[illegible] OF AGRICULTURE
[illegible] FRUIT FLIES
[illegible] OF ALL KIND [illegible] UNDERTAKEN
[illegible] FRUIT FLIES IN HAWAII.
(Formerly Oriental Fruit Fly Investigations.)

FRUIT FLY POLICY MEETING

Open Session -- Held October 2, 1953, at 8:30 A. M. in the Pineapple Research Institute Assembly Room

Introductory Remarks:

Mr. Christenson: Our purpose this morning is to review the Fruit Fly Biology-Ecology and Biological Control Investigations. Our emphasis will be on the progress since our last Policy Committee meetings 17 months ago, but the discussions will also bring us up to date on all that has transpired since our investigations first started. Before we get on with the program I would like to say again that we are very happy that Mr. C. P. Clausen of the University of California and Dr. B. A. Porter from Washington, D. C., could get over to participate in these meetings. Mr. Clausen drops in on us quite frequently these days. We also have a visitor from New Zealand this morning, Mr. J. Gordon Morrison. We are very happy to have you with us.

My own remarks will be very brief. I just want to call your attention to some of the recent trends in our fruit fly population curves. You will note in Figure 1 that there was a very definite upward trend on three of the major islands, which began just about a year ago. On Kauai the populations have continued at rather high levels since that time--at least higher than they were for some time previously. Representative curves for Maui sites are given in the second figure. Populations here also increased on the Big Island (Fig. 3). Kaimu high densities prevailed in the Kapaau district particularly, in the Kalapana area, and even in Kona where the flies were at quite a low ebb for a long time, they have built up records within the last few weeks. Very recent information which Mr. Kajahara brought over from Maui shows that the flies are still very abundant on Maui, setting an all time record during the last 18 months of trapping records in the Kaupo area. This area, according to our records, has had more flies by 2 or 3 times than practically any other area we have found so far. The oriental fruit fly also increased in abundance on Oahu about a year ago but in recent weeks the trend has been downward once more. Intermediate kolinas here also show a tendency to be somewhat higher in recent months (see Figs. 4 and 5).

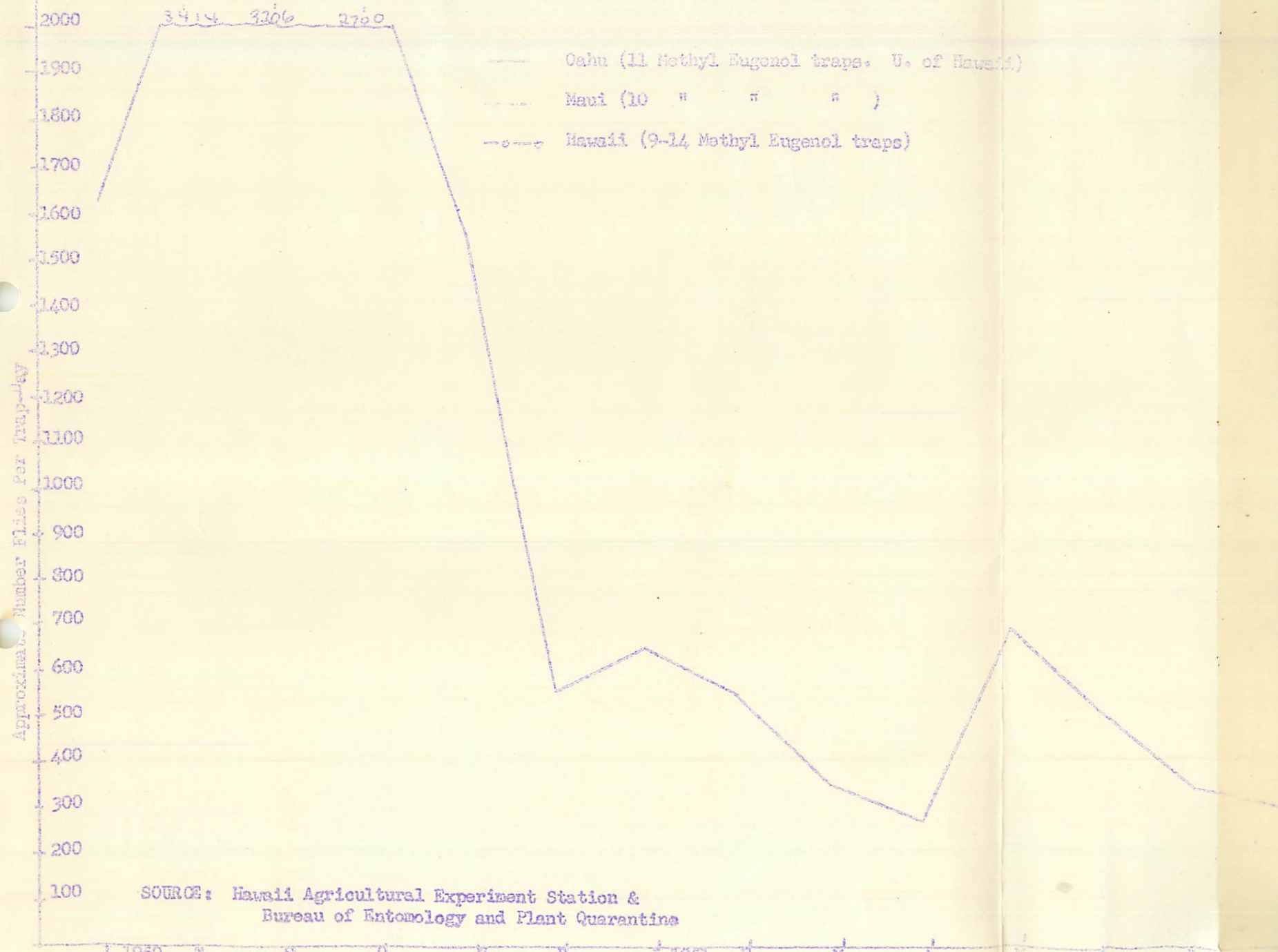
Mr. Fitters, who is now in charge of the Bureau's Ecology-Biology studies, will give us a progress report on his investigations.

Mr. Fitters: Perhaps I should begin by presenting a brief resume of the changes that have occurred in the Biology-Ecology project since the last policy committee meeting in 1951.

We have had the normal anticipated turnover of personnel, but our professional staff was depleted by the transfer of Dr. Edgar Kresmer to a Point-4 appointment in Indonesia early this year. This vacancy has, unfortunately, not been filled and as a consequence a heavier burden has been placed upon those of us responsible for the Honolulu cabinet of fly.

Fig 1 (1 of 3)

FIGURE 1. ORIENTAL FRUIT FLY POPULATION TRENDS - OAHU, MAUI, HAWAII.



SOURCE: Hawaii Agricultural Experiment Station &
Bureau of Entomology and Plant Quarantine

Fig. 1 (2 of 3)

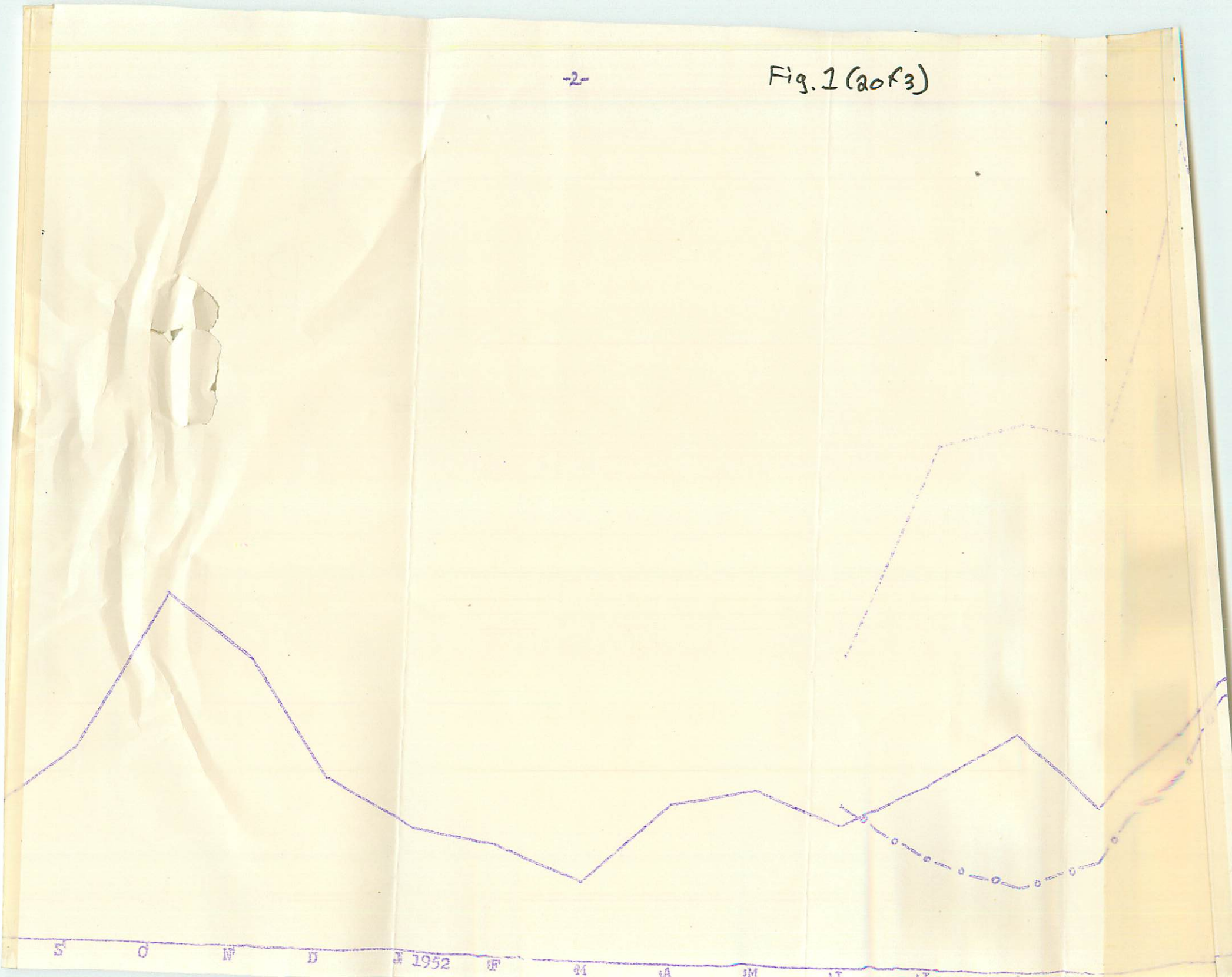


Fig. 1 (3 of 3)

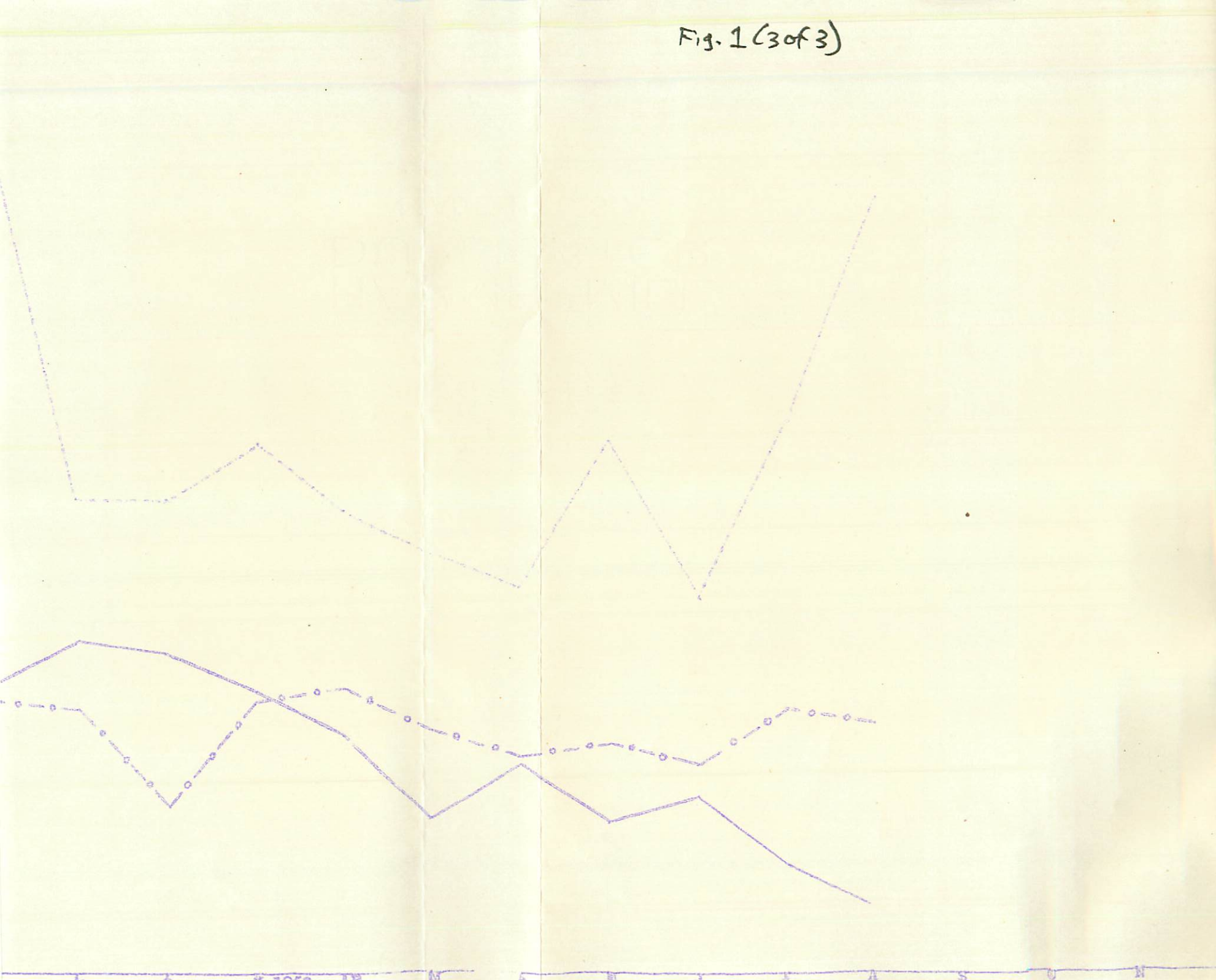
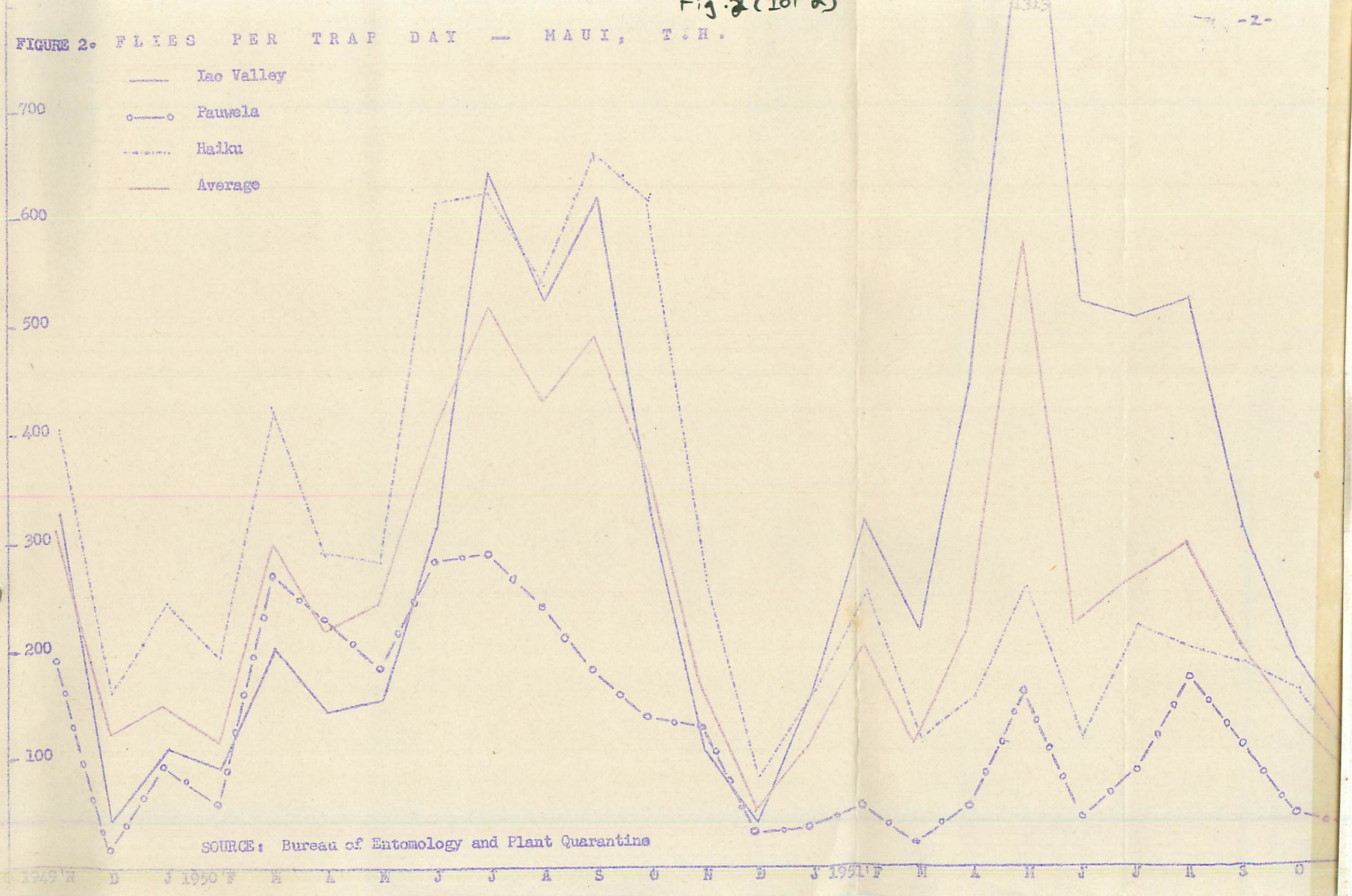


Fig. 2 (1 of 2)

FIGURE 2. FLIES PER TRAP DAY — MAUI, T.H.



