species in the families Diapriidae, Pteromalidae, Braconidae, and Cynipidae from the South India shipments, which probably developed as parasites of *Drosophila* and various muscoid Diptera, contaminants in the shipments, were also tested briefly in the laboratory. These tests yielded only a few male cynipids and *Trichopria* sp. from *D. dorsalis* and *Drosophila* spp., respectively.

TABLE 18.—*Results of rearing tests with imported parasites on Dacus dorsalis*

Parasite species	Tests conducted	Females used	Host puparia reared	Parasites emerged	
				Female	Male
BRACONIDAE	*Number*	*Number*	*Number*	*Number*	*Number*
Opius africanus	19	174	4, 270	3	26
Opius "caudatus"	9	51	6, 390	0	1
Opius compensans	11	161	5, 058	205	669
Opius deeralensis	51	1, 103	21, 702	20	64
Opius fijiensis	41	766	13, 151	5	135
Opius fletcheri var.?	5	40	623	0	1
Opius formosanus	79	1, 360	26, 719	798	3, 121
Opius froggatti	8	72	1, 814	0	2
Opius fuscipennis	8	180	11, 242	0	2
Opius hageni	5	28	3, 250	0	1
Opius kraussii	60	1, 106	15, 298	18	65
Opius longicaudatus:					
var. *novocaledonicus*	55	1, 173	20, 873	656	3, 065
var. *taiensis*	21	620	19, 758	157	382
Opius makii	39	494	12, 601	546	1, 549
Opius manii	13	78	5, 881	0	76
Opius perkinsi	29	282	10, 779	17	705
Opius persulcatus	70	4, 338	55, 941	298	6, 441
Opius phaeostigma	31	410	14, 954	4	79
Opius skinneri	6	107	1, 522	0	30
EULOPHIDAE					
Aceraloneuromyia indicum	34	[1] (6, 165)	12, 185		[1] (26, 872)
Tetrastichus daricida	24	[1] (4, 407)	3, 730		[1] (5, 120)
Tetrastichus giffardianus	3	[1] (46)	256		[1] (109)
CYNIPIDAE					
Trybliographa daci	100	3, 764	20, 602	897	1, 763
Cynipidae [2]	2	6	1, 785	0	4
ENCYRTIDAE					
Tachinaephagus sp.	8	[1] (95)	841		[1] (36)
Encyrtidae sp.	3	[1] (15)	655		[1] (12)

[1] Sexes undetermined.
[2] Included several unidentified species of *Pseudeucoila* and *Cothonaspis*.

Negative results were obtained in rearing tests on *Dacus dorsalis* with the following parasites:

Braeon fletcheri
Opius anastrephae
Opius angaleti
Opius arisanus
Opius bevisi?
Opius carpomyiae
Opius cereus
Opius concolor var.?
Opius crawfordi
Opius fullawayi
Opius giffardii
Opius watersi
Opius spp. (So. Africa, Kenya, So. China)
Trichopria sp. (So. India)
Halticoptera sp. (So. India)

TABLE 19.—*Results of rearing tests with imported parasites on Ceratitis capitata*

Parasite species	Tests conducted	Females used	Host puparia reared	Parasites emerged	
				Female	Male
BRACONIDAE					
	Number	*Number*	*Number*	*Number*	*Number*
Opius angaleti	3	26	841	0	72
Opius "caudatus"	15	68	4, 892	0	49
Opius cereus	6	115	3, 357	4	1
Opius compensans	3	38	752	32	29
Opius concolor var.?	7	102	2, 291	0	4
Opius desideratus	2	50	762	1	1
Opius fletcheri var.?	1	5	180	0	2
Opius formosanus	4	60	595	5	20
Opius fuscipennis	19	449	4, 917	4	14
Opius giffardii	10	38	3, 358	0	18
Opius hageni	7	27	1, 391	3	7
Opius incisi	5	56	410	0	12
Opius longicaudatus	6	170	820	0	1
var. *malaiensis*	5	266	838	12	84
var. *novacaledonicus*	9	87	2, 021	14	41
var. *taiensis*	6	138	1, 180	2	79
Opius makii	8	100	1, 133	14	38
Opius manii	7	27	1, 336	0	16
Opius oophilus	6	418	1, 143	4	46
Opius persulcatus	4	153	641	6	95
Opius phaeostigma	35	574	6, 998	100	466
Opius watersi	2	40	94	1	7
Opius vandenboschi	8	549	913	51	153
EULOPHIDAE					
Aceratoneuromyia indicum	4	[1] (250)	265	.....	[1] (60)
Tetrastichus dacicida	3	[1] (109)	101	.....	[1] (257)
CYNIPIDAE					
Tryblographa daci	13	397	811	41	125

[1] Sexes undetermined.

Negative results were obtained in rearing tests on *Ceratitis capitata* with the following parasites:

Bracon fletcheri
Opius anastrephae
Opius carpomyiae
Opius crawfordi
Opius decoralensis
Opius fijiensis
Opius perkinsi
Opius skinneri
Opius spp. (So. Africa)

TABLE 20.—*Results of rearing tests with imported parasites on Dacus cucurbitae*

Parasite species	Tests conducted	Females used	Host puparia reared	Parasites emerged	
				Female	Male
BRACONIDAE	*Number*	*Number*	*Number*	*Number*	*Number*
Opius angaleti	46	420	43, 395	851	6, 1[illegible]
Opius hageni	1	4	275	0	[illegible]
Opius watersi	23	464	15, 005	544	556
CYNIPIDAE					
Trybliographa dari	10	300	11, 081	84	[illegible]82

Negative results were obtained in rearing tests on *Dacus cucurbitae* with the following parasites:

Biosteres fletcheri
Opius anastrephae
Opius arisanus
Opius carpomyiae
Opius "caudatus"
Opius crawi
Opius compensans
Opius crawfordi
Opius dacicidus
Opius desideratus
Opius fletcheri var.?
Opius formosanus
Opius froggatti
Opius fullawayi
Opius fuscipennis
Opius giffardii
Opius incisi
Opius krausii
Opius longicaudatus
Opius longicaudatus maluiensis
Opius longicaudatus novacaledonicus
Opius makii
Opius oophilus
Opius persuleatus
Opius phaeostigma
Opius skinneri
Opius vandenboschi
Opius spp. (So. Africa, So. China)
Aceratoneuromyia indicum
Tetrastichus dacicida
Tetrastichus giffardianus
Tachinaephagus sp.

Observations on Biology of Introduced Parasites

Brief comparative studies were conducted with several of the introduced species to determine the salient features of their biology under local conditions, and to compare these with the Mediterranean fruit fly parasites formerly studied in considerable detail by Pemberton and Willard (*30*). An attempt was made particularly to discover morphological characters that might be used to separate the primary larvae of the established Malayan *Opius* spp. in field studies of these parasites.

Opius longicaudatus var. *maluiensis* Full.—This species was readily propagated as a parasite of the oriental fruit fly and was the first to become established in Hawaii, where it attacks mostly second- and third-instar larvae, particularly those infesting mature and fallen fruits. The biology and immature stages of this parasite were found

to be very similar to those of *Opius* (*Diachasma*) *tryoni* Cameron as described by Pemberton and Willard.