SOURCE: Bureau of Entomology and Plant Quarantine

Fig. 2 (2 of 2)

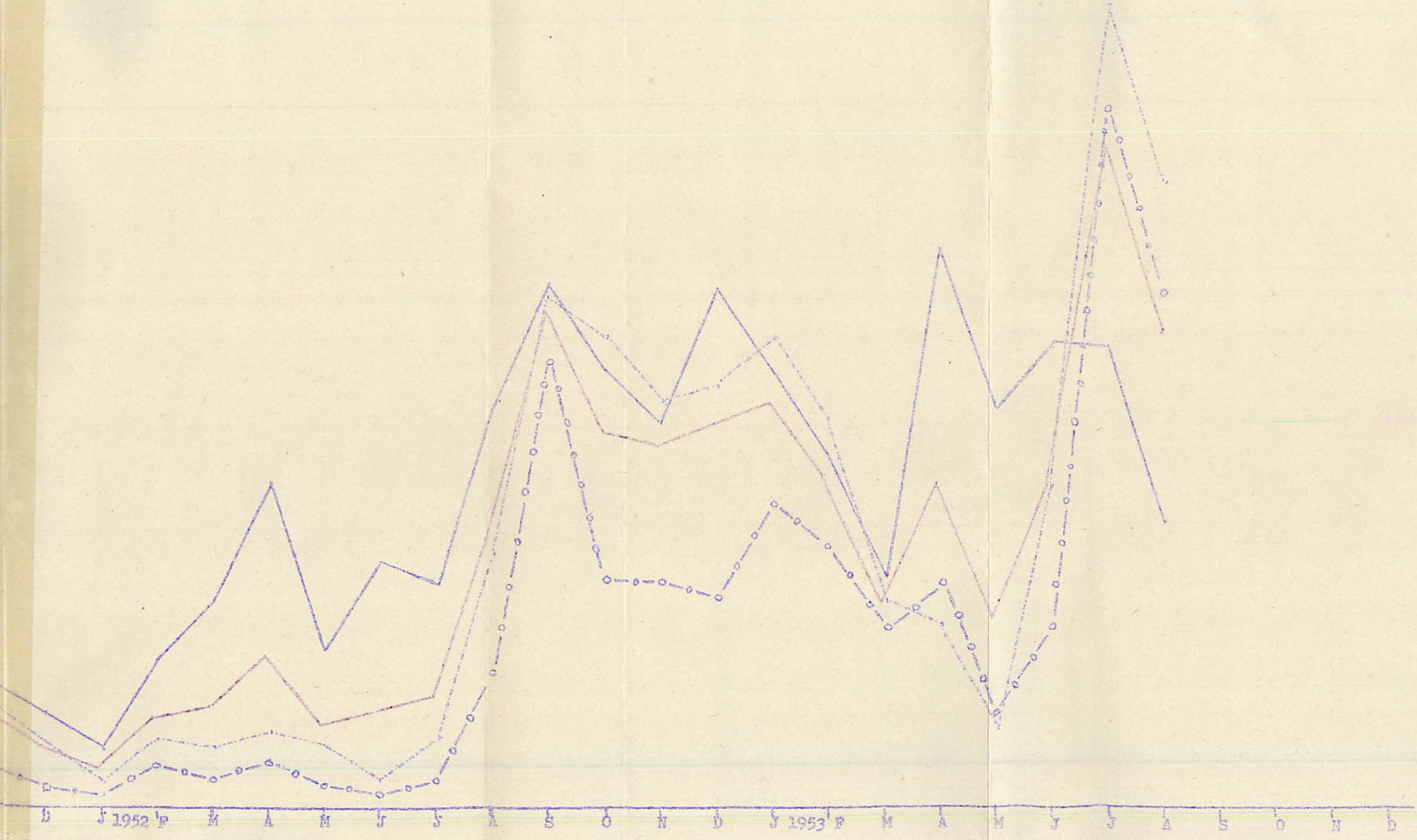


FIGURE 3. FLIES PER TRAP DAY — HAWAII, T. H.

Fig 3 (1 of 2)

——— Hilo (Costa's) 75'

..... Hilo (Sunada's) 100'

o——o Kupaahu 100'

——— Average

SOURCE: Bureau of Entomology and Plant Quarantine

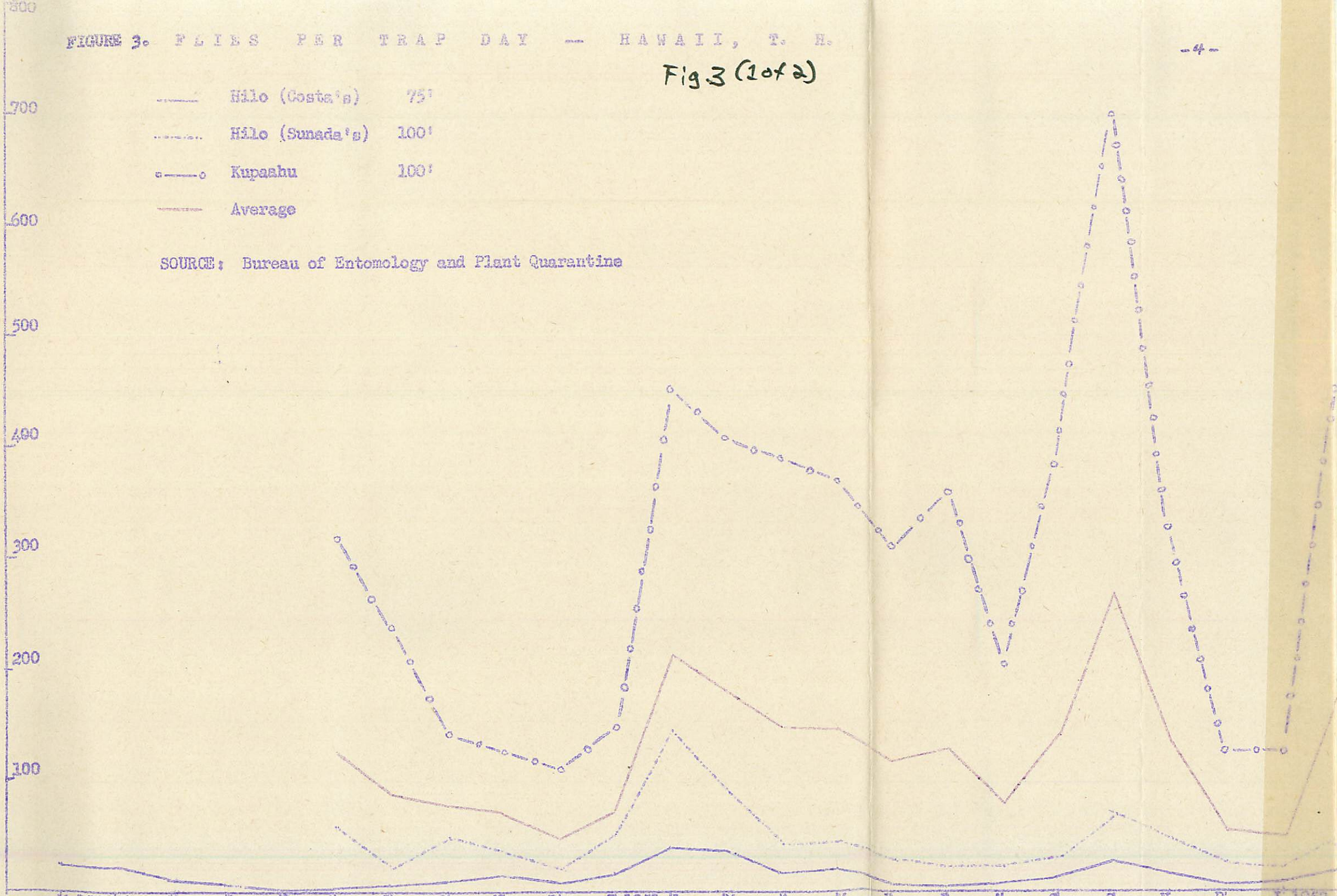


Fig. 3 (2 of 2)

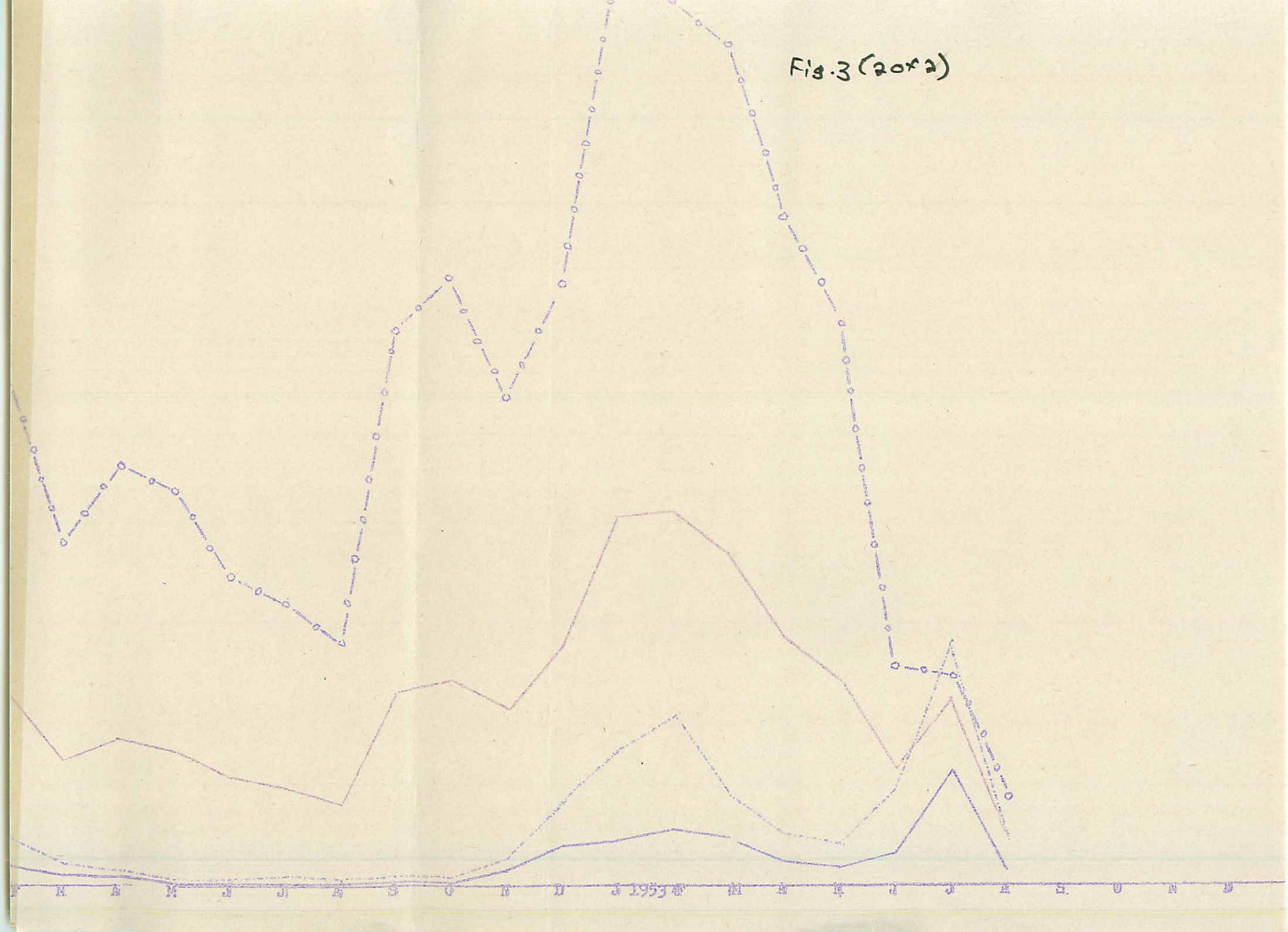
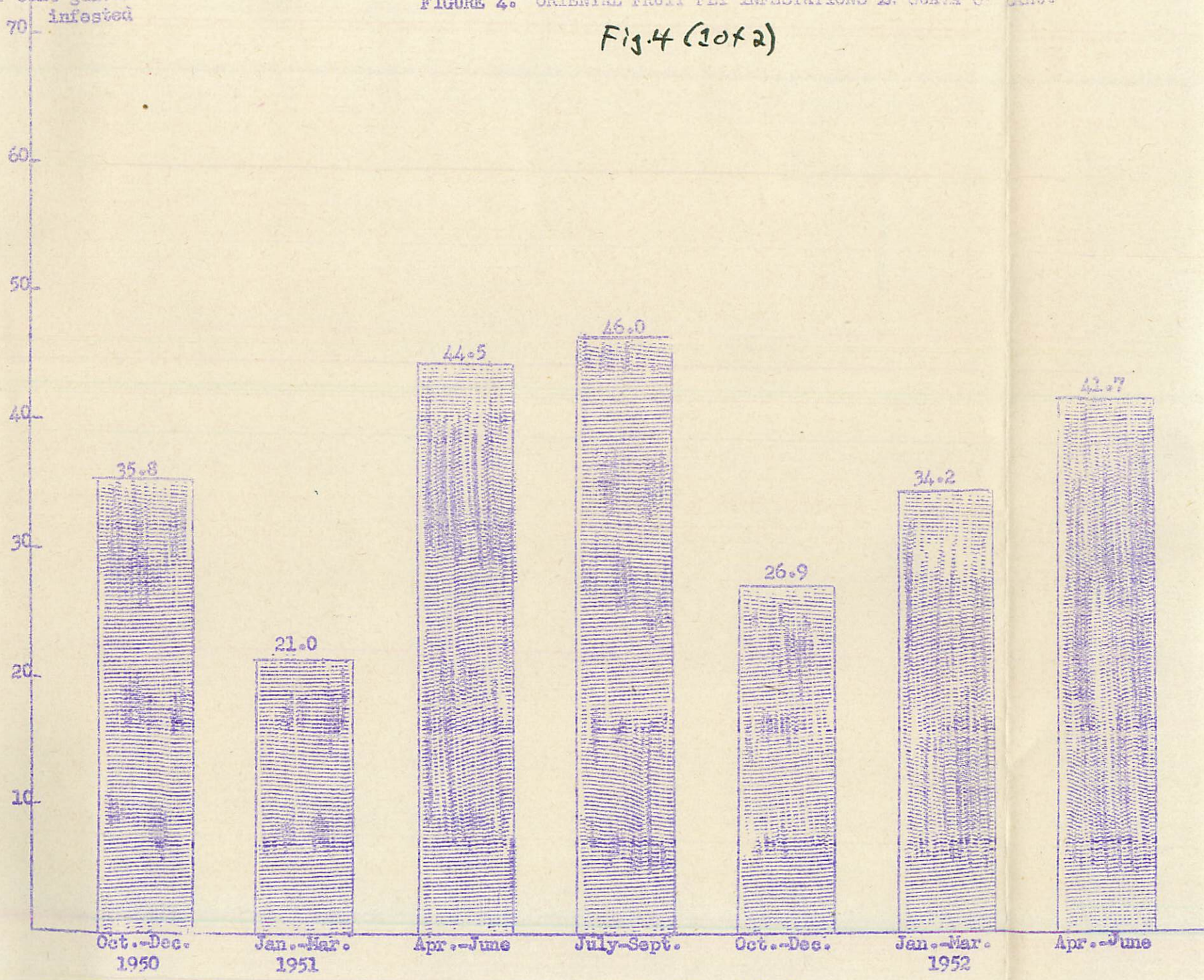


FIGURE 4. ORIENTAL FRUIT FLY INFESTATIONS IN GUAVA ON OAHU.

Fig. 4 (1 of 2)



SOURCE: Hawaii Agricultural Experiment Station

Fig. 4 (2 of 2)

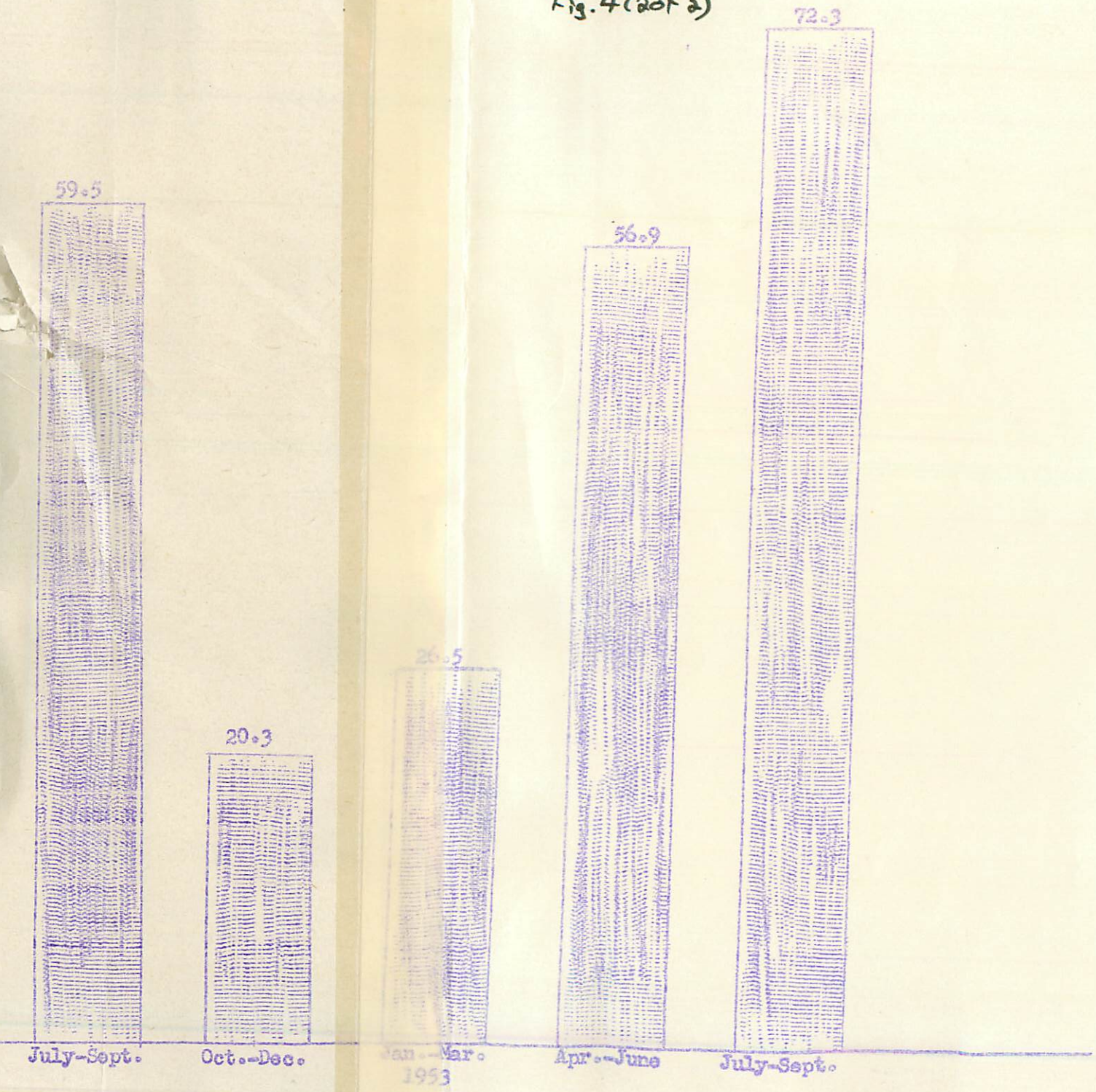
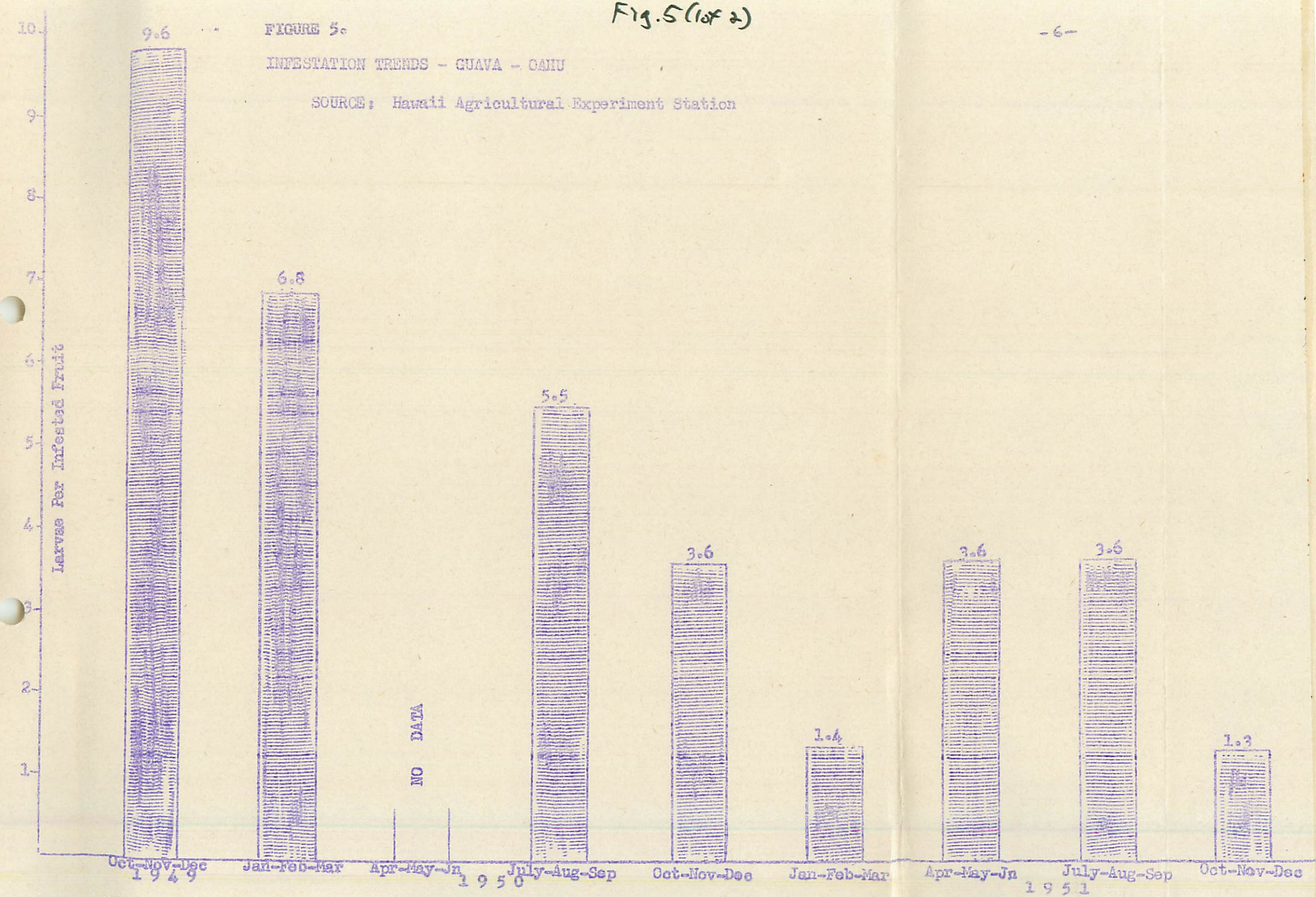

59.5
20.3
26.5
56.9
72.3
July-Sept.
Oct.-Dec.
Jan.-Mar.
1953
Apr.-June
July-Sept.

Fig. 5 (1 of 2)

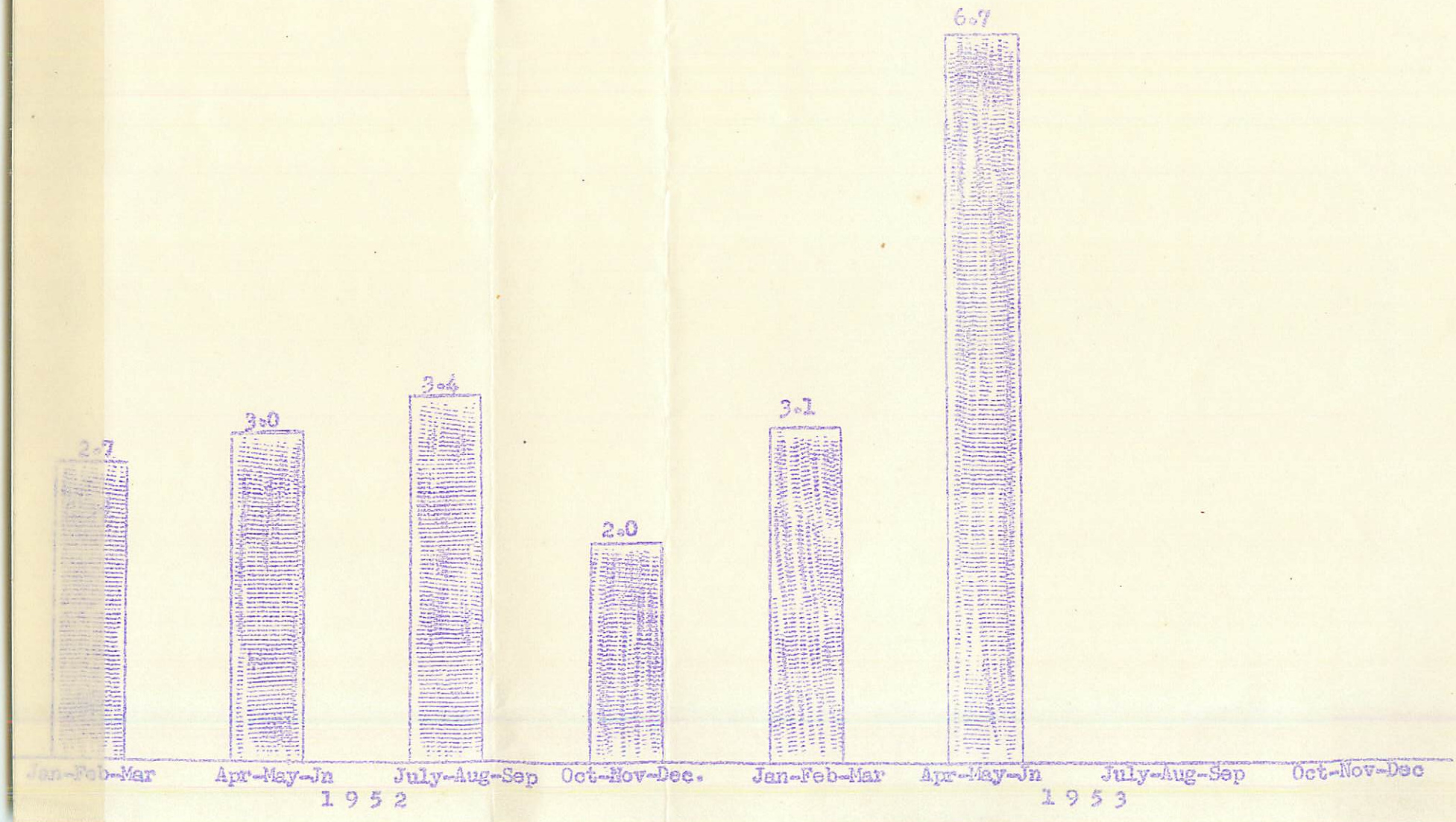
FIGURE 5.

INFESTATION TRENDS - GUAVA - OAHU

SOURCE: Hawaii Agricultural Experiment Station



F:1.5 (2 of 2)


2.7
3.0
3.4
2.0
3.1
6.7
Jan-Feb-Mar
Apr-May-Jn
July-Aug-Sep
Oct-Nov-Dec.
Jan-Feb-Mar
Apr-May-Jn
July-Aug-Sep
Oct-Nov-Dec
1952
1953

Dr. Roan, who was conducting the studies on the physiology of the fruit flies, was transferred to Beltsville in September of last year and as a consequence the mass culture of fruit flies was absorbed by the biology-ecology project. A series of 30-day methyl eugenol traps were established on Maui (10), Hawaii (15), and Kauai (4), and Mr. Stephen Au of the Territorial Board of Agriculture is very graciously servicing them for us. Fruit collections and population trends are still being conducted on both Maui and Hawaii and the biology, host determinations, mass rearing and bioclimatic cabinet studies are being conducted here in Honolulu.

Our present staff consists of 11 sub-professions, 2 are on Maui, 2 on Hawaii, and the rest are at the Dole Street laboratory.

The biology-ecology project is presently following six main avenues of investigation:

(1) Life history and habits of fruit flies in Hawaii.

(2) Hosts of fruit flies in Hawaii.

(3) Effect of climate and other factors on the development of fruit flies under field conditions.

(4) Biological studies of natural enemies of fruit flies.

(5) Rearing of fruit flies for experiments.

(6) Effect of temperature and humidity under controlled conditions in the laboratory.

The first project, dealing with the life histories of the fruit flies, has been dealt with in detail in previous reports. However, for those of you who may not be familiar with some of the facts we have uncovered, perhaps I should give you a brief "Kinsey" report on the oriental fruit fly. In the first place it takes from 6 to 10 days for the oriental fruit fly to become sexually mature. Copulation takes place at twilight and usually continues from periods of a few minutes up to 12 hours. The female, after a single copulation, is fertile for the remainder of her life span. The female is capable of depositing over 100 eggs per day and between 2,000 to 3,000 eggs during her lifetime. We have found that the actual potential of one female is somewhere in the region of 31 sextillion flies per year. The actual longevity of the fruit fly under laboratory conditions is between 30 and 35 days.

I think that this is enough of the biology of the fruit fly to bring you up to date. There are other things that we are still working on that we have not got sufficient data to report on. This will give you an overall picture of the biology of the fly and will tie in very well with what I want to speak about later.

The second project, "Hosts of the Fruit Flies in Hawaii," is very, very important. Since host fruits are responsible for supporting the fruit fly populations, and since the peaks of both fruit flies and fruits show an excellent correlation, a review of the infestation indices and parasitization in host fruits since 1949 up to the present time might prove interesting. I want to deal particularly with the thin-walled fruits and fleshy fruits. Figures 6 to 9 represent those fruits collected on the Island of Hawaii. The Maui infestations are so close and the correlation is so near that there was no point of making two bar graphs on the same fruits.

Figure 6 deals with false kamani. The index is based on the total puparia per 1000 grams of fruit. In 1949 we were getting about 85.4 per cent D. dorsalis. Longicaudatus at that time was about 14.2 per cent. The index for fruit infestation was 243. In 1950 the picture changes just a little--we have 56 per cent oriental fruit fly emergence, 7 per cent longicaudatus, but vandenboschi suddenly appears on the scene, and here we have 36 per cent vandenboschi. The index was 310. In 1951 there was a very little drop. We got 48 per cent oriental fruit fly emergence, 4 per cent of longicaudatus, and vandenboschi was down to 29 per cent, but here we had coming into the picture oophilus. Oophilus comprised 17 per cent. In 1952 the emergence of oriental fruit fly was 30 per cent, there was a trace of longicaudatus (.3%), vandenboschi had dropped to 12 per cent, but oophilus had jumped up to 59 per cent. Our index of infestation was 146. In 1953 (up to July) there was 16 per cent dorsalis emergence, .9 per cent vandenboschi, and 83 per cent oophilus, and the indices of infestation was 60.