The newly deposited egg of *O. longicaudatus* var. *malaiensis* is slightly smaller than that of *O. tryoni*, averaging about 0.35 mm. in length, but is otherwise identical in shape, with a distinct mammilla at each end. It also swells considerably during the incubation period, becoming about 0.65 mm. long by 0.17 mm. at its greatest width just prior to eclosion, when the developed embryo is clearly discernible.

As in *Opius tryoni*, the distinctive primary larva possesses a large, heavily sclerotized and brownish head bearing strong sickle-shaped mandibles, a pair of soft fleshy appendages on the ventral surface of the first thoracic segment, and a gelatinous serosal membrane, consisting of large cells with prominent nuclei, which clings to the venter of the newly hatched larva (fig. 2 A). There is also a pair of toothlike projections forming a broad U on the antero-ventral head margin, a much smaller central "tooth" being apparent only when the cover glass is strongly depressed; a pair of soft antennal papillae above the mouth; a very simple closed tracheal system; and minute colorless setae, visible only at high magnification, on the mouthparts and antennae, the thoracic appendages, and along the lateral margins of the body segments, as shown in figure 2A. The larva apparently hatches by straightening the body, thus bringing the sclerotized head and roughened "tail" segment into contact with the serosal membrane and chorion. At this stage the larva measures from 0.75 to 1.00 mm. in length and is very active, but soon becomes quite sluggish as the

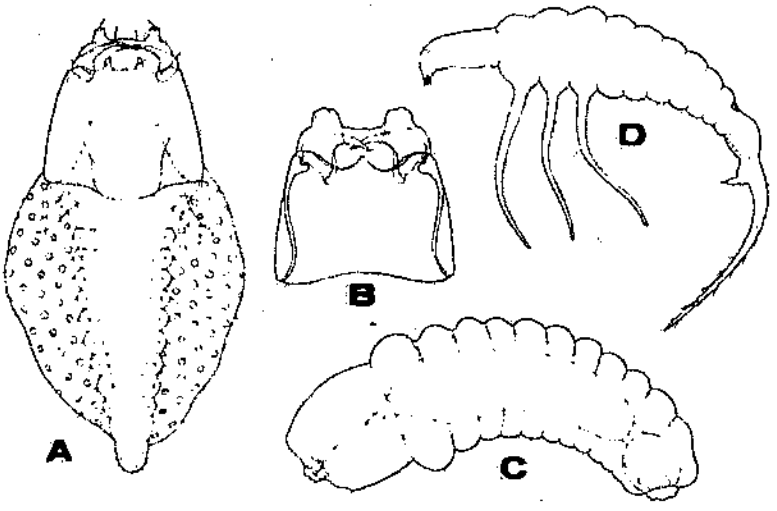

FIGURE 2. Newly hatched primary larvae of oriental fruit fly parasites. A, *Opius longicaudatus* var. *malaiensis* Full. (serosal membrane removed ventrally to show body structures). B, Head of *Opius vandenboschi* showing mouth parts. C, *Opius vandenboschi* Full. D, *Tryblographa daci* Weld.

body swells with ingested food. Supernumerary larvae are eliminated by cannibalistic attack during the active period, as with *O. tryoni*, and some of the competing larvae of *O. vandenboschi* are also killed in this manner (*35*). The serosal membrane begins to degenerate soon after eclosion and only small fragments are found clinging to the thoracic pseudopods of engorged larvae. As in other species of *Opius* that have been studied, larval development never proceeds beyond the first instar until the host has formed its puparium.

The primary larvae of *Opius formosanus* and *O. watersi* could not be distinguished from *O. longicaudatus* var. *malaiensis* despite very close examination, indicating that these species in the *longicaudatus* "complex" are extremely similar in the larval, as well as adult, stages.

Three members of the *Opius longicaudatus* "complex" from areas having lower winter temperatures exhibited a definite larval diapause when propagated in Hawaii. These were *O. longicaudatus* var. *novacaledonicus* from New Caledonia, *O. formosanus* from Formosa, and *O. watersi* from North India. A similar phenomenon was previously reported by Pemberton and Willard (*29*) for *O. tryoni* from Australia and *O. fullawayi* from Africa.

Many mature larvae of *O. longicaudatus* var. *novacaledonicus* reared on the oriental fruit fly entered diapause in July and August, the winter season in New Caledonia, the majority producing adults about 6 months later, although a few remained in diapause a full year. An estimated 22 to 75 percent of the mature larvae of *O. formosanus* also entered diapause when propagated on the same host during the winter months, the percentage gradually decreasing to 8 or 10 percent in April and early May. About 88 percent of the winter-bred diapausing *formosanus* larvae produced adult parasites during the ensuing 6 months, though some 10 percent required 6 to 12 months, and the remainder issued up to 15 months from date of parasitization. Approximately 22 percent of *O. watersi* mature larvae went into diapause when reared on melon fly in January, about one-third emerging as adults in March and April, and 60 percent during May and June. A few adults continued to emerge until mid-October for a maximum larval diapause of 9 months. Experimental exposure to low temperatures (36° to 50° F.) for about 2 weeks appreciably shortened the dormant period.

The occurrence of a larval diapause should enhance the survival of these species at higher elevations in Hawaii, where fruit fly development is retarded by cool winter temperatures, but it may be deleterious to them in lowland areas where their hosts continue breeding during the winter and the dormant parasites would be exposed to predation for longer periods. Since the oriental fruit fly and melon fly are primarily lowland pests in Hawaii, this habit may be more detrimental than beneficial to these parasites.

Opius vandenboschi Full.—The egg of *O. vandenboschi* is considerably longer and very different in shape from that of *O. longicaudatus* (*34*), and swells only slightly before eclosion. The primary larva is also readily distinguishable by its different shape, nonsclerotized and colorless head with internal yellowish tentorial ridges and unique oral structures, the absence of thoracic pseudopods, body setae, and serosal membrane (fig. 2 B and C). The mandibles are shorter and broader at the base than those of other *Opius* spp. previously studied. There is only one prominent central "tooth" on the anterior head

margin just below the mandibles, no evidence of a tracheal system, and the alimentary tract terminates in an enlarged globose proctodeum plugged with delicate colorless tissue. It is also interesting to note that the nerve cord lies along the convex side of the body, usually regarded as the dorsum, indicating that this side may actually be the ventral surface, although the heart or dorsal vessel could not be located to prove this point.

When first hatched, the primary larva measures only about 0.32 mm. in length but increases to nearly 1.0 mm. before moulting. The development of supernumerary larvae, and occasionally eggs as well, is prevented by a toxic or physiological reaction initiated by the hatching of the first larva, rather than through actual combat, as with *O. longicaudatus* (*34*). Apparently this species sometimes attains the second instar before its host has formed the puparium.