Figure 7 shows the trend in rose apple. In 1950 it was giving us an emergence of 76 per cent oriental fruit fly, 6 per cent longicaudatus, 17 per cent vandenboschi, and the indices of infestation was 434. In 1951 there was 41% dorsalis, 8% longicaudatus, 24% vandenboschi, and oophilus had crept into the picture and amounted to 26 per cent. In 1952 the oriental fruit fly went up quite a little--62 per cent, longicaudatus 1 per cent, vandenboschi 5 per cent, and oophilus 32 per cent. Up to July 1953 we had 45 per cent dorsalis, .7 per cent longicaudatus, 2 per cent vandenboschi, and 52 per cent oophilus. The index of infestation was 262.

In figure 8 guava is given. In 1949 we had 99 per cent emergence of oriental fruit fly and .7 per cent of longicaudatus. Our index of infestation was 107. In 1950 we had 71 per cent dorsalis, 4 per cent longicaudatus, and 23 per cent vandenboschi, with an infestation index of 91. In 1951 the oriental fruit fly had dropped to 48 per cent, longicaudatus .7 per cent, vandenboschi 18 per cent, and oophilus 32 per cent. There was an infestation indices of 44. In 1952 we had almost the same emergence of dorsalis but longicaudatus had dropped by the wayside, vandenboschi had dropped to 5 per cent, but oophilus had gone up to 50 per cent. Here the index of infestation was up to 68. For the first six months of 1953 we had 43 per cent oriental fruit fly emergence, 3 per cent vandenboschi, and 54 per cent for oophilus with an infestation index of 65.

In figure 9 we see an entirely different picture in the fleshy fruit--mango. The oriental fruit fly infestation was 80 per cent, there was a trace of Medfly (4%), longicaudatus 8 per cent, vandenboschi 10.4 per cent, and the index of infestation was 70. In 1951 the oriental fruit fly emergence dropped to 64 per cent, there was still a trace of Medfly, longicaudatus was 6 per cent vandenboschi 15 per cent, and oophilus 16 per cent. The index of infestation was 61 per cent. In 1952 the oriental fruit fly bounced back up to 82 per cent, there was a trace of Medfly, almost 1 per cent of longicaudatus, 3 per cent vandenboschi, and 13 per cent oophilus with an index of infestation of 29. For the first six months of 1953 the oriental fruit fly had 73 per cent emergence, longicaudatus .9 per cent, vandenboschi 2 per cent, and 22 per cent for oophilus, and the index of infestation was 31.

FIGURE 6

CHANGES IN PARASITE - DORSALIS COMPLEX ON

HAWAII FROM SEPTEMBER, 1949 TO JULY, 1953

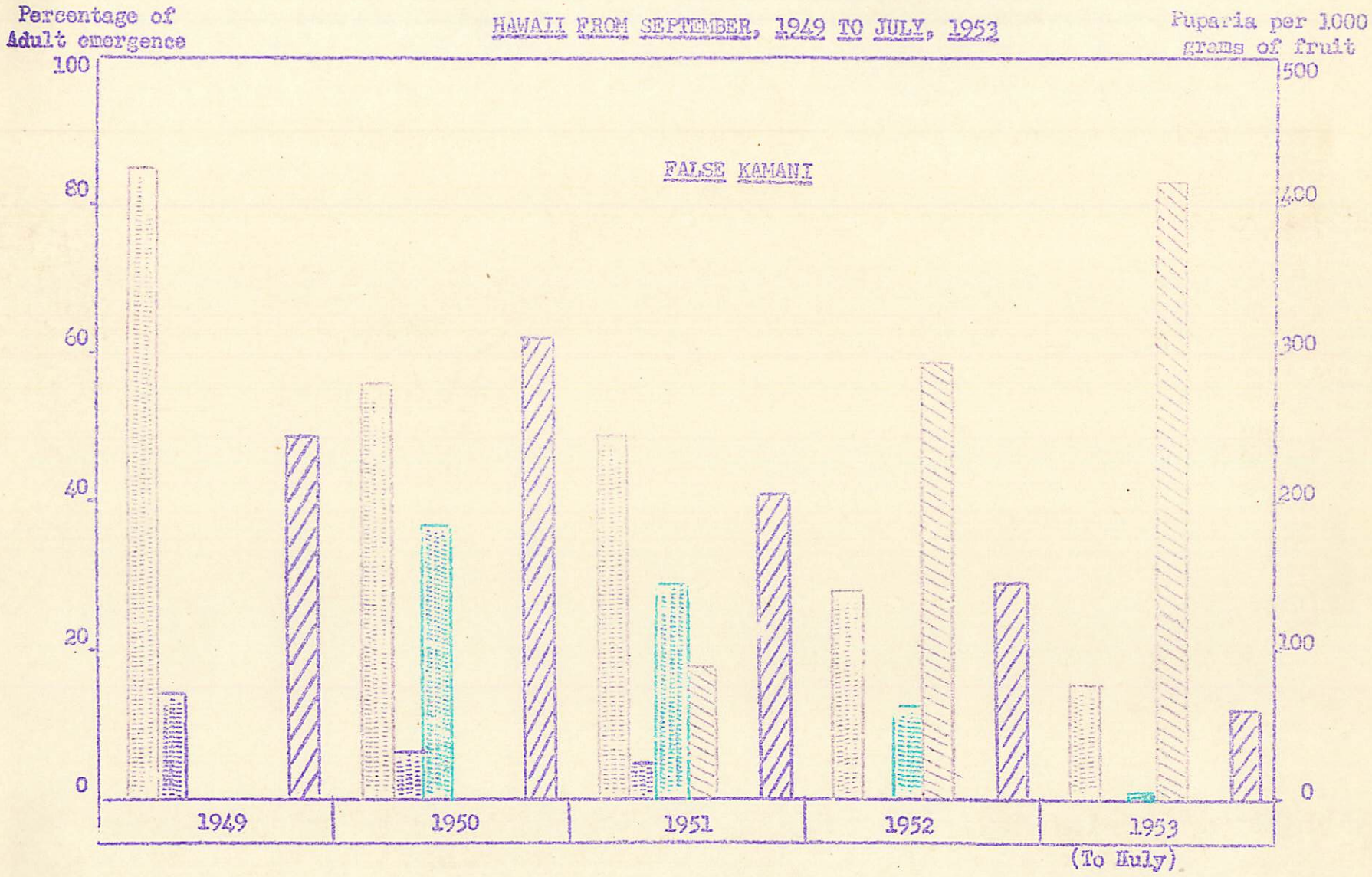


FIGURE 7.

CHANGES IN PARASITE - DORSALIS COMPLEX ON

HAWAII FROM APRIL, 1950 TO JULY, 1953

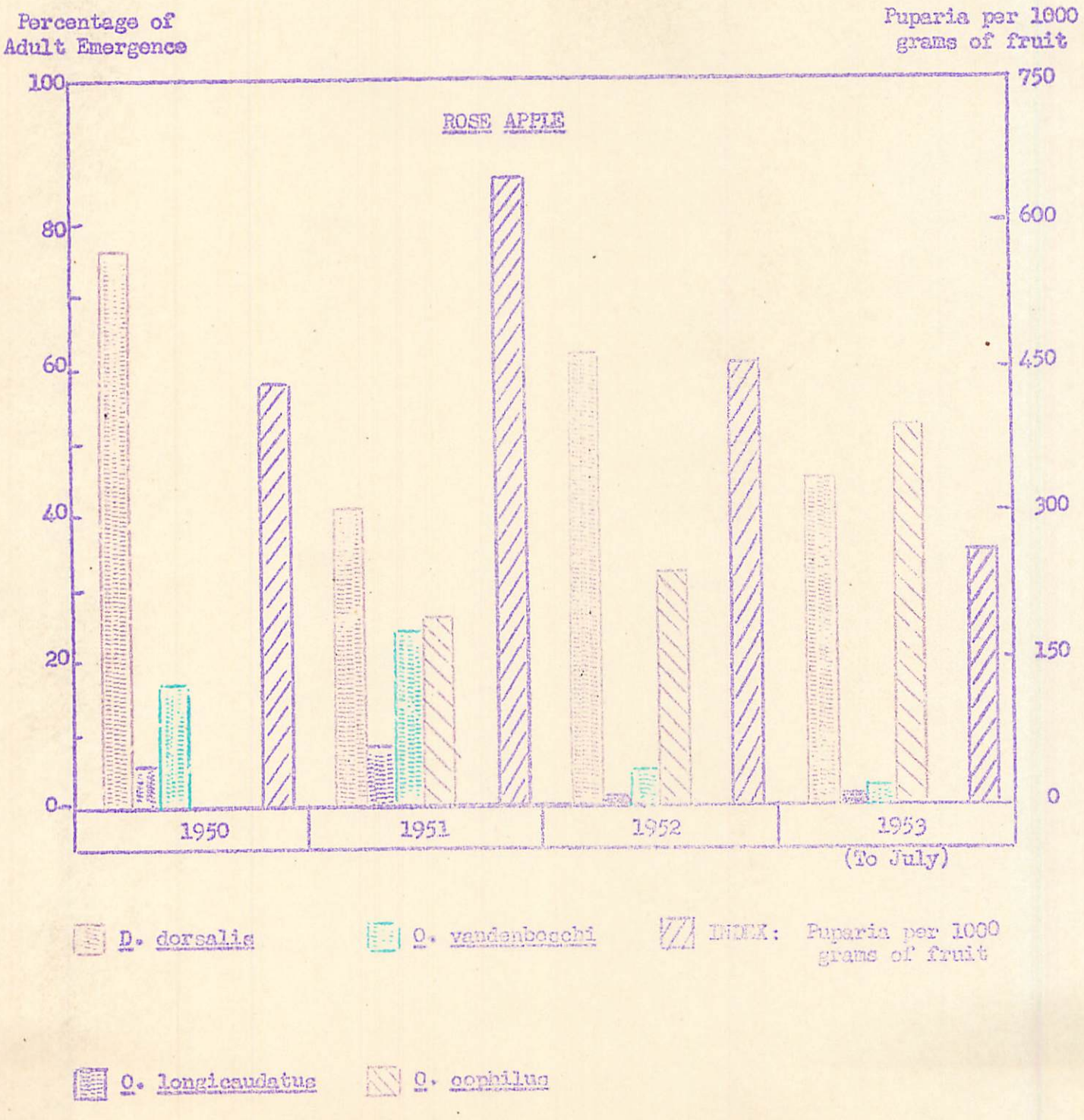


FIGURE 8.

CHANGES IN PARASITE-- DORSALIS COMPLEX ON

HAWAII FROM SEPTEMBER, 1949 TO JULY, 1953

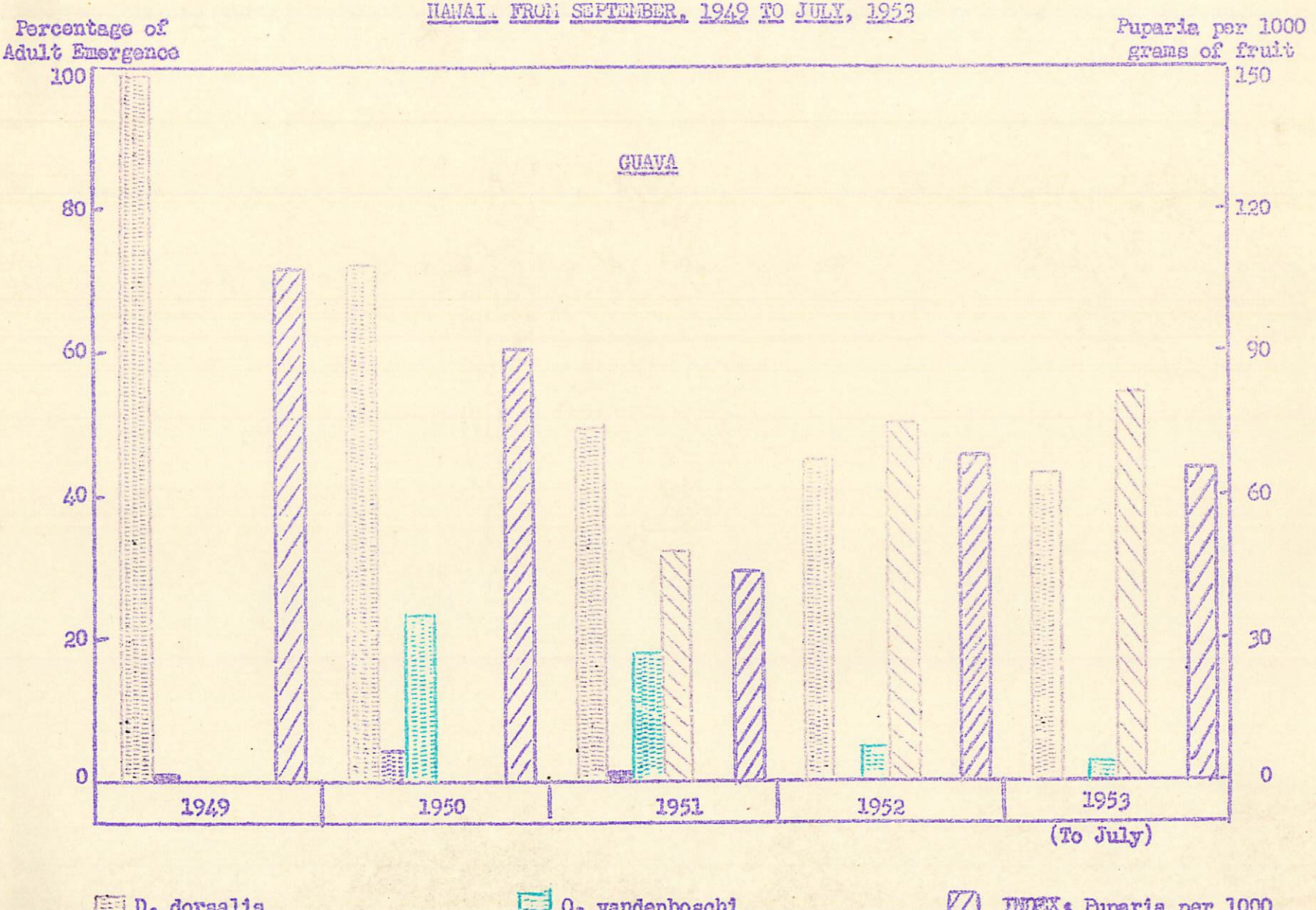
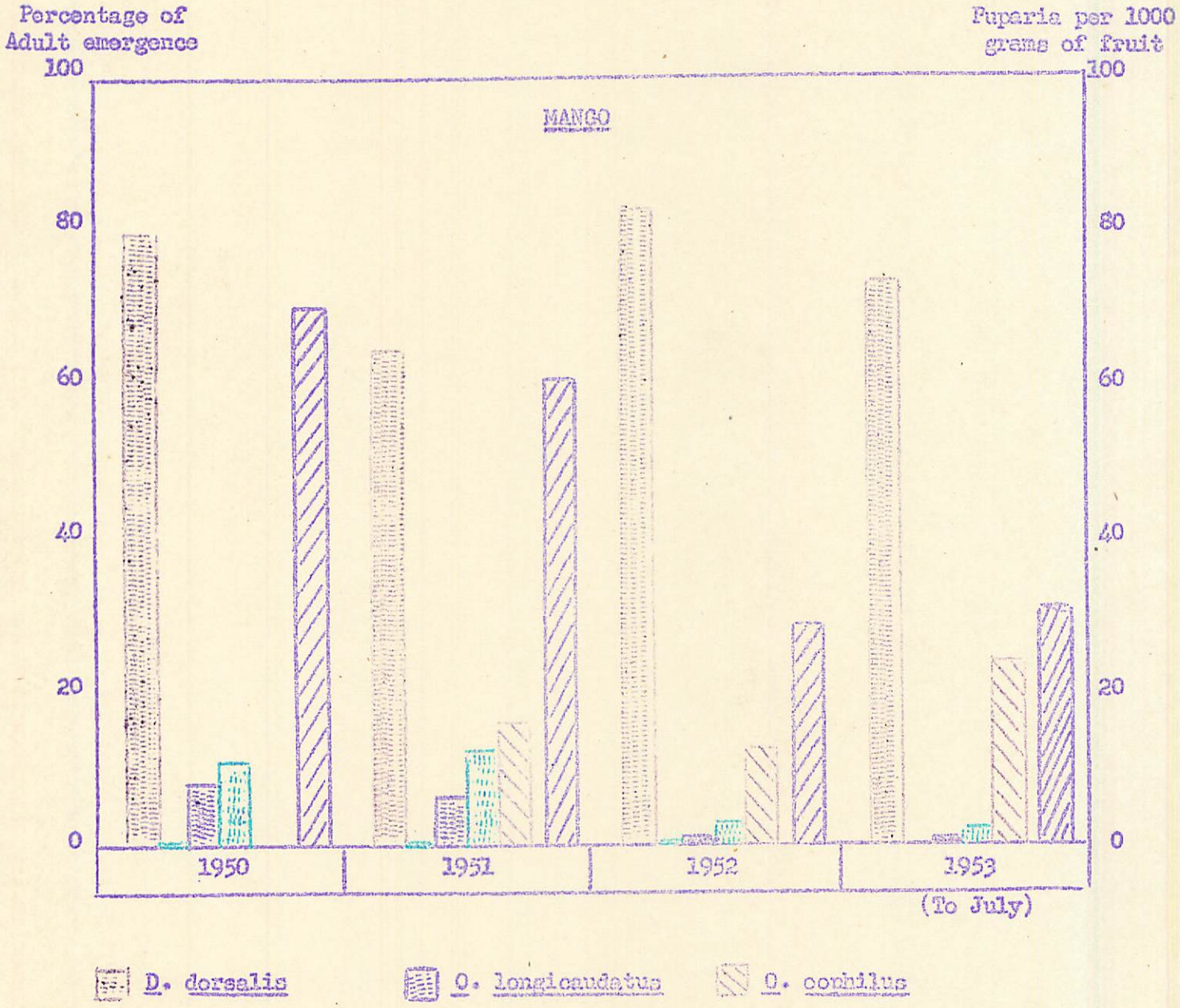


FIGURE 9

CHANGES IN PARASITE-- DORSALIS COMPLEX ON HAWAII FROM MARCH, 1950 TO JULY, 1953



The reason I have pointed out these different findings in the thin-walled fruits against the heavy, fleshy fruits is to show that on islands such as Maui and Hawaii where the mango is a dominant host it can be very important. It also shows that in some of our fruits such as rose apple we have a decided drop in the amounts of fruit flies recovered and a big build-up in parasites whereas in mango it is just the reverse.

(Editor's note: Because of its bearing on the foregoing discussion we are inserting here a tabulation of all records obtained on Maui thus far which shows the differences in parasitization records for the different hosts.)

Type of fruit	Number of fruits	Total puparia	Number puparia per fruit	Per Kg.	Per lb.	Number of parasites	Percentage parasitization	Total Emergence %
Rose apple	1,042	10,044	9.6	412.0	187.3	3,085	53.9	57.0
Guava	33,518	106,945	3.2	51.5	23.4	24,044	44.7	50.2
Mango	14,365	132,048	9.2	76.0	34.5	12,424	17.5	53.8
Kamani	15,205	74,729	4.9	210.7	91.2	23,143	53.8	58.3

Note: Data includes all infestation records obtained on Maui from December 1, 1949, to June 30, 1953.

The elevation at which our fruits are gathered is also very important both from the standpoint of the type of infestation and the amount of infestation. Of particular interest is the fact that on Maui at an elevation of 25 to 50 feet we collected cotton bolls found to be infested by the Medfly. While it is true that the infestation was not especially heavy (ranging from 9 to 45 per 1000 grams of bolls, it is significant that this is the first time that we have recovered a pure Medfly infestation at a low elevation.

Apple collections made at Waikii on Hawaii at an elevation of 4700' and consisting of 108 fruits yielded 1,546 pupae from which 1,482 Medflies emerged.

Mr. Christenson: Were those apples?

Mr. Flitters: Yes. In 1949, 71 apples collected from this same site, and possibly the same trees, produced only 1 Medfly. No parasites were recovered from either the cotton bolls or the apples.

Dr. Carter: What is the infestation in guava?

Mr. Flitters: On this island the average infestation is running up to about 72 per cent. It is now about 71 to 73 per cent on Maui and Hawaii.

Of interest is the fact that the records of fruit infestation compiled on Maui and Hawaii are now showing an increase in infestation this year over last year. It now appears very possible that the population level of the oriental fruit fly may be stabilized at a higher level than that indicated two years ago.

A comprehensive study was undertaken to determine the status of commercial pineapples of export grade as hosts of the oriental fruit fly. At times between collecting and shelling pineapples I didn't know whether I was a plantation worker or a ginsea machine.

More than 10 tons of smooth Cayenne pineapples were collected on Maui, Hawaii, and Oahu last year. Of this number, some were shelled in a manner comparable to that employed by the housewife and the rest were held whole. From this great tonnage of fruits not a single fruit fly puparia was recovered. Natural field infestation in these Cayenne pineapples was estimated to be about 45 eggs per ton on the basis of an examination made of approximately 3,000 fruits.

Representative groups of smooth Cayenne pineapples in five stages of development--1/8-, 1/4-, 1/2-, 3/4-, and full-ripe were selected at random and brought to the laboratory where 6 of each grade were exposed to oriental fruit flies in an induced oviposition test. Six individual fruits from each of the five grades were exposed individually to 25 gravid oriental fruit flies in standard rearing cages. After 6 days of exposure the fruits were removed and isolated in the conventional manner. Altogether 680 fruits representing a total of some 3,000 pounds were used in these tests. From this total only 9 puparia were recorded which in turn yielded 5 adult flies.

In order to arrive at some idea of the number of eggs deposited in individual fruits by the caged oriental fruit flies, pineapples were dissected eye by eye in the laboratory and the eggs or larvae carefully removed and counted. It was determined that fruits exposed to the flies for six days contained over 3,500 eggs and approximately 350 first-instar larvae.

The 680 smooth Cayenne fruits which produced the 5 adult flies in the induced oviposition study probably contained about 2-1/2 million eggs which, when applied to the estimated field infestation would indicate that several thousands of tons of field fruits would have to be held whole in order to yield a single fruit fly. It is exceedingly unlikely that fruit fly abundance in Hawaii or elsewhere will ever reach a level sufficiently great as to infest fruits in comparable numbers to those occurring in the induced oviposition studies.

In confirmation of reports by other workers that the smooth Cayenne pineapple is not a host of the Medfly, one hundred pineapples were individually caged with 25 gravid Medflies, with negative results.

Smooth Cayenne fruits were sleeve-caged with 25 gravid fruit flies in other field tests and fruits removed after 7, 14, 21, and 30 days' exposure in the field and then returned to the laboratory for isolation. In one isolated instance a fruit, exposed to the oriental fruit flies when it was 1/4 ripe and for 30 days thereafter and returned to the laboratory and held in isolation for 32 days more, was found to contain 4 abnormally undeveloped third-instar larvae. The larvae were discovered in the vascular tissue and among the procambial strands, illustrating the limited nutritional properties present in the fruit at that time.

Of these 4 larvae, 2 were able to migrate into the sand and form abnormally small pupae; the other two succumbed before they could pupate. No flies emerged from the pupae recovered. This further indicates that even though occasional larvae can survive under certain conditions in smooth Cayenne pineapples, their ultimate development into normal flies is very speculative.

Much speculation has been made as to why fruit fly larvae do not successfully develop in pineapple fruits. The most common reasons given for their failure were:

(1) Gummosis.
(2) Translucence
(3) Fermentation
(4) Thermal conductivity
(5) Bromelin

In the 1/8-ripe group of fruits the tissues of these fruits emitted a flow of gum after injury either from oviposition or larval activity. The sealing of the ovipuncture or larval gallery by the gum reduced aeration and it was found that direct contact of the larvae with the gum was deleterious.

In the 1/4 and 1/2 ripe stage most larval mortalities appeared correlated with excessive exudation of juice in the ovipuncture or larval gallery. It would appear that suffocation or drowning may be solely responsible for these mortalities.

(3/4- and full-ripe)

In the remaining grades, anaerobic fermentation was a primary factor appearing shortly after oviposition. It is quite possible that this yeasty fermentation depletes the oxygen supply below the tolerance of the fruit fly larvae, or during the gaseous exchange accompanying this fermenting process the build-up of CO_2 in the galleries might be very high. However, the studies have not been sufficiently comprehensive to rule out the possibility that the Cayenne pineapple may lack essential nutrients or the possible influence of other factors related to biochemistry and physiology of this host.

In order to determine whether bromelin, a proteolytic enzyme present in pineapples, had any deleterious effect on egg hatch or larval development of the fruit fly, a series of experiments were conducted with bromelin extracted and supplied by Dr. R. Heinicke of the Pineapple Research Institute.

Standard carrot medium used for the mass rearing of fruit flies was mixed with measured amounts of bromelin and was standard agar medium. The medium was seeded with fruit fly eggs and held in a constant temperature of 80° F. Egg hatch and larval development was equivalent to that of the checks, and in subsequent tests where bromelin and medium were used in proportions up to 1- to 1, the supported larval development at a normal level. Obviously then, bromelin does not inhibit the development of fruit fly larvae.

These pineapple tests proved conclusively that the smooth Cayenne pineapple does not represent a quarantine hazard, and, as a consequence, the fumigation requirement for fruits being shipped to the mainland was removed and pineapple fruits upon inspection are allowed to be transported without any form of treatment.

The removal of this treatment has been estimated to have saved the commercial shipper 1 cent per pound which in round figures may run as high as about $50,000 this year. To the Plant Quarantine Division it represents a savings of about 1500 man hours, or $3,000 per year based on the volume of last year's shipments.

Another avenue of pineapple investigation is presently being explored—that of determining varietal susceptibility to fruit fly infestation. Collections of species and varieties have been made possible through the courtesy of Dr. Collins, Senior Geneticist at the Pineapple Research Institute. The fruits are being exposed to caged oriental fruit flies to determine their susceptibility to successful infestation. The procedures are similar to those followed in the smooth Cayenne pineapple experiment.

Fruits exposed to the oriental fruit flies (25) are removed, half of them shelled, and the remainder held whole. Perhaps the best example of certain varietal susceptibility to infestation can be shown by outlining the results of an experiment involving 50 fruits. Successful infestation occurred in 23 whole fruits which yielded 1,322 pupae, and from 23 shells 1,776 pupae were recovered, making a total of 3,098 pupae recovered from 46 fruits which had an estimated infestation of 150,000 eggs.

These results may appear alarming in view of the previous study, but actually they are a valuable substantiation of the values, techniques, and conclusions made from the Cayenne study and further illustrate the possible risk of fruit fly infestation that could be a costly factor to commercial growers if hybrids with a high degree of susceptibility were inadvertently introduced without considering the possibility of their susceptibility to fruit fly attack.

However, I would like to emphasize that the fruits presently being investigated are not released for propagation.

A quarantine problem of some local importance stems from the desire of tourists to take back certain kinds of exotic fruits that are grown here in the islands. Under present regulations (Quarantine 13) this is prohibited. In order to relieve this source of irritation the true host status of these ornamentals is being determined. Sausage fruits, mahogany, Pandanus, and foxheads are among the many fruits under study.

Line Project 3. The effect of climate and other factors on the development of fruit flies under field conditions.

Much of the time spent in the field is devoted to fruit collecting and servicing the established trap lines. However, pupal studies have been conducted on both Maui and Hawaii. Two stations are located on the slopes of Haleakala at elevations of 7,030' and 5,500', respectively, while a third station is at the 3,750' level at Kula. On Hawaii, comparable stations are located along the Mauna Loa Truck Trail.

Newly formed pupae of the oriental fruit fly are taken to these stations weekly, placed in small wire screen cages and imbedded in the soil to a depth of from 1 to 1-1/2". In some instances pupae in sufficient numbers have been imbedded in the soil and a sample removed each week to determine how long the pupal period can be extended without affecting viability and emergence. It has been demonstrated that the pupal stage may readily be extended by cool soil temperatures and a small percentage may remain viable for as long as 90 days. No survival has been recorded beyond this period.

In previous studies conducted upon the life cycle of the fruit flies in cage studies at the higher elevations it has been demonstrated that the adult fruit flies can live for extended periods under cool temperatures and produce progeny when the temperatures again become favorable.

Line Project 4. Biological Studies of Natural Enemies of Fruit Flies.

A test series was undertaken in the bioclimatic cabinets to determine what effect the fluctuating temperatures and humidites of certain simulated mainland sites would have on the development of the introduced opiine parasites. Fruits that had been exposed to the oriental fruit flies and later to caged parasites of the longicaudatus complex type were placed in fine mesh cages and introduced into the various cabinets. It was determined at an average temperature of approximately 64° F. Opius formosanus, compensans, New Caledonia, and Siam were able to complete their development and emerge in a total elapsed time just in excess of 1 month.

Of particular interest is the fact that O. compensans and formosanus went through diapause emerging after two months.

Techniques for culturing large populations of parasites have been explored in the laboratory. The most successful method found thus far is that of exposing fruit fly-infested papayas to parasites held in fine screen rearing cages with a more or less standard number of not less than 25 female parasites in each cage. The fruits are exposed for a period of from 3 to 4 days, removed and isolated in the conventional manner. Regular weekly siftings of the sand beneath the fruit is practiced and the pupae recovered are held in jars until fruit fly emergence is through and the parasite emergence begun. The first two days of parasite emergence is predominantly male with emergence of the females occurring after the second day. These techniques and observations are but slight variations of those previously reported by the biological control group. Like other workers who attempted the massculture of O. cophilus, we discovered its reluctance to reproduce under laboratory conditions in a manner comparable to the longicaudatus types.

This parasite has presented a rearing problem due to its special requirements which appear to be indirect sunlight, a plentiful circulation of air to induce mating, and a smooth-skinned host fruit that is bathed in indirect light and raised above the level of the cage floor to encourage oviposition.

Since the dietary needs of the parasites can be sufficed with carbohydrates, solidified creamed honey served in souffle cups and bridged with random-sized excelsior proved to be most satisfactory and certainly much more efficient than the old method of making hair streaks of liquid honey on the glass front of the cage three or four times per day.

Parasites totalling over 33,000 and including the longicaudatus types and cophilus were shipped to the Pacific northwest for pilot testing and field release to determine whether they can become established as parasites of the cherry fruit fly.

Another shipment totalling 2,100 parasites and including all aforementioned groups with the exception of cophilus was recently dispatched to Bolivia in an effort to determine their effectiveness against Anastrepha, the Medfly and other fruit flies occurring there. We have also shipped about 150 female cophilus to

Mexico in order that they could test them out on Anastrepha there. To date no progress reports have been received as to any results.

Now we will go into the project dealing with the rearing of fruit flies for experiments.

This particular phase of our operations was inherited as a going concern from the California Division of Biological Control upon the completion of their assignment in Hawaii in June of 1951. Since that time, very little modification of the methods or larval medium has been made. The carrot medium has proved sufficiently productive, economical, easy to handle, and readily available at all times. The only change we have made is one of mechanization. A large food grinder is now employed to grind the carrots, but Waring blendors have to be used still to liquify the medium. We have determined that island-grown and second-grade mainland-grown carrots are not satisfactory for use as a substitute for mainland grade A carrots. Apparently the fruit flies demand the best.

We are attempting to maintain stock cultures at levels that will insure adequate production of the estimated normal needs of the various projects. Periodic checks are made of fertility, larval recovery, and weight, and a check of adult emergence in order that we can insure some uniformity of production in the various life stages of the insect.

The Medfly has presented a rearing problem that has not yet been solved. It requires much more careful attention in each of its stages and during the late fall and winter, in spite of the fact that pupae are recovered, the adult emergence is particularly low. Rearing techniques, changes of medium, and addition of ultra-violet and infrared lights, and the use of a constant temperature room have provided limited relief. The problem has only been alleviated by the inclusion of field-bred stocks of flies recovered from Maui. More detailed nutritional studies need to be conducted on this fruit fly.

The melon fly has long been known to suffer from conditions associated with heavy Nosema infections and depleted stocks have been supplanted with newly newly emerged flies reared from field-infested fruits. To date we have been fortunate in being able to recover such fruits when we needed them, and in a sufficient quantity.

Total fruit fly production from July, 1951, to last month amounted to over 23 million flies, of which 50 per cent of this total were oriental fruit flies. Mediterranean fruit flies and melon flies were produced in almost identical amounts.

Line Project 6. The Effect of Temperature and Humidity Under Controlled Conditions.

The effect of temperature and humidity under controlled conditions in the laboratory encompasses the bioclimatic cabinet studies. Since Dr. Messenger is going to present a comprehensive picture of our cooperative cabinet study, I shall very briefly touch on a few of the pertinent points that may serve as an introduction.

I think that everyone is aware that we have seven bioclimatic cabinets, 3 of which belong to the University of California Agricultural Experiment Station, and the remainder to the Bureau, with each of the two parties absorbing a proportional measure of the personnel and operating costs. Our bioclimatic cabinet studies have progressed to the point that we have sufficient information available to convince the most avid skeptic that the use of equipment to simulate climate is not only possible but its performance and operational efficiency opens up vast fields of climatological study that can be explored in this type of cabinet.