Opius oophilus Full.—Although the egg of *O. oophilus* is very different from that of *O. vandenboschi* (*33*), the primary larvae of these species could not be separated even when studied intensively under high magnification. It is thus apparently identical to that shown in fig. 2 B, and C. A brief study of the later instars also failed to show any obvious differences between these two parasites. The males of both *O. oophilus* and *O. vandenboschi* were found to require a 5- to 6-day premating period before the spermatozoa are ready for discharge and copulation is attempted (*21*). This discovery greatly facilitated the propagation of these parasites.

Opius incisi Silv.—Very little is known concerning the biology of this parasite because of its general scarcity and lack of importance in Hawaii. However, it has been recovered in fair numbers from small host fruits, particularly those of mock orange, *Philadelphus* sp., on the University of Hawaii campus. Its short ovipositor apparently prevents it from reaching many of the host larvae in larger fruits.

The primary larva of *Opius incisi* was found to be identical to that of *O. fletcheri* as figured and described by Willard (*37*), and is thus quite similar to *O. longicaudatus* var. *malaiensis* (fig. 2A) except for its more distinct tracheal system, quadrate head, and the narrower and more rounded "U" formed by the ventral cephalic "teeth." *O. incisi* was first identified as *fletcheri* and there is still some question as to their separate identities despite very different host preferences.

Trybliographa daci Weld.—These cynipids have very thin, laterally compressed bodies, which help them to penetrate decaying fruits in search of host larvae, the hairlike ovipositor being coiled within the flattened abdomen like a watch spring. When fully extended, the ovipositor is nearly as long as the body and remarkably flexible, enabling the parasite to probe in all directions until a host is located. This was readily observed through the petrie dishes as the parasites probed in the agar medium. The pedicellate egg is then deposited internally where it undergoes considerable enlargement before producing the peculiar eucoiliform primary larva shown in fig. 2D. This larva is similar to those of other Eucoilinae in general morphology, possessing an elongate head, three pairs of long slender ventral appendages on the thoracic segments, and a prominent cauda bearing a single ventral protuberance basally and minute colorless setae apically. The anus opens dorsally near the base of the cauda from which it is separated by a swollen segment with ventral scalelike corrugations. There is no discernible tracheal system or larval mandibles. The

newly-hatched larva measures about 1.0 mm. in total length, and is quite active until the body becomes distended with ingested food.

In the second instar the cauda is greatly reduced and simplified, the thoracic appendages have disappeared, the head and body segments become broader and less differentiated, and the larva has small though definite mandibles. The mature larva bears nine pairs of functional spiracles on segments 2 to 10, large lateral swellings on most of the body segments, and prominent bidentate mandibles with melanized tips.

Special studies and dissections also showed that *Trybliographa daci* cannot develop as a hyperparasite through *Opius* spp.

Aceratoneuromyia indicum Silv.—An account of the biology of this small, gregarious eulophid has been presented by Silvestri (*30*). The adults mate and the female is able to oviposit immediately after emerging from the host puparium, seeking out fruit fly larvae by entering breaks in ripe and decaying fruit. Once the ovipositor is inserted, the female allows herself to be dragged into the pulp by the burrowing host larva, sometimes being trapped therein after depositing a number of eggs. Development is completed within the fly puparium, from 1 to 52 adults (average 18.6 adults) emerging from each puparium of the oriental fruit fly. In laboratory tests, only 16 percent of these puparia yielded more than 30 *A. indicum* each. The sex ratio averaged 2.5 : 1, the females predominating.

An experiment was conducted to determine the result of larval competition between *Opius* and *Aceratoneuromyia indicum*. A large number of mature oriental fruit fly larvae previously exposed to laboratory parasitization by *O. vandenboschi* were divided into two equal lots, one being exposed to ovipositing *A. indicum* and the other held as a check. However, *A. indicum* apparently developed only in those hosts not already inhabited by *Opius* larvae, as indicated by the greatly reduced emergence of adult fruit flies from that lot, and the almost identical parasitization by *O. vandenboschi* in both series. The apparent inability of *A. indicum* to compete successfully with the introduced opiines probably limits its opportunity to become effectively established in Hawaii.

Tetrastichus spp.—The biology of *T. dacicida* is similar to that of *T. giffardianus* (*29*), both species developing readily as parasites of the oriental and Mediterranean fruit flies, but not of the melon fly, except that *giffardianus* can develop in the latter if it is first parasitized by *Opius fletcheri* Silv. The method of host attack and gregarious larval development is also similar to that described for *Aceratoneuromyia indicum*. Up to 60 adult *T. dacicida* were reared from single oriental fruit fly puparia, but the average was about 10 per host.

The result of larval competition between *Tetrastichus* spp. and the opiine parasites of *Dacus dorsalis* was not investigated, but Willard and Mason (*38*) found in studies with *Ceratitis capitata* that although some of the *T. giffardianus* larvae were killed by solitary *Opius* larvae before the latter died of starvation, only *Tetrastichus* survived. The situation was therefore the reverse of that reported herein for *Aceratoneuromyia indicum*.

Mass Production of Fruit Flies and Parasites

In the early days of the development of the biological control project, when incoming shipments of fruit fly material were limited in quantity, the breeding of the parasites at the Territorial Board

insectary, and somewhat later at the U.S. Department of Agriculture insectary, was accomplished by the use of field-collected, infested fruits, mainly guava. Certain of the imported parasites soon became abundant in the field, however, and the percentage of parasitization was so high that such material proved unsuitable for insectary use because of competition between the parasite stages already present in the larvae in the fruit and those of the species being propagated.

As in many similar projects, the key to mass production of the many parasite species being imported was the development of methods for production of the host insect itself in great numbers and at low cost. Marucci and Clancy (*24*) found that an agar-based medium, following the Texas *Drosophila* formula, provided the essential dietary requirements of the oriental fruit fly, the Mediterranean fruit fly, and the melon fly. The agar content of the medium needed to be adjusted to provide a suitable physical environment for parasite oviposition.

Maeda, Hagen, and Finney (*23*) developed a highly satisfactory medium based, with modifications, on one previously found suitable in the rearing of the European corn borer. This modified medium contained several ingredients lacking in the one previously mentioned. Both of these media, however, proved to be too expensive for the production of fruit flies on the scale required.

In the early stages of the program, blended Hubbard squash had been used successfully in the rearing of fruit fly larvae, but the results were erratic. To remedy this situation a fortified carrot medium was developed by Finney (*14*) that was inexpensive, very stable, and possessed of highly favorable physical properties. It consisted of blended carrot fortified with Brewer's yeast, 2N HCl, and Butoben, the latter constituent serving to suppress the growth of undesirable molds and exotic yeasts.

The above medium, placed in rearing pans to a depth of at least 1 inch, provided a surface film of liquid of such consistency that the young fruit fly larvae could migrate freely over it. The channels made by the feeding larvae tended to remain open, thereby permitting feeding to the bottom level of the pan as they attained greater size. One unit (20″ x 13″ x 3″) containing 3,200 cc. of the medium, in which approximately 21,000 fruit fly eggs were introduced, would yield about 15,000 full-grown larvae. While this medium proved highly satisfactory for production of the oriental fruit fly and the Mediterranean fruit fly, it was not so for the melon fly, which could not tolerate the Butoben. Without that mold inhibitor the surface would scum over and the medium deteriorate before larval development was complete.

A later modification on the carrot medium is reported by Christenson, Maeda, and Holloway (*7*), who found that dehydrated carrot was superior to fresh carrot in several respects and, on a cost basis, was more economical.

In addition to the development of the larval food media that have been mentioned, it was found by Hagen and Finney (*22*) that the fecundity of the female flies could be greatly increased by the addition of certain food supplements to their diets, thus contributing further to economical production. A commercial enzymatic protein, hydroly-

sate of yeast, added to honey or sucrose, not only shortened the preoviposition period but brought about a consistently high level of egg production throughout the life of the flies, much higher than that obtained with other foods.

The above methods for mass production of the fruit flies solved the problem of providing the base stock of adults for several programs, including that of parasite propagation, which required large numbers. For the latter work, however, various modifications had to be made in the handling of the larvae to obtain maximum oviposition by the many parasite species being propagated.

Initially, in the rearing of several species of *Opius* first imported, infested guavas were used at the U.S. Department of Agriculture insectary to test the adaptability of the different species to the oriental fruit fly. Full-grown, green wild fruits were collected, held until they began to ripen, and then exposed to the flies. Oviposition was facilitated by extensive puncturing of the skin of the fruits with a needle. Exposure to the parasites was at different times after fly oviposition to allow for any variation that might exist in the stages of the host preferred for oviposition by the different parasite species. Melon fly cultures in ripe cucumbers, and Mediterranean fruit fly cultures in ripe papayas, were maintained by essentially the same techniques.

Chong (*6*) has described briefly the methods employed at the Territorial Board insectary in the production of the several million parasites of 18 species and varieties for field release against the oriental fruit fly. Papaya fruits, available throughout the year in Hawaii, were used in this program. Eight or 10 firm mature green fruits were placed in a sleeve cage, measuring 30″ x 18″ x 17″, in which about 2,000 flies were contained. The skin of the fruits was punctured extensively by needle to facilitate oviposition by the flies and to insure uniform distribution of the eggs. Powdered soy bean hydrolysate, cube sugar, and water served as food. The fruits were exposed to the flies for 3 days, after which they were removed and placed in a holding cage.

For production of *Opius* species of the *longicaudatus* complex that oviposit in fruit fly larvae, the infested fruits were removed from the holding cage after 4 days and placed in a screen cage (14″ x 14″ x 14″) with a glass front, into which 100 parasites were then introduced. The fruits were exposed to the parasites for 3 to 4 days, after which they were removed and placed in trays over sand. Each fruit normally yielded about 300 parasites.

In the rearing of *Opius oophilus* and others of the *persulcatus* complex that oviposit in the host eggs, papayas were exposed to the fruit flies for only 1 day, and then transferred to the screen cage and immediately exposed to parasite attack for 1 to 2 days.

After the fruit fly larvae are fully grown, which is 10 to 12 days after deposition of the eggs, they normally leave the fruit and pupate in the sand trays beneath. The sand was sifted about 2 weeks later and the puparia set aside in glass jars for fly and parasite emergence.

In other biological-control programs, involving the rearing of opiine parasites of fruit flies, considerable difficulty was experienced in effecting general mating of the parasites. As a result, the progeny often were exclusively males, or the ratio of females to males was highly unfavorable. With the many species of *Opius* included in the current program, a considerable number mated readily in the in-

sectary cages and special provision to induce mating was unnecessary, while with others, best results were obtained when the parasite adults were exposed to alternating periods of sunlight and shade. The discovery by Hagen (*21*) that the males of *O. oophilus* and *O. vandenboschi* are sexually immature at the time of emergence, and that 5 to 6 days must elapse before successful mating can take place, may explain the difficulties encountered in rearing certain other species of the genus.

By the procedures described, it was possible for one trained assistant to produce about 50,000 parasites per month, and 25 to 80 pounds of fruit were required for this output.

The melon fly parasite *Opius watersi*, which attacks the larger larvae, reproduced readily when confined with cucumbers, squash, or pumpkin containing larvae of the proper stage of development, and could also be propagated with ease on larvae of the melon fly grown in artificial media.

Parasite species of the genera *Aceratoneuromyia*, *Tetrastichus*, and *Trybliographa*, reared in the course of these investigations, oviposit in full-grown larvae, often entering broken or decaying fruits in search of their victims. They were reared in quantity simply by exposing fruit fly larvae in glass jars to them, the exposure period being 5 to 6 days, after which the larvae were set aside for pupation. With *Aceratoneuromyia indicum*, of which up to 30 or more may develop in a single host, several thousand larvae in each jar were exposed to 1,000 or more parasites.

The true pupal parasites of the genera *Dirhinus*, *Psilus*, *Spalangia*, and *Pachycrepoideus* were reared with ease (*13*), it being necessary only to expose the fresh host puparia in glass jars to them, the ratio of host and parasite numbers being adjusted to prevent excessive superparasitization.

Rearing of the staphylinid predator *Thyreocephalus albertisi* was accomplished by confining the beetles in jars with an adequate quantity of broken fruits, such as guava, well infested with fruit fly larvae of the different stages of development. The eggs are laid beneath the fruit, among the debris at the bottom of the jars, or, under more natural conditions, in soil tunnels a short distance beneath the surface (*25*).

Insectary production of 18 parasite species and varieties, and one predator, almost entirely by the Territorial Board, is shown by years in table 21.

Field Colonization

The first field releases of imported fruit fly parasites took place on March 15, 1947, when 7 females and 2 males of the "*persulcatus* complex" from the Philippine Islands were released on Oahu. The totals for that year were small, but the program expanded greatly in 1948 and ensuing years. During 1947 to 1953, inclusive, total releases on the six islands of Hawaii by the Territorial Board were 1,110,912, representing 29 species and varieties of parasites and 1 predator. A number of the parasites were released directly after emergence from the imported puparia, and without insectary propagation. The individual colonies of braconid parasites usually comprised 100 to 500 adults and of the remaining species 1,000 or more. The numbers of each species by year and by island are given in table 22.

TABLE 21.—*Insectary production of fruit fly parasites and predators, 1947–53*

Species	1947	1948	1949	1950	1951	1952	1953	Totals
Opius angaleti Full					718			718
O. compensans Silv					50, 963	29, 773	17, 515	98, 251
O. formosanus (Full.)				19, 641	56, 602	32, 631	24, 955	133, 829
O. incisi Silv		3, 348	36, 265	54, 976	929			95, 518
O. kraussii Full				2, 363	5, 837	8, 029	5, 600	21, 829
O. longicaudatus (Ashm.):								
var. *malaiensis* Full		51, 233	76, 526	10, 399				138, 158
var. *novacaledonicus* Full				1, 730	46, 679	31, 707	26, 495	106, 611
var. *taiensis* Full					32, 483	31, 238	50, 358	114, 079
O. makii Sonan				162	6, 848			7, 010
O. oophilus Full. / *O. vandenboschi* Full. (mixed)	42	277	31, 857	6, 662				38, 838
O. watersi Full				215, 467				215, 467
Dirhinus giffardii Silv				87, 686				87, 686
Spalangia sp. (India)				1, 254				1, 254
Aceratoneuromyia indicum (Silv.)	18			2, 325	91, 143	197, 280	210, 135	500, 901
Tetrastichus dacicida Silv				38, 577				38, 577
Tetrastichus giffardianus Silv				36, 284	2, 175			38, 459
Thyreocephalus albertisi (Fauvel)	(1)	(1)	(1)	3, 493				3, 493
Trybliographa daci Weld			1, 811	22, 020	25, 668	10, 247	13, 200	72, 946
Total	60	54, 858	146, 459	503, 039	320, 045	340, 905	348, 258	1, 713, 624

[1] Production figures not available.