Since our bioclimatic cabinet studies began in 1950 we have encountered no major mechanical breakdown, have had very minor electrical failures, and limited operational difficulties. This may sound as if we have had nothing to do, but actually the control system does need almost constant supervision and adjustments, and corrections are very necessary from time to time.

From our experience and constant association with the mechanism and operation of these cabinets we were able to develop specifications for modifications and new improved features for 5 new cabinets the bureau is installing in its Brownesville, Texas laboratory. The inclusion of variable automatic heat transformers (which will give finer control), cooling and dehumidification in 4-step capacity control, and the inclusion of atomizing nozzles for humidity control in the air distribution plenum will provide the acme of temperature and humidity control with a minimum of adjustment and inconvenience to the operator.

Our studies have encompassed the simulation of humidity and temperature conditions representative of 19 agricultural sites, 9 in California, 3 in Florida, 2 in Texas, and 1 each for South Carolina, Louisiana, Indiana, Arizona, and Maui. The climate of the latter site, you may recall, was simulated to compare biological results obtained in the cabinets with those obtained at ecological stations in the field where the simulated conditions were recorded. Both the original and cabinet simulation records, both climatologically and biologically, were remarkably similar.

During the early experiments, it was possible for the cabinet personnel to get frost bitten in Vincennes (Indiana) one minute and receive a sunburn in Fresno (California) the next. Our present simulation series do not include any frigid eastern sites, but the torrid heat experienced in Tempe, Arizona, provided us with a balanced biological record. Fruit flies emerging in the morning were killed that same afternoon, and as one of our personnel expressed it, they were "cremated" immediately thereafter.

Of particular interest are the biological results obtained from the simulation site of Orlando, Florida, for that period of 1929 to 1930 during which time the Medfly occurred there. The winter bridging these two years was regarded by many as critical insofar as fruit flies were concerned and was credited by them for being responsible for the eradication of the Medfly.

The climatological conditions such as were experienced throughout the Orlando simulation year showed that the Medfly was more adaptable to these conditions and able to build up both population strength and multiplicity of generations far in excess of either the oriental or melon fly. However, the oriental fruit fly demonstrated its ability to produce much higher populations in its earlier generations, but both the Medfly and melon fly proved their capacities for reproducing under much lower temperature conditions than the oriental fruit fly.

All three species of fruit flies were able to maintain themselves in entirety throughout the year with the Medfly establishing 10 generations; the oriental fruit fly, 5; and the melon fly which was introduced later into the study produced 4 distinct generations. These findings serve to substantiate the success of the Mediterranean fruit fly eradication work as performed by Bureau personnel in 1929-30.

These and other data from the bioclimatic cabinet studies show rather definitely that self-sustaining infestations of the three fruit flies may survive winter conditions in those areas on the mainland where the average year has no more than a 2-1/2 month period with an average temperature below 58° F.

Dr. Newell: Norm, have you tried rearing the fruit fly larvae in planted pineapple medium?

Mr. Flitters: Yes, we have. We have taken the planted pineapple medium and we also have taken the juice of the pineapple and we have seeded the juice with eggs and the media with eggs, we have even taken slices of pineapples and placed our larvae on them. Dr. Stewart from P. R. I. told us that he felt that due to the fact that we have changed the physiology of the fruit by cutting through it we weren't getting a true picture of what normally occurs in the growing fruit.

Dr. Newell: You would then eliminate all of these factors illustrated here?

Mr. Flitters: Except that they represent physiological conditions occurring in the whole fruit instead of the cut. In the cut fruit you would cut through the cells and get a trans-exudation of juice, you would also get a depreciation of moisture in the fruit, and you would get an almost dry vascular tissue for larvae to tunnel in which would in turn create an artificial condition especially in some of those fruits where the translucence is so heavy. The anaerobic fermentation is pretty heavy in some of the more developed fruits.

Mr. Keiser: How many flies did you get to complete in 2 1/2 million eggs?

Mr. Flitters: In 2 1/2 million eggs we got 5.

Mr. Keiser: Did any mature?

Mr. Flitters: Two.

Mr. Keiser: In the resistant studies the data seem to be the other way around. If two flies survived DDT and with constant oviposition in the field you would have a build-up of population.

Mr. Flitters: You missed the point entirely. In the selection of pineapple for shipment to the mainland if there is any bruise or damage of any kind the fruit is immediately thrown out. You can readily see that when you puncture pineapple the exudation of juice is sufficient that you will either get a spongy fermentation arising or else you would get a dark, black mark at the eye of the fruit. I don't think there is any type of fruit grown on the island that you can compare with the strobiliform type of pineapple where you have so many sutures in which the fruit fly can oviposit and yet it doesn't take advantage of, this is largely because of the fact that the fruit is not attractive enough to them. I don't think there is a question of a doubt that even if you ever had a population density as we did at one time the actual chance of getting fruit fly survival out of fruit shipped to the mainland would be absolutely negligible.

Mr. Christenson: Under field conditions you might get a maximum of 45 eggs per ton of fruit.

Mr. Flitters: We also found it true that in all of the fruits examined in which we found an infestation there was an indication of infestation before we examined the fruit. So actually, Irving, you would be bending over backwards in order to prove a point by going out in the field and picking those fruits that have any abrasions.

Dr. Messenger: About the possibility of some flies being reared out and becoming resistant (so to speak), the flies that did emerge would breed back into the wild population and get lost.

Mr. Bolock: It may not be the ability of the larvae to develop but the difference may be in the insects.

Q. What is the history of the smooth Cayenne? Is it a hybrid?

A. Yes.

Q. Is it possible for it to throw mutants?

Dr. Carter: Yes, you have vegetative mutations.

Q. It is a thing to think about because most of the other varieties are susceptible.

Mr. Maehler: The hybrids were found uninfested in the field?

Mr. Flitters: Yes. There are none grown commercially in the fields at all. They are confined to experimental plots. We have discovered no field infestation in any of the hybrids.

Mr. Christenson: The Hilo variety, a form of smooth Cayenne, shows the same resistance to fruit fly development as does smooth Cayenne, isn't that right?

Mr. Flitters: Our exhaustive studies, which are still in progress, indicate that that is definitely so.

Mr. Christenson: Thank you very much, Norm. We will now hear from Dr. Messenger, who represents the University of California here in Honolulu. He will discuss the practical application of bioclimatic cabinet data to the fruit fly problem from a mainland standpoint.

Dr. Messenger: After that very interesting talk I think I am going to show a singular lack of imagination--I am just going to talk about the weather. The more we get into this study of climates, the more interesting it gets, however the more complicated it proves and one becomes frustrated. I wish it would give the flies as much trouble as it gives us.

The primary purpose of this cooperative ecological project is to evaluate here in Hawaii the ability of the fruit fly to reproduce, develop, and build up in

various mainland climates. The study has progressed to the extent that several broad generalizations as to findings can now be made. Tentative conclusions as to the potential hazard to the various mainland agricultural areas of this pest are also becoming apparent.

The results of the studies so far seem to follow quite a logical pattern insofar as climate suitability and geographic locality go. The results of the first year's tests pointed out those areas on the mainland that would appear to be the most liable to the establishment and build up of the fruit fly. The subsequent choices of weather sites to be studied were governed by these first findings, and the subsequent results confirmed the former.

The following broad generalizations are apparent in the data collected so far:

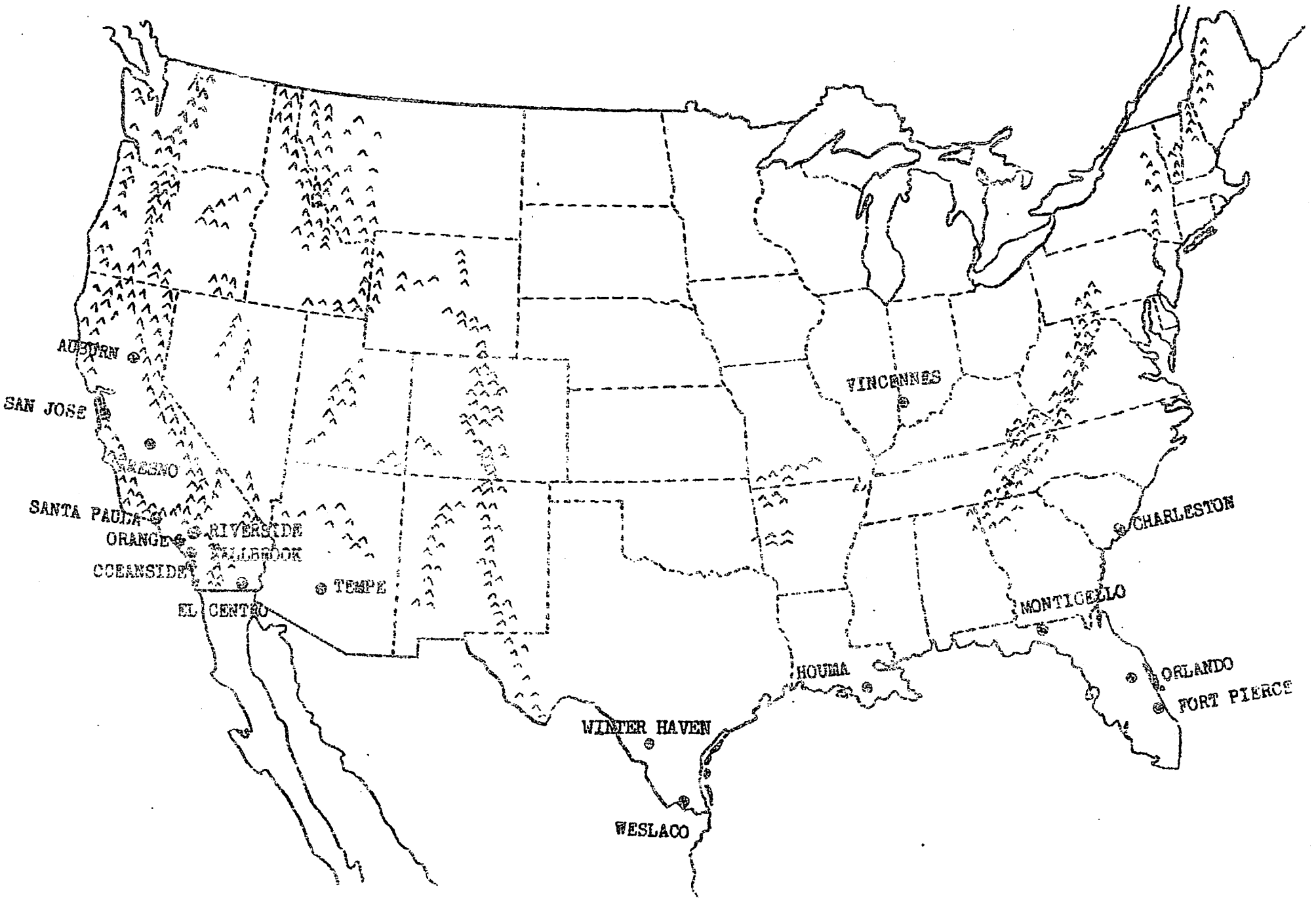
(1) In all the climates studied, from Indiana in the north to Florida in the south, there are periods of weather of at least five to six month's duration wherein the fruit flies are able to approach activity and rates of reproduction and development characteristic of Hawaii. These periods, quite naturally, fall in the summer season. This is an important finding from the standpoint of infestation spread, quarantine reactions after initial discovery, initiation of eradication measures, etc. Timing is an important factor here, whether or not a detectable infestation is discovered in the early summer or late fall. For example, should an incipient infestation be discovered in an agricultural area in the spring there would be no climatic barrier, in the majority of cases, to the build up and spread into contiguous areas until late the following fall. Suppression of spread under such circumstances would probably devolve upon quarantine activities. Initiation of eradication measures could not count upon aid from weather, in contrast to what could be the case should the infestation only reach detectable proportions in the late summer or fall.

Not all climates studied provide this result in the same degree. For instance the suitable period at Vincennes lasted only five months, while that at Charleston lasted eight months. Hence the degree of danger in the former case would not seem to appear as large as in the latter.

(2) There are several areas, primarily in the southwest, where the summer season is not entirely suitable for fruit fly reproduction and spread. This occurs when temperatures rise above 100° F. Actual development of the immature stages, egg through pupa, does not seem to be affected, but adult activity is definitely influenced. Oviposition under such conditions is suppressed. Adult longevity is materially reduced, and, in the cabinets, newly emerged adult flies are killed off before they are able to develop sexually. It is for this reason that the fruit fly is not able to build up more than an F-1 generation during the summer in such sites as Fresno, Riverside, Tempe, etc.

These findings must be accepted with reservations. In such areas where afternoon temperatures rise to the high nineties and above there may be escape nitches in the visinity of the weather stations which are not recorded by instruments. In such event there may not be such a marked suppression of the adult population.

Map #1. Sites of simulated climates studied in the bioclimatic cabinets from 1950 to 1953.



(3) Ability of the fruit flies to develop and reproduce during a part of the year in an area is not sufficient to determine the long range hazard at the site in question. The fruit fly must be able to maintain itself and carry over any and all climatic barriers that may be met during the entire year, in order to be of any outstanding importance. To date, all climates except those of central Florida, southern Louisiana, and southern Texas have presented winters too cold or too long for continuous reproduction and development. Only in the above three areas are the winter temperatures sufficiently high for year-around fly production. From these results it may be immediately inferred that these areas are the danger spots from the standpoint of fruit fly infestations. Work is now in progress directed towards the determination of the limits of these danger sites.

If a criterion of climate suitability be the infestation of fruits, and the development of immature stages, at least up to the pupal stage, then there are several other areas of potential danger aside from those mentioned above. This occurs along the southern California coast (Orange, Fallbrook), and in the Imperial Valley of southern California (primarily from the standpoint of the melon fly). This also appears to occur along the northern limits of the danger areas discussed above (at least in the case of Florida). In such regions, while completion of the life cycle is prevented, oviposition is not, nor is partial development of the immature stages. It is conceivable that mature adults may be able to live long enough under such conditions to be able to infest fruits and eventually produce offspring as much as three months later.

To account for the above findings there has been developed the concept of marginal zones. In these zones the fruit fly could not reproduce and develop continuously throughout the winter period, but the possibility of "overwintering" may carry an infestation over such a period. Such "overwintering" would probably occur in the pupal and the adult stages. The event would not be true overwintering, as occurs with typical univoltine fruit flies (cherry fruit fly) but actually extended development and extended longevity, as the case may be. Again, the importance of escape nitches must not be overlooked. Especially insofar as the pupal stage is concerned, it must be determined whether or not during the winter periods soil temperatures are much different from those of the weather shelter. In the cabinets the pupal environment is the same as for all the remaining stages. This follows since the cabinets duplicate only one set of temperature conditions at a time. Should it be found that the actual pupal environment in nature be somewhat higher than the temperatures in the shelters, then it is possible that these areas may have to be classed as dangerous.

(4) The lowest average temperature under which the fruit fly can successfully develop was found to be 57° F. At such an average temperature the developmental period takes from 75 to 80 days. A part of this period can be cooler than the remainder, but only so long as the overall temperature average is 57° F. or higher can the immature stages successfully develop. This general result can be illustrated by our original control studies of the Maui climates. At a station on Haleakala the monthly temperatures averaged 57°, 56°, 55°, and 56° F. Under such conditions development took place only up to the pupal stage. At Kula the average temperatures during the study were 61°, 62°, 63°, and 62° F. Adult progeny were produced here.

WINTER CHARACTERISTICS OF CLIMATES TESTED

	Monthly Average Temperatures				
	Nov	Dec	Jan	Feb	Mar
Suitable Winters:					
Fort Pierce	-	70	64	60	66
Orlando	-	61	64	64	61
Houma	58	59	69	62	62
Weslaco	65	58	61	65	71
Kula, Maui	61	62	63	62	-
Marginal Winters:					
Orange	57	52	57	55	56
Fallbrook	56	52	55	54	56
Haleakala, Maui	57	56	55	56	-
Sub-marginal Winters:					
Riverside	64	54	46	54	54
Charleston	55	50	42	47	56
Oceanside	62	51	49	51	55
El Centro	63	53	50	56	60
Fresno	60	45	44	52	53
Auburn	53	45	41	48	54
Vincennes	49	37	>40	>40	>50
San Jose	55	46	>40	>40	54

All of the mainland climates whose winters were suitable for fruit fly development gave monthly average temperatures of 58° F. or more. The marginal winters gave monthly average temperatures around 55° to 57°, and allowed partial development. Unsuitable winters gave three or more months of cold weather in which the monthly average temperatures were in the low fifties and the forties.