TABLE 22.—*Numbers of fruit fly parasites and predators released in Hawaii, 1947–53*

Species	Island	1947	1948	1949	1950	1951	1952	1953	Totals
Opius anastrephae (Vier.)	Oahu					274			274
	Hawaii					35			35
O. angaleti Full	Oahu					1, 289			1, 289
	Hawaii					475			475
O. bevisi Brues(?)	Oahu			502					502
	Hawaii			1, 645					1, 645
	Maui			400					400
	Kauai			1, 839					1, 839
O. cereus Gahan	Oahu					803			803
	Hawaii					408			408
	Maui					196			196
O. compensans (Silv.)	Oahu					6, 099	7, 813	2, 715	16, 627
	Hawaii					9, 710	5, 431	1, 200	16, 341
	Maui					2, 618	1, 808	840	5, 266
	Kauai					3, 589	2, 013	3, 875	9, 474
	Molokai					985	990		1, 975
O. deeralensis Full	Oahu				713				713
	Hawaii				966				966
	Maui				180				180
	Kauai				76				76
	Molokai				34				34
O. fijiensis Full	Oahu				227				227
	Maui				20				20
	Molokai				92				92
O. fletcheri Silv	Oahu				41				41
	Hawaii					1, 098			1, 098
	Molokai					125			125
O. formosanus (Full)	Oahu				550	4, 235	6, 360	3, 310	14, 455
	Hawaii				6, 150	9, 946	6, 180	1, 915	24, 191
	Maui				2, 350	4, 130	2, 567	720	9. 767
	Kauai				1, 155	3, 380	2, 641	1, 630	8, 806
	Molokai				2, 000	1, 661	830		4, 491

TABLE 22.—*Numbers of fruit fly parasites and predators released in Hawaii, 1947–53*—Continued

Species	Island	1947	1948	1949	1950	1951	1952	1953	Totals
O. incisi Silv	Oahu		293	5,552	10,005	250			16,100
	Hawaii		250	8,308	3,580	625			12,763
	Maui		417	4,088	4,470	550			9,525
	Kauai		442	4,950	6,425	350			12,167
	Molokai			454	5,045				5,499
	Lanai			300					300
O. kraussii Full	Oahu				1,439	775	1,350	225	3,789
	Hawaii				461	1,334	1,800	1,510	5,105
	Maui				607	645	1,695	1,255	4,202
	Kauai				455		275	1,020	1,750
	Molokai				140				140
O. longicaudatus var. *chocki* Full	Oahu				1,783				1,783
	Hawaii				80				80
	Kauai				211				211
O. longicaudatus var. *novacaledonicus* Full.	Oahu					2,830	8,645	3,055	14,530
	Hawaii				350	5,754	5,905	1,935	13,944
	Maui				150	2,165	1,360	1,580	5,255
	Kauai				150	2,301	2,293	2,240	6,984
	Molokai					1,025	650		1,675
O. longicaudatus var. *malaiensis* Full.	Oahu		19,908	22,106	1,230				43,244
	Hawaii		9,058	25,977	3,300				38,335
	Maui		6,756	16,344	2,280				25,380
	Kauai		5,273	11,995	2,525				19,793
	Molokai		727	1,757	1,150				3,634
	Lanai		150	500					650
O. longicaudatus var. *taiensis* Full	Oahu					2,460	6,200	10,170	18,830
	Hawaii					3,288	4,405	4,235	11,928
	Maui					630	2,680	2,360	5,690
	Kauai					1,555	2,525	5,375	9,455
	Molokai					270	765		1,035
O. makii Sonan	Oahu					440			440
	Hawaii					380			380
	Maui					150			150
	Kauai					210			210

O. oophilus Full. (mixed)	Oahu	82	1,412	5,838	600	470			8,402
O. vandenboschi Full	Hawaii			6,694	2,500	845			10,039
	Maui		25	4,775	1,635				6,435
	Kauai		100	7,187	2,150				9,437
	Molokai			355	850				1,205
O. oophilus Full	Oahu				850				850
	Hawaii				730	50			780
	Maui				530				530
	Kauai				490				490
	Molokai				385				385
O. phaeostigma Wilk	Hawaii					328			328
O. skinneri Full	Oahu				22				222
	Kauai				67				67
O. vandenboschi Full	Oahu					175			175
	Hawaii					712			712
O. watersi Full	Oahu				16,430				16,430
	Hawaii				16,446				16,446
	Maui				34,076				34,076
	Kauai				22,096				22,096
	Molokai				25,615				25,615
Opius spp. (ex Africa)	Oahu			900					900
	Hawaii			512					512
	Maui			620					620
	Kauai			400					400
Bracon fletcheri Silv	Oahu				1,693				1,693
Dirhinus giffardii Silv	Oahu				10,635				10,635
	Hawaii				21,550	450			22,000
	Maui				17,308	250			17,558
	Kauai				12,685				12,685
	Molokai				5,875				5,875
Spalangia endius Wlk	Oahu			380					380
Aceratoneuromyia indicum (Silv.)	Oahu				1,400	19,100	71,600	64,300	156,400
	Hawaii				4,600	32,550	26,200	77,250	140,600
	Maui					9,050	6,500	8,500	24,050
	Kauai					12,100	23,000	5,300	40,400
	Molokai					3,500			3,500

TABLE 22.—*Numbers of fruit fly parasites and predators released in Hawaii, 1947–53*—Continued

Species	Island	1947	1948	1949	1950	1951	1952	1953	Totals
Tetrastichus dacicida Silv	Oahu				5, 370				5, 370
	Hawaii				1, 975	3, 200			5, 175
	Maui				5, 200				5, 200
	Kauai				6, 500	125			6, 625
	Molokai				950				950
Tetrastichus giffardianus Silv	Oahu				1, 550	4, 790			6, 340
	Hawaii				6, 825	5, 150			11, 975
	Maui				2, 800	1, 600			4, 400
	Kauai				2, 075	1, 204			3, 279
	Molokai				5, 450				5, 450
Thryeocephalus albertisi (Fauvel)	Oahu	220	188	282	[1] 3, 597				4, 287
	Hawaii				280				280
Trybliographa daci Weld	Oahu			565	5, 770	2, 372	2, 070	2, 040	12, 817
	Hawaii			450	2, 240	6, 906	1, 390	1, 240	12, 226
	Maui			360	4, 158	2, 271	725	720	8, 234
	Kauai			640	1, 355	2, 464	895	1, 640	6, 994
	Molokai				305	570			875
Total		302	44, 999	136, 675	317, 208	189, 275	209, 558	212, 175	1, 111, 192

[1] Comprising 1,399 adults and 2,198 eggs and larvae.

Two of the parasites in this series, *Dirhinus giffardii* and *Tetrastichus giffardianus*, were already established in Hawaii from West African importations during 1913–14. At the time the current importations were made, there appeared to be grounds for belief that different but closely related species were involved. Accordingly, they were reared and released in considerable numbers during 1950–51. It was finally concluded that they were identical and further rearing and release for purposes of establishment were discontinued.

The importation program came to an end in October 1951. By the end of 1953, even those parasite species last received had been given a 3-season, test-release period, which is considered adequate to determine if establishment can be effected. However, production and release of many of the species continued on a large scale to provide for special needs and to determine if reinforcement of colonies of several species, recovered in limited numbers in certain localities, would be beneficial and increase the possibility of permanent establishment. The 1954–62 releases in Hawaii under this program are shown in the following tabulation. This supplementary production program also provided parasite stocks to meet requests from many foreign countries that are faced with serious fruit fly problems.

Fruit fly parasite releases in Hawaii, 1954–62

Species	Number released
Opius compensans (Silv.)	229, 890
O. formosanus (Full.)	206, 388
O. incisi Silv.	675
O. kraussii Full.	280
O. longicaudatus (Ashm.):	
var. *novocaledonicus* Full.	358, 927
var. *taiensis* Full.	357, 290
O. oophilus Full.	16, 505
Dirhinus giffardii Silv.	59, 750
Acerataneuromyia indicum (Silv.)	1, 015, 120
Tetrastichus giffardianus Silv.	12, 100
Tryblliographa daci Weld.	30, 110
Total	2, 287, 035

Field Recovery and Establishment

Field recoveries of several of the parasites of the oriental fruit fly imported from the Philippine Islands and Malaya were made very soon after the initial releases in Hawaii during 1947–48. These were of *O. longicaudatus* var. *malaiensis* and "*Opius persulcatus* complex," later determined to consist of *O. oophilus* and *O. vandenboschi*. The first-named species, received from Malaya in June 1948 and released from August onwards, was first recovered on Oahu in October of that year. *O. oophilus* and *O. vandenboschi* were first recovered on the same island in early December of the same year, but it is uncertain whether establishment was from Philippine or Malayan stocks, though the latter source is the more probable.

Of the remaining species of *Opius* released against the oriental fruit fly, field recoveries have been made of *O. longicaudatus* varieties *taiensis* and *novocaledonicus*, *O. incisi*, *O. formosanus*, *O. compensans*, and *O. kraussii* (4). Of these, according to C. J. Davis, state entomolo-

gist of Hawaii (personal commun. 3-22-63), only the first three have maintained themselves, and they are of infrequent occurrence.

Among the several chalcidoid, cynipoid, and proctotrupoid parasites imported from various parts of the world, and not previously established in Hawaii, only *Tetrastichus dacicida* and *Aceratoneuromyia indicum* were ever recovered in the field. The latter is reported to be established, though present in only small numbers. Evidence of breeding in the field by the staphylinid predator *Thryeocephalus albertisi* was noted shortly after certain releases, but establishment was not obtained.

It had been hoped that the importation and release of a wide range of fruit fly parasites from many areas of the world, including several obtained from *Ceratitis capitata* in Africa, might result in establishment of one or more that would supplement *Opius tryoni* in Hawaii and enhance the degree of field control. The amount of *C. capitata* material obtained in Africa was small, and none of the parasites of that or other Tephritidae from that region became established in Hawaii.

Somewhat unexpectedly, the three most effective parasites of the oriental fruit fly, *Opius longicaudatus* var. *malaiensis*, *O. vandenboschi*, *and O. oophilus*, were found to be well adapted to the Mediterranean fruit fly. *C. capitata* has been almost completely crowded out by *D. dorsalis* in the lowlands of Hawaii, and consequently information as to attack upon natural field populations from 1950 onwards by these newly imported species of *Opius* could be obtained only at the higher elevations.

Very large numbers of puparia of *Dacus cucurbitae* and other species of the genus obtained from a variety of Cucurbitaceae and other host fruits were shipped to Hawaii in the hope that they might yield one or more parasite species that would be more effective than *Opius fletcheri*, which had been imported from India many years previously (see pp. 4, 55). The outcome was disappointing. *O. watersi* was more abundant than *fletcheri* in the collections of melon fly in North India, and more than 114,000 adults were released in Hawaii during 1950. Clancy (*9*) records a few recoveries of *O. watersi* on the University of Hawaii campus during September to December of that year, but about 50 percent of the larvae were in diapause and the species did not survive the winter.

Opius angaleti from Borneo, the only other species of the genus reared from *Dacus cucurbitae*, likewise failed of establishment. It was reared on that host in the insectary only with some difficulty and its normal host may be some other fruit fly associated with the melon fly in the mixed lots of puparia from several fruits imported during 1951. None of the other species of *Opius* reared from a wide range of fruit flies proved adaptable to the melon fly.

Results of the Biological-Control Program

Oriental Fruit Fly

The consistently high parasitization of the oriental fruit fly by *Opius oophilus* in Hawaii since 1950 has resulted in a substantial reduction in fruit infestation. It is not intended to give here any detailed analysis or evaluation of the different factors bearing upon this

outcome. Such a study was made by I. M. Newell and F. H. Haramoto, and their account will be published shortly.

Bess and Haramoto (*2*) have given their conclusions, based mainly on periodic collections of guavas and trap collections of male flies during 1950–55. Fly populations had been extremely high during 1947–49, and even in 1950, when the decline was well under way, trap collections averaged 2,000 per day during June to December. By 1951, when the population level had been much reduced as a result of parasitization by *Opius oophilus*, trap catches of flies averaged 400–500 per day. The average number of larvae per guava fruit declined from 8.5 in 1950 to 2.6 in 1955. Average parasitization of larvae from that fruit during the same period ranged from 60 to 79.1 percent. A later publication by the same authors (*3*) includes data for the years 1956 and 1957, and the findings are in accord with those from the preceding years.

The figures given above for infestation of wild guavas, the favored host fruit of the oriental fruit fly, indicate that a high population is still being maintained in areas where that plant occurs abundantly. Some reduction in fruit infestation has taken place, this being from virtually 100 percent in 1947–49 to 60.5 percent showing evidence of attack, and 22.2 percent actually containing maggots, in 1955.

Certain disease-producing microorganisms cause high mortality of the eggs of the oriental fruit fly, these being transmitted mechanically by *Opius oophilus* at the time of oviposition. Whether this is advantageous from the point of view of control is open to question, as mortality of the host eggs involves also the destruction of the parasite eggs contained in them. However, the reproductive potential of the parasite is sufficiently high to enable it to consistently effect a high rate of successful parasitization despite this substantial loss. The incidence of these parasite-transmitted diseases may explain the difference in the figure given above for the percentage of guava fruits showing evidence of fruit fly attack and the much lower figure for those actually containing maggots.