With these results, it remains to interpolate between weather stations, and to evaluate the areas of the mainland that we cannot be expected to study in detail. By taking recourse to weather information disseminated by the U. S. Weather Bureau all the areas in the continental United States having winter months whose average temperatures fall below 57° for only two months, or less. These areas would be classed as dangerous. A marginal zone can also be delimited, wherein there are between two and three months of average temperature below 57°. This zone is found to lie along the northern boundary of the dangerous areas, and also along the southern California coast and in the Imperial Valley--Gila Valley area. All other areas in the U. S. are too cold during the winter for continuous fruit fly infestations.

These areas presented in the map are for average conditions. Naturally, each year would see some departures from the norm, and in such instances these zones will change shape somewhat. In a year of marked cold weather during the winter months the zones will recede southward. In mild winters the zones will advance northward.

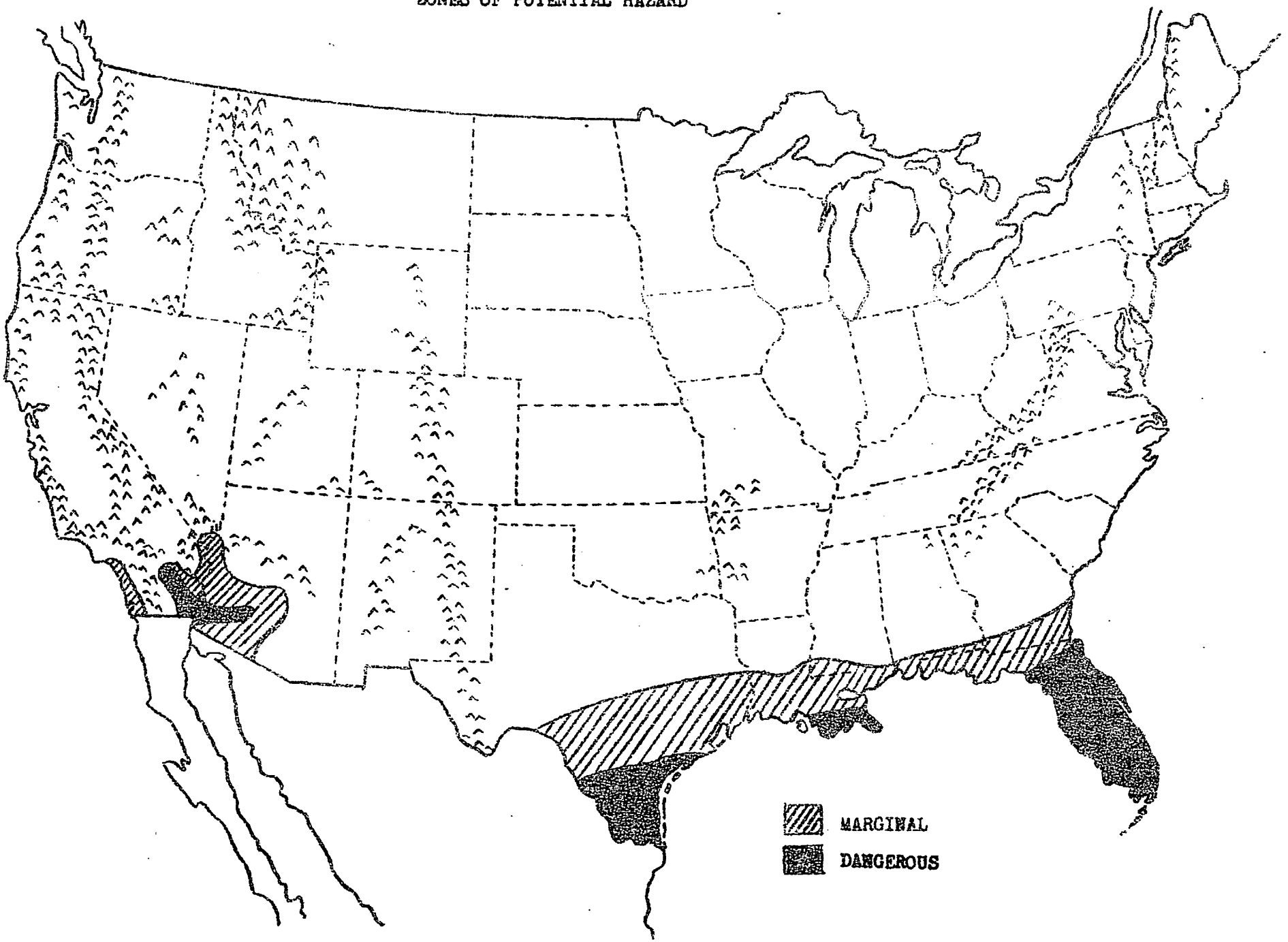
Agricultural areas in contact with the zones depicted in the map will be potentially susceptible to periodic invasions from a permanent infestation in the dangerous areas. These periodic infestations will be influenced by weather in much the same manner as in the case of Anastrepha ludens in Texas, but with the Hawaiian fruit flies, it would be presumed that fly movement northward would occur in the spring and summer seasons, and movement southwards, if any, in the fall and winter.

The above discussion has been based upon results with the oriental fruit fly. In much the same manner the potential hazards of the melon fly and the Mediterranean fruit fly can be evaluated. In brief, it has been found that these two species are slightly more tolerant of cold weather, and somewhat less tolerant to hot weather. Therefore the potential danger zones for these two species would take in slightly more area than in the case of the oriental fruit fly. However, hot summers would appear to offer even greater retarding effects. In the cabinets, it was found that in those climates where the oriental fruit fly could do well, these latter two species did not build up in the same ratios, but that they were able to maintain themselves with lesser numbers. Further, in the Imperial Valley area, while the oriental fruit fly was influenced considerably, melon fly was able to maintain a more or less intermittant ovipositing activity, with resultant infestations, at least to the pupal stage.

It should again be emphasized that these present conclusions are tentative ones only, and that final conclusions must await the outcome of additional simulation studies and a thorough study of a great mass of accumulated data.

In the entire discussion above no mention has been made of host fruits, host succession, wild hosts, etc. This does not mean that phenological factors will have no bearing upon this entire problem. On the contrary, such factors may even outweigh climatic factors. However, the original purpose of the project

ZONES OF POTENTIAL HAZARD



was to evaluate weather factors in the bioclimatic cabinets. It is to be expected, however, that a comprehensive consideration of phenology will also be included in the analysis of the project's results.

Mr. Christenson: Are there any questions?

I would like to mention that in an area like Southern California as far as summer temperatures are concerned you always have high, well vegetated mountains that might provide a good escape from hot dry conditions. There may be good hosts on the slopes of these mountains.

We will turn now to Dr. Bess of the Hawaii Agricultural Experiment Station for a report on the recent developments in the fruit fly research carried on by his Department. Dr. Bess.

Dr. Bess: I shall attempt to just hit some of the high points, refer to a few papers that have been published on the different phases during the past 18 or 20 months, say a word or two about them, and then will certainly be glad to have questions that can be directed toward the men that actually did the work.

We are doing some work on all three flies. However, you might say 90 per cent or more of the work is done on the melon fly and the oriental fruit fly. First, I would like to say just a word about the capitata work however. We have had some collections made monthly for many months now in Kona at three different elevations with the idea of trying to find the change in status as far as capitata and dorsalis are concerned at these elevations. All of you locally know that we presented a paper at the December meeting of the Hawaii Entomological Society on that and it was published in the March proceedings of the Hawaii Entomological Society. Actually what this showed was that at 2300' we had almost a pure population of capitata in coffee and at 700' we get almost 100% dorsalis in mid-summer. At other seasons we may run about 50-50 at the 700' foot elevation. At the mid-point (1200') we had variations between the two as you might expect. From these collections we also obtained information on parasitization. The complex of parasites seems to be about the same whether we have a pure population of capitata, whether we have a 50-50 population, or even when there is a preponderance of dorsalis. Admittedly, we can't tell, by examining the puparia in the field, whether the parasite actually develops in a dorsalis or a capitata, and some might be inclined to believe that at the higher elevations there is 100 per cent elimination of dorsalis. We don't think so and I believe that the work done by Dr. Clancy and others clearly showed that the parasite can develop in capitata.

One word about chemical control. We have done relatively little as far as chemical control work against capitata. However, a year ago we did some spray work on Maui with persimmons. In essence, what we did was to go in and spray 2 orchards where we did a complete job, treating all trees whether they contained fruits or not, so as to eliminate the fly population that was present. I think all will agree that the population of flies or rather the flies that attack persimmons do not breed in persimmons. They come from peaches, loquats, and other fruits. We also sprayed at that time half of an orchard of persimmons and obtained data on the infestation in the sprayed and unsprayed portions. In the orchard only one-half of which was sprayed we got about 80 to 85 per cent control (calculated in the way that you would normally calculate control). Injury was based on punctures rather than infestation because capitata does not develop readily in persimmons--it's only in the fully ripe persimmons that you will be able to rear the larvae through. These data were obtained from fruits that were picked at

the stage of maturity that they would be picked commercially. In the two orchards that we sprayed everything, including citrus or any other tree that was close by, control was much higher; we have no quantitative estimates of it, but the orchardists themselves say we got 100%. We went back a year later and made some checks in the same two orchards where they were following through on the same procedure that we had used the year before and both said they were getting 100% control. Actually we did some checking and we found that we did have a slight infestation but the crop was in the neighborhood of 98 per cent clean. With those results we figured we should discontinue the spray work. Our population of capitata is quite limited from the standpoint of economic crops. It is only in the Kula area that we would be able to do spraying of commercial orchards and there they are pretty scattered. We feel that good control is being obtained and that the reason we are getting good control is because the whole population is eliminated at the time of spraying and that the migration into those orchards during the short fruiting period is very limited.

Dr. Pemberton: What did you spray with?

Dr. Bess: DDT—2 lb. per 100 gal.

Mr. Flitters: What was the population prior to spraying?

Dr. Bess: I don't remember now but I would say that we were running probably 50% or more of the ripe persimmons (42 per cent of all persimmons, ripe, partially ripe, and green, on the trees at the time of spraying were stung). We did have quite an infestation, 65 per cent of the fruits picked from the sample unsprayed trees during the study were stung (see Quart. Rpt. for July, Aug., and Sept., 1951). They normally get more than 50% damage to loquats and persimmons, even when they applied sprays with backtype sprayers.

As far as the Dacus cucurbitae work, it is being done by Dr. Nishida. Dr. Nishida has spent several months at the University of California doing graduate work during the last 3 years but he did work on the ecology of the melon fly between Christmas 1951 and January 1953. For a complete year he was able to follow through on certain points that I will mention. Most of the work was ecological. We stopped the spray work to allow him to concentrate on the ecological work for his doctorate's dissertation. In order to give you a picture of the type of work brought out in this study one of the papers published recently was "The Influence of Opius oophilus on Dacus cucurbitae." This parasite, as you know, attacks and can develop successfully in both capitata and dorsalis, but in cucurbitae, even though they attack and kill them, they cannot develop in them. Dr. Nishida and Mr. Haramoto looked into this problem and from their results concluded that it would only be of importance in papaya where you get cucurbitae and dorsalis developing together. Those conditions where you get a very high infestation in papaya with cucurbitae are so rare that we feel that oophilus is of very little value as far as cucurbitae is concerned, but from a fundamental standpoint it was of interest. That paper was published in the May Journal of Economic Entomology.

Dr. Messenger: You said the stings caused mortality. Is that much of a factor in keeping a population in check?

Dr. Bess: Dr. Nishida and Mr. Haramoto are convinced that the eggs that are attacked are killed all right but it is rare that you would get a high population of cucurbitae in papaya. Dr. Nishida found that the opihilus adults do not go into tomato fields even though they are close by a papaya field. If you did have a high population of cucurbitae in papaya, many of them would be killed by opihilus.

Dr. Nishida in conjunction with his ecological work has gone a bit further in writing up one phase of it--that which had to do with the biological control inside and outside of cultivated fields. Over a period of 12 consecutive months he has obtained a considerable amount of detailed data on parasitization of cucurbitae by fletcheri in 2 areas--the Waianae and the Waimanalo areas. He found that parasitization was of no importance inside the field, and that it fluctuated with the season outside of the field. He is convinced that there is no further need for further releases of fletcheri in the islands because they just do not work very well in cultivated areas. That paper is just clearing for publication and we hope to have it published in the Annals of the Entomological Society of America.

Coming down to some of the aspects of his thesis that he is putting into shape for publication:

Seasonal abundance of cucurbitae; adult behavior from the standpoint of emergence, time of day, etc.; feeding (early in the morning); emergence (in the morning); mating (seems to be associated with late afternoon in a normal day, or if it's a cloudy day you may get mating all day); oviposition; and the movement of individuals, as well as populations. We are especially interested in population movement since this is important from the standpoint of how to get control. Those are the details on which we will have data published soon. If you have questions in regard to those points, would you direct them to Dr. Nishida at this time.

We have something else which you might call ecology-chemical control. In other words we are trying to utilize the ecological information so as to get chemical control. Recently in conjunction with this other work, Dr. Nishida conducted a study on the use of conventional spray equipment in border spraying. You may recall that a few years ago we did some work with the mist blower and were able to practically eliminate the fly population around tomato fields. So we simply directed our spraying to the outside rather than to the inside of the fields. Naturally from the standpoints of the farmers it would be nice to know whether you can get by with a conventional type of spray equipment for border spraying, rather than to have to use something that was the size of a large mist blower. He found that spraying with the conventional spray equipment was effective. He has recently submitted a manuscript on this study and it has already gone to the Journal. If you have questions in regard to the use of conventional equipment and how those data were worked out, please ask them now.

Dr. Messenger: Was it primarily corn?

Dr. Bess: No. Not necessarily. That is one of the things that will be brought out in this manuscript. He found that other plants are very important and in at least one spray experiment the spraying of the corn alone failed to give control. The problem is to kill the flies where they are. If you have a variety of plants there on which they congregate you have to spray all of such plants. If you had only corn present, spraying of the corn would probably do the job.

Mr. Steiner: What did you use on the border and how frequently did you spray? What concentrations?

Dr. Bess: That is quite a question. I would say that it is well known that most of the common materials will kill the flies, but so far we have not been able to determine how much of this killing is done by space action and how much by residual action, but we believe you have both types going on--you might say space-residual action, and we believe that space action is a very important aspect of it. In other words, it is a case of eliminating the fly population. We did a study 3 or 4 years ago where we actually did no spraying but we collected the flies out of the field at least once a week with nets. We did not have a high fly population but we went through the field very carefully every Monday, collected all of the gravid flies that we could find in the field, and there was very little infestation.

Mr. Flitters: How did you know that they were gravid before you collected them?

Dr. Bess: Excuse me, we collected all of the flies and found that they were gravid. The flies enter a tomato field to oviposit. Tomatoes are that type of a stimulus to gravid flies. Neither immature flies nor male flies are attracted to tomatoes, except an occasional one from time to time.

Mr. Christenson: Has Dr. Nishida found any evidence of periodicity in the oviposition habits of the melon fly?

Dr. Nishida: They oviposit most frequently between 4 to 6 p.m., or possibly just before dusk on some days.

Mr. Christenson: We are finding that the oriental fruit fly shows little tendency to oviposit early in the morning. During the latter part of the forenoon there may be some oviposition and this accelerates from about 3 o'clock until late evening when practically all flies found on the fruits are ovipositing.

Dr. Nishida: At Kula I noticed that the melon fly did not oviposit at all until 3 or 4 in the afternoon.

Dr. Bess: We found that in the fields we had only 10 or 15 per cent of the flies present at any time, so why not apply the sprays where they are?

Mr. Steiner: Why are some of those growers using TEPP for control?

Dr. Bess: I don't know. We certainly do not recommend it but I would say if they get control, and some tell me that they do, I think it's a pretty good indication that they are getting it because of its space action.

Mr. Steiner: It seems to me they are wasting a lot of material and expense and getting no control.

Dr. Bess: One of the most progressive farmers on this island and who gave quite a little impetus to the border spray work did use TEPP as a dust. He was dusting the borders and he thought that he got very good results with it. I think that the influence of Mr. Araki has been a great one and may be one reason why some farmers use TEPP today.

Mr. Steiner: Did Mr. Araki have adequate controls?

Dr. Bess: Yes, he did have. I had not seen any cantaloups grown until he started growing them. He said, "I'm getting such good control with border dusting that I have decided to grow something that is even more susceptible to melon fly."

Dr. Pemberton: Where did he grow them?

Dr. Bess: Out in that Lualualei area up near the radio towers.

Mr. Gow: How far back do you have to go in your border spraying?