The present situation, with respect to a number of cultivated fruits, is markedly different from that which prevails in guavas. Many of these had been totally infested during 1947–49 but, after the general build-up of *Opius oophilus*, a substantial portion of the fruit was free from attack, even without spray treatments. Fruits such as avocado, banana, and papaya, grown at low elevations and once heavily attacked, were seldom found to be infested. The same was true of loquat, peach, and persimmon grown at elevations of 2,000 feet and higher. Infestation of mangoes, a favored host fruit, declined greatly, seldom exceeding 10 percent. Thus, it became possible once again to produce a number of the more common fruits in home plantings without loss of any serious portion of the crop. In commercial plantings of mango, the 10-percent infestation represented a loss that could be further reduced, and on an economical basis, by spray treatment. Such treatments had been ineffective against the massive infestations that prevailed during the early years of the outbreak.

The progress of the three important parasite species in the field and the outcome of competition between them has been reported in some detail by van den Bosch, Bess, and Haramoto (*32*), and van den Bosch and Haramoto (*34*). *O. longicaudatus* var. *malaiensis* increased rapidly, and collections of fruit fly material from guava on

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Oahu showed parasitization up to 30 percent from January 1949 onwards. *O. vandenboschi* then came into the picture the middle of the year, attaining high parasitization by October. Concurrently with this buildup was the decline of *malaiensis* to an inconsequential level. The upsurge of *O. oophilus* began in early summer of 1950, culminating in an average parasitization of larvae in guavas of 70–75 percent by the end of the year. The population of *O. vandenboschi* declined sharply during this period, just as *malaiensis* had done the preceding year when dominated by *vandenboschi*. Bess, van den Bosch, and Haramoto showed that the field situation was stabilized from 1951 onwards, with parasitization by *O. oophilus* in guavas on Oahu amounting to 77, 68, and 67 percent during 1951, 1952, and 1953, respectively. The two competing species faded permanently from the picture, representing 1–2 percent or less of the aggregate parasitization of the oriental fruit fly (table 23) during those years. In fact, the reduction in numbers was so great that only three specimens of *malaiensis* and none of *vandenboschi* were reared from the regular guava collections during the 1955 season (*2*). The initial rapid buildup of *malaiensis* in 1949 is attributed to the large numbers released, as compared to those of *vandenboschi* and *oophilus*.

TABLE 23.—*Relative abundance of the 3 major species of Opius reared from oriental fruit fly in guava on Oahu, 1948–53*

Year	Parasite species		
	Opius longicaudatus malaiensis	*Opius vandenboschi*	*Opius oophilus*
1948	158	4	0
1949	4, 428	4, 092	10
1950	1, 972	10, 583	12, 034
1951	138	196	10, 258
1952	64	7	6, 829
1953	2	8	6, 969

There are several points of interest in the habits of the three species of *Opius* previously mentioned that bear upon the outcome of the competition in which *O. oophilus* triumphed so decisively. *O. oophilus* oviposits in the fruit fly eggs, the entire host population thus being exposed to its attack. *O. vandenboschi* prefers the first-instar larvae for oviposition and a very large portion of them are accessible to the parasite regardless of the type of fruit in which they occur. *O. longicaudatus* var. *malaiensis*, on the other hand, is limited mainly to second- and third-instar larvae, a large portion of which, in deep-pulped fruits, is beyond reach of its ovipositor.

Another important factor bearing on the outcome of competition between the three species is multiple parasitism, which was of frequent occurrence before equilibrium was attained. Van den Bosch and Haramoto (*34*) found that the presence of eggs or larvae of either *vandenboschi* or *oophilus* inhibit the development of eggs or larvae of *malaiensis* occurring in the same host individual, the larvae

dying from starvation. Furthermore, the presence of *oophilus* in a host larva inhibits development and causes degeneration of such *vandenboschi* eggs as may be deposited in that host.

It is thus seen that *O. oophilus* has a substantial advantage over the other two species in that (1) the host stage which it attacks is within reach regardless of the type of fruits in which it occurs and (2) it is dominant when in competition with other species in individual host larvae. The rapid and complete replacement of *malaiensis* and *vandenboschi* by *oophilus* is thus understandable. It may also have been directly responsible for the failure of establishment of other species of *Opius* that were later released in large numbers.

Whereas the major imported parasites of the oriental fruit fly have proven to be equally adapted to the Mediterranean fruit fly, *O. tryoni*, the long-established parasite of the latter, has not shown a similar adaptability to *D. dorsalis*. Clancy (*8*) reports that guavas heavily infested with larvae of this fly and then exposed to 69 field-collected females of *O. tryoni* yielded 820 puparia, from which only two parasites of this species emerged. The parasite females oviposit readily in *D. dorsalis* larvae, both in the field and in the insectary, but only an occasional individual is able to develop to maturity. At one site on Oahu, where *O. tryoni* was breeding in large numbers in the larvae of the lantana gall fly *Eutreta xanthochaeta* Ald., many parasite females were seen to oviposit in infested guavas nearby but none of those collected yielded parasites of this species. It also is known to develop in another tephritid gall fly, *Procecidochares utilis* Stone.

Mediterranean Fruit Fly

Although none of the parasites of the Mediterranean fruit fly imported from Africa during the current program became established in Hawaii, substantial progress in biological control of that pest has come about through the oriental fruit fly parasites obtained from Malaya. Bess, van den Bosch, and Haramoto (*4*) report the results of rearings from coffee berries at 2,500 feet elevation at Kona, Hawaii during 1949–53. Both fruit flies were present in the collections, though *C. capitata* was much the more abundant. *Opius oophilus* almost completely replaced *O. tryoni* by the middle of 1951, and thereafter only occasional single specimens of others were obtained. The same general pattern was evident in parasite attack on the Mediterranean fruit fly as on the oriental fruit fly—the complete dominance of *O. oophilus* over all other species of that genus. Field parasitization of larvae of *C. capitata* in coffee by *O. oophilus* was substantially higher than had previously been effected by *O. tryoni*, and infestations were much reduced.

Clancy (*10*) has reported on the incidence of parasitization of *C. capitata* and *D. dorsalis* in ripe papayas and peaches at five sites on Oahu during 1951. Fruits infested in the laboratory were exposed for the proper period in the field and the flies and parasites then reared out. It was found that parasitization by the four newly imported parasite species was approximately equal in the two host species, and ranged up to a total of 43 percent. *Opius longicaudatus* var. *malaiensis* was the most abundant parasite from both hosts under the conditions of this test, while *O. incisi* was a strong second. It is surprising that the usual order of parasite abundance was reversed in this study, as *O. oophilus* and *O. vandenboschi* were much less numer-

ous than the two species previously mentioned. At this time, the late summer of 1951, *O. oophilus* was strongly dominant in practically all rearings from field-collected fruit. Although the test demonstrated that the parasites are equally well adapted to the two fruit fly species, the relatively small numbers of *O. oophilus* that were reared may have been the result of a scarcity of host eggs in the fruits during the exposure period. It is highly significant that not a single specimen of *O. tryoni* emerged from the 1,277 puparia of *C. capitata* obtained from the infested fruit.

An extended account has been given by Bess (*1*) of the status of the Mediterranean fruit fly as a pest of a variety of fruits in the various ecological zones of the Islands since it became subject to heavy attack by the several oriental fruit fly parasites. Periodical collections of peaches, coffee, Jerusalem cherry (*Solanum pseudocapsicum*), guava, and loquat (*Eriobotrya japonica*) were made at different elevations up to 5,300 feet, and on several of the islands. Data are also given on the relative abundance of *C. capitata* and *D. dorsalis* at the different elevations, showing the increasing dominance of the first-named species as the elevation increased.

The reduced abundance of *C. capitata* at the higher elevations since 1951 is attributed to attack by the newly introduced parasites. Guava collections on Molokai at elevations of 1,000–2,000 feet, which yielded both species of flies, showed a marked reduction of *C. capitata* from the early part of 1950 to late 1952. Although there is a marked difference in the abundance of the two fruit fly species at increased elevations, this factor apparently had little or no influence on the activities and effectiveness of *Opius oophilus*.

Discussion

In reviewing the development and outcome of the biological control project as it relates to the two major fruit fly pests, one fact stands out conspicuously. The importations of oriental fruit fly material from the Philippine Islands and Malaya by the Hawaii Board of Agriculture and Forestry during 1947–48, before the other cooperating agencies entered the picture, resulted in the immediate establishment in Hawaii of the three important parasites, *Opius longicaudatus* var. *malaiensis*, *O. vandenboschi*, and *O. oophilus*, of which the latter quickly became dominant and was alone responsible for the partial control that was brought about. Although several additional species of parasites, obtained from the several million puparia from many parts of the world during the cooperative program of 1948 to 1951, were also recovered in small numbers and apparently became established, they have contributed nothing to control of the two pests.

The outcome of this project lends weight to the argument sometimes advanced that a parasite-importation program should be limited to collections of the host species itself and to the geographic areas in which it is native, and that detailed studies on the biology, habits, and interrelations of the different parasites should precede their importation. In this instance it is probably true that such studies in Malaya would have revealed the dominance of *O. oophilus* over *malaiensis* and *vandenboschi* when in competition. The collection records show, however, that *O. oophilus* is not dominant over the other two in all areas of the Indo-Malayan region in which they occur.

This indicates that competition alone is not always the controlling influence and that the introduction of the three species into new areas might not always result in dominance by *O. oophilus*.

It is very much a question as to the relative efficiency of the three species of *Opius* in control of the oriental fruit fly in the absence of competition. Certainly *malaiensis* and *vandenboschi* in turn exhibited capacity for a high rate of parasitization before being overwhelmed by *oophilus*. Had the latter species been the first to become established and generally abundant in the Islands, it might then have been difficult even to establish the other two species, and certainly their potential value in control, in the absence of competition, would have been completely masked.

Past experience on other biological-control problems has demonstrated that limitation of search to the single host species or genus may result in passing over the most effective parasite. This was shown, for example, by the early work on *Ceratitis capitata* in Hawaii, in which the dominant parasite *Opius tryoni* originated, not from that host in its native habitat in Africa, but from *Dacus tryoni* in Australia. Further, developments in Hawaii since 1950 have demonstrated that *O. oophilus* is much more effective against the Mediterranean fruit fly than is *O. tryoni*, which it has now replaced. Consequently, it would have been highly advantageous if, in 1913–14, the Malayan parasites of *D. dorsalis* had been included in the importation program.

Opius oophilus (then recorded as *O. persulcatus*) was undoubtedly represented in the material imported into Hawaii from Malaya and India by F. C. Hadden (*20*) in 1935–36, and an uncertain number were released. Insectary propagation was not successful, very probably because its oviposition habit was not then known, and only larvae may have been provided in the rearing cages. Had this parasite become established on the Mediterranean fruit fly at that time, it would be interesting to speculate on the repressive effect it might have exerted on the oriental fruit fly immediately following establishment of the latter in Hawaii in 1945.

SUMMARY

The initial search for effective natural enemies of the oriental fruit fly was conducted by the Hawaiian Board of Agriculture and Forestry in the Philippine Islands and Malaya during 1947–48. Following this, a cooperative project was set up involving that organization, the U.S. Bureau of Entomology and Plant Quarantine, the Hawaii Agricultural Experiment Station, the Hawaiian Sugar Planters' Experiment Station, the Pineapple Research Institute, and the University of California. During the period covered by the foreign explorations, from 1947 to 1951, approximately 4¼ million puparia, representing more than 60 species of fruit flies, were collected in many tropical and subtropical areas of the world and shipped to Hawaii for parasite rearing. From them were obtained 25 species and varieties of parasites, in addition to 4 already established in the Islands, in sufficient numbers for rearing and field release. Two staphylinid predators were also included among the importations.

Field releases were made of 29 species and varieties of parasites and one predator. Twenty-two of the parasites were of the genus *Opius*.

Insectary production provided a total of more than 1.1 million adults for colonization in Hawaii during 1947–53, and an additional 2¼ million were released during 1954–62. Seven of the imported parasites became established on the oriental fruit fly in Hawaii, these being *Opius longicaudatus* var. *malaiensis*, var. *novacaledonicus*, and var. *taiensis*, *O. oophilus*, *O. vandenboschi*, *O. incisi*, and *Aceratoneuromyia indicum*.

Opius longicaudatus var. *malaiensis* became abundant in 1948–49, but was quickly superseded by *O. vandenboschi*, which in turn was soon dominated by *O. oophilus*. Thereafter, all other established parasite species were present in such small numbers as to contribute nothing to control. The latter species has a marked advantage in competition with the other two, in that it oviposits in the host egg, whereas *malaiensis* attacks the second- and third-instar larvae, and *vandenboschi*, those of the first instar.

Opius oophilus consistently effects a parasitization of about 75 percent of the fruit fly larvae in guavas, the wild fruit that provides the main reservoir of flies in the Islands. In addition to this direct mortality, the parasite is responsible for transmission, at the time of oviposition, of disease-producing microorganisms that cause high mortality of the fruit fly eggs.

A detailed evaluation of the role of *O. oophilus* in control of the oriental fruit fly is not yet available, but preliminary data, mainly from collections of guavas, show much reduced populations since 1950. Several cultivated host fruits, previously very heavily infested, are now practically free from attack. While full economic control was not attained, substantial benefits accrued from the parasite-importation program.

Opius oophilus was equally effective as a parasite of the Mediterranean fruit fly at the higher elevations, to which the latter has been largely confined as a result of its displacement at the lower levels by the oriental fruit fly.

The discovery of *Opius watersi* as a parasite of the melon fly in North India and its greater abundance than *O. fletcheri* in some areas, gave hope that it might supplement the attack of the latter species on the melon fly in Hawaii. Despite field releases of more than 100,000 adults during 1950, however, it failed to become established.

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