Dr. Bess: I am sorry but we cannot answer that question. This is what we did in the Waianae area. We used a mist blower. How far the spray will go, as you know, depends upon the wind and maybe the concentration of material that you are using would affect the width of the border that would be sprayed. I would think that under normal conditions, when it was very quiet in the morning, we probably covered 200 feet effectively and maybe in some places 600 to 800 feet because flies are pretty easily killed and we were using a pretty heavy dosage of insecticide—a DDT formula. I don't really know how far the spray carried. We hope to get into this problem next spring. We are going to concentrate on the chemical control of the melon fly. We think that with the ecological information that is now available as a background, we may be able to design our spray programs so that we can get effective results. However, there are many things to learn about this fly. We don't know how far they migrate, and the influence of other fields on control. We can't break up a field and use only half of it very well. In our work with capitata we had the same problem—excellent control was obtained where we sprayed everything but where we sprayed only half of it we got a lot of infiltration from the unsprayed side.

On dorsalis—I have relatively little to say. (1) Taxonomy, handled by Dr. Hardy. He and Miss Adachi have recently completed a manuscript "Fruit flies of the Philippine Islands, Indonesia, Malaya" Part I. There is a lot more work in the making.

Mr. Christenson: I would like to ask Dr. Hardy if he has decided upon the relationship of ferrugineus and dorsalis?

Dr. Hardy: Long ago. They are the same. Entomologists in India insist on using ferrugineus. I pointed out long ago that this name was preoccupied.

Mr. Steiner: Do you know what their ferrugineus is?

Dr. Hardy: It is dorsalis. They speak of a pale form in India. For the most part these are teneral specimens of dorsalis.

Dr. Messenger: Dr. Koidzumi in Japan has been using two terms—Dacus ferrugineus, var. dorsalis, and D. ferrugineus, var. okinawaensis. Are these two different species?

Dr. Hardy: No, they are both dorsalis.

Dr. Messenger: Then if you run across publications referring to both of those we can assume they are the same?

Dr. Hardy: Yes, ignore them. There are 16 species close to dorsalis.

Mr. Gow: Can the pale form of dorsalis be regarded as a polymorphic ?

Dr. Hardy: Yes, definitely. About 10% of our dorsalis have white markings. However, there are not many from other parts of the world.

Mr. Gow: It might be useful to determine the advantage or disadvantage of these markings.

Dr. Hardy: When Dr. Mainland was here he planned to work out the genetics of it, but did not get to it.

Q. Is it a varietal difference?

Dr. Hardy: No, it is not.

Dr. Bess: This type and other work is certainly very interesting and I think it is a very basic part of the fruit fly work. If we didn't have the taxonomists I don't know what we would do. Dr. Hardy still has work to be done. Dr. Hardy, you mention "Part I" in the title of this paper. Do you have another part coming?

Dr. Hardy: Yes, I do. Part I will include only the sub-family dacinae.

Dr. Bess: By the way, this will be published in Pacific Science.

Frank Haramoto used as a problem for his thesis, "Biology of Opius oophilus." He included a lot more than just biology and the paper has been prepared for presentation at the Eighth Pacific Science Congress in Manila. Frank found out some very interesting things about this parasite. Along the point that Norm made about the circulation of air, I think that Frank must have a very keen nose to detect odors. He says that with the circulation of air, which eliminates the odor, you get mating. Without the circulation of air you don't get it. There are many interesting points that might be made about the species. This was the first egg-larval parasite found on fruit flies and it is the only one known today. Dr. van den Bosch and Mr. Haramoto also recently published a paper on the interaction of dorsalis parasites, which was published in the Proceedings.

The other major work is being done by Dr. Newell and Mr. Haramoto and this will be reported upon by Dr. Newell.

Dr. Newell: In evaluating any mortality factor affecting an insect population it is necessary to take up the problem as an integrated study of all the major mortality factors acting on the population. For that reason we have organized our parasite evaluation work along several lines, studying the effect of parasites, larval mortality in fruits on the ground, the influence of predators, etc.

As Chris and Norm have already pointed out there have been certain changes in the Dacus dorsalis picture in the last year. In fact, these changes appeared at the end of 1951 and in the first quarter of 1952, when increased infestations and lowered rates of parasitism were first observed.

This bar graph (1) shows the trap catches we have obtained since the last six months of 1950. The graph is based on catches in eleven 30-day methyl eugenol traps on Oahu. In the last six months of 1950 we had somewhere in excess of 1,000 cc. of flies per trap day; in 1951 this fell to about 240 cc. of flies per trap day during the first half of the year, and was approximately the same during the second half. During the first half of 1952 the trap catch reached an all time low of about 150 cc. flies per trap day and since that time it has been increasing. I would like to point out here that for the last half of 1953 the average trap catch is about 180 cc. of flies per trap day for the first two months, and it is believed that the average for the 6 months will be considerably higher than this.

Changes also have been apparent in the infestation guava on Oahu. Back in the first half of 1950 the average infestation was 12.2 larvae per fruit (Graph 2). In the last half of 1950 that fell to 4.3 larvae per fruit and it continued to drop until the last half of 1951 when over a six months' period the average infestation was only 2.5 larvae per fruit. Since that time the trend has been consistently upward and it is quite probable that for the next 6 months' period the infestation will be higher than at any time since 1950.

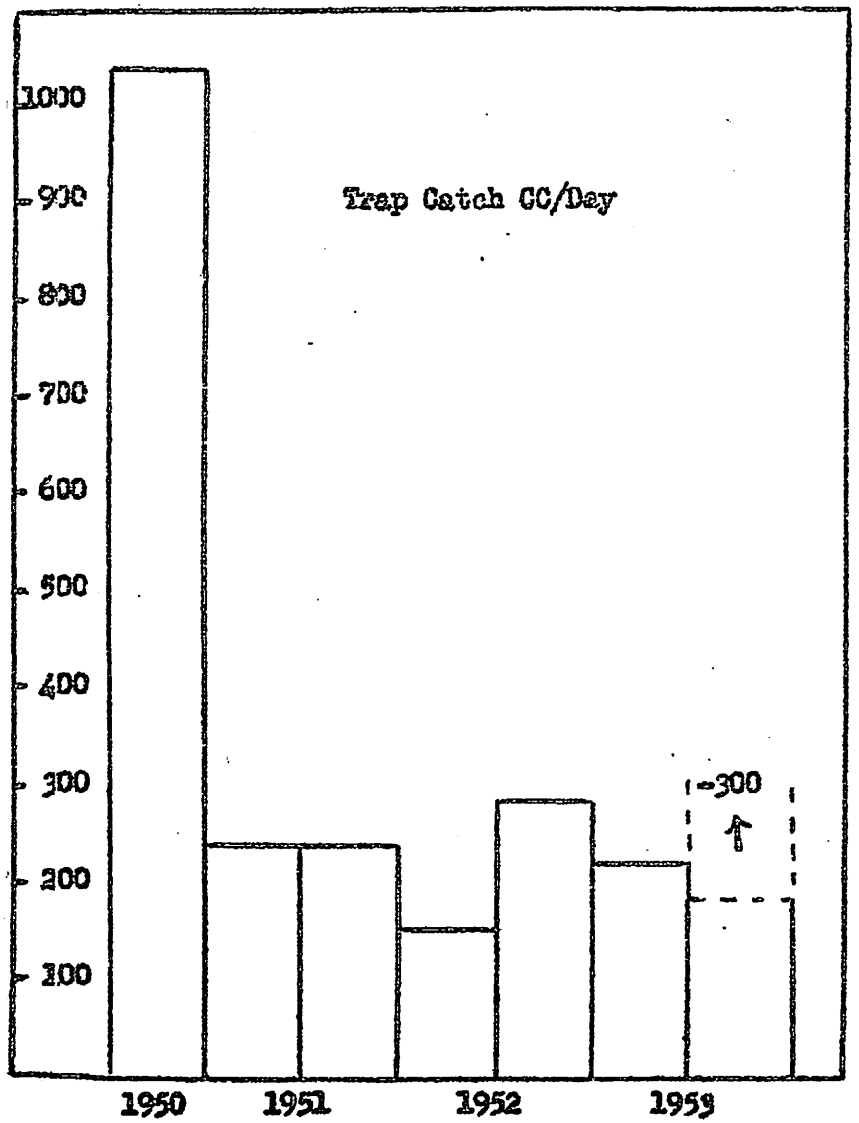
Between June and July of 1950 Opius oophilus became the dominant parasite of D. dorsalis here on Oahu. This point I have indicated on graph 3 was the high point in parasitism by O. oophilus (81.4% for the last six months of 1951) and since that time the parasitism has been dropping off (71.4% in the first six months of 1953). Back in the first half of 1950 only 52.6% of the larvae were parasitized and that is at a time when O. oophilus comprised only 13% of the total parasites. Between June and July of 1950 O. oophilus became the dominant parasite, at which time the parasitism rose to 76.4% of the reared larvae and continued upward until the last half of 1951 when 81.4% of the larvae were parasitized. Since then the parasitism has dropped off steadily except for an increase in the fall of 1952, which was a seasonal change and did not reflect a reversal of the trend.

Along toward the end of 1950 it became rather generally observed that a large proportion of the egg lesions of D. dorsalis were moldy. Whether this was a new development or one which had gone unobserved is not known. We tried to find out just what had happened to those eggs. A number of possibilities presented themselves or were raised by various investigators, including corking-off, natural infertility, etc., and of course, the fact that we had a highly efficient egg parasite at work naturally suggested that these might be responsible. To make a long story short, we found that corking-off did not occur when flies alone were allowed to oviposit in growing fruits, and that 95 to 100 per cent of all eggs laid in the field were fertile.

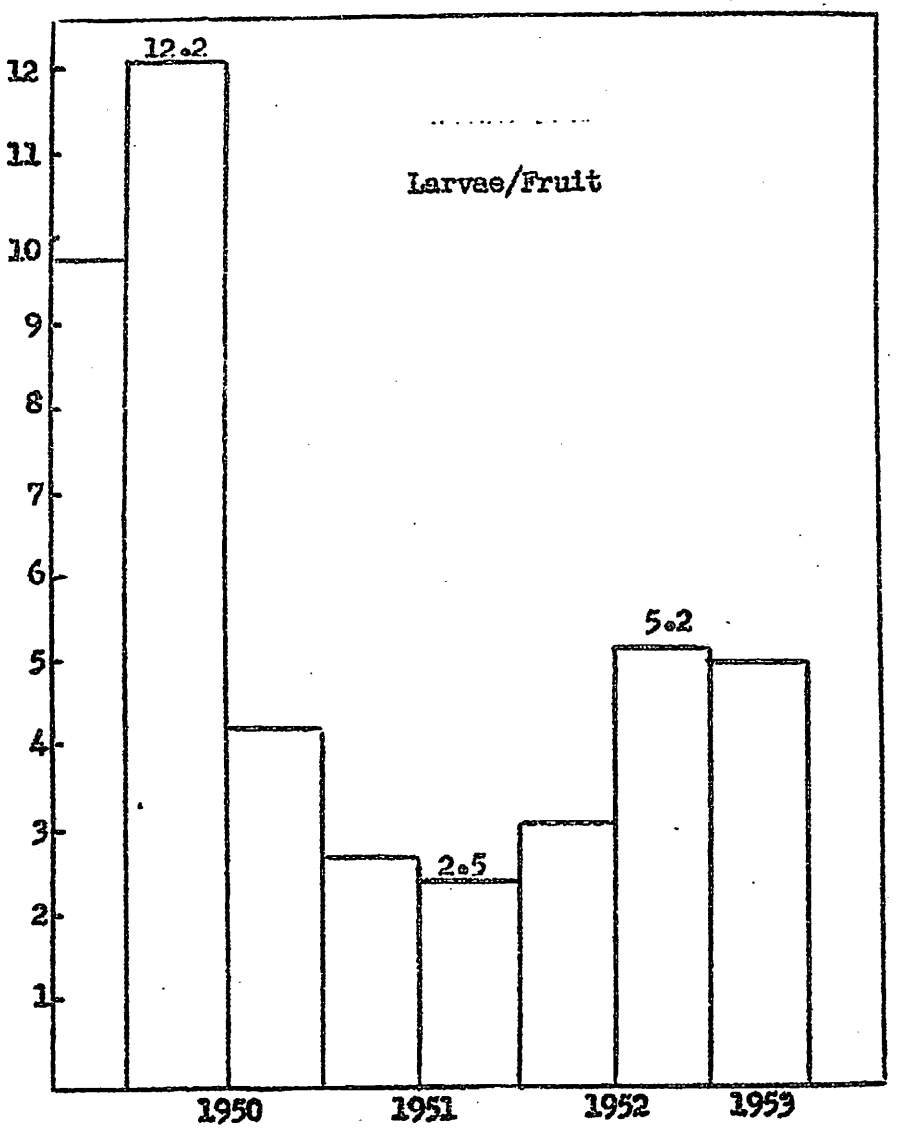
When field-caught flies (from areas in which natural egg mortality was high) were caged on growing fruits, all the eggs laid by them hatched, but when parasites were allowed to work on them, mortality was observed, sometimes reaching levels comparable with that in the surrounding area. These experiments showed conclusively that the egg mortality observed in the field was due directly or indirectly to parasite activity.

We took quite a large number of samples between late 1950 and 1952 and we found that the percentage of mortality of the eggs ranged anywhere from about 4% (very good laboratory survival) to 100%, and averaged 76% (graph 4). I should point out that this mortality is a little low because in many cases we were study-

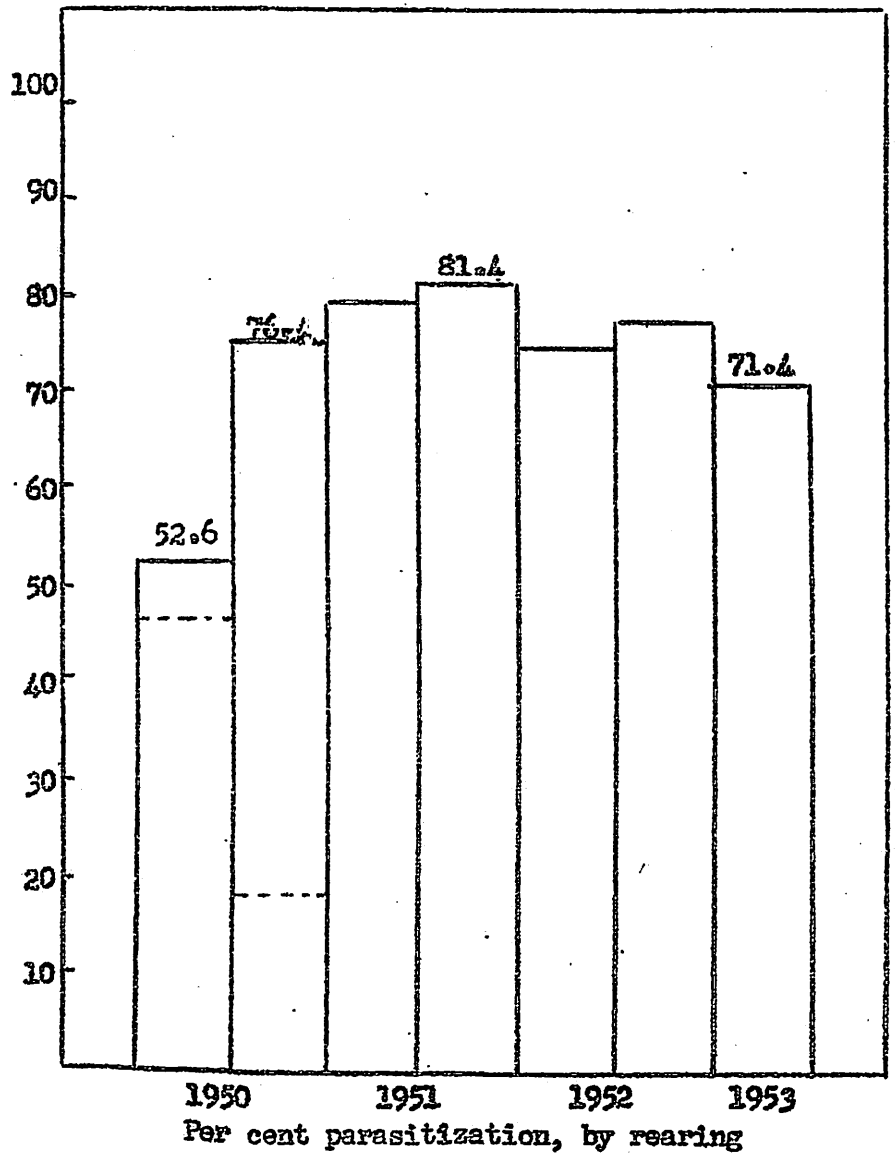
Graph 1.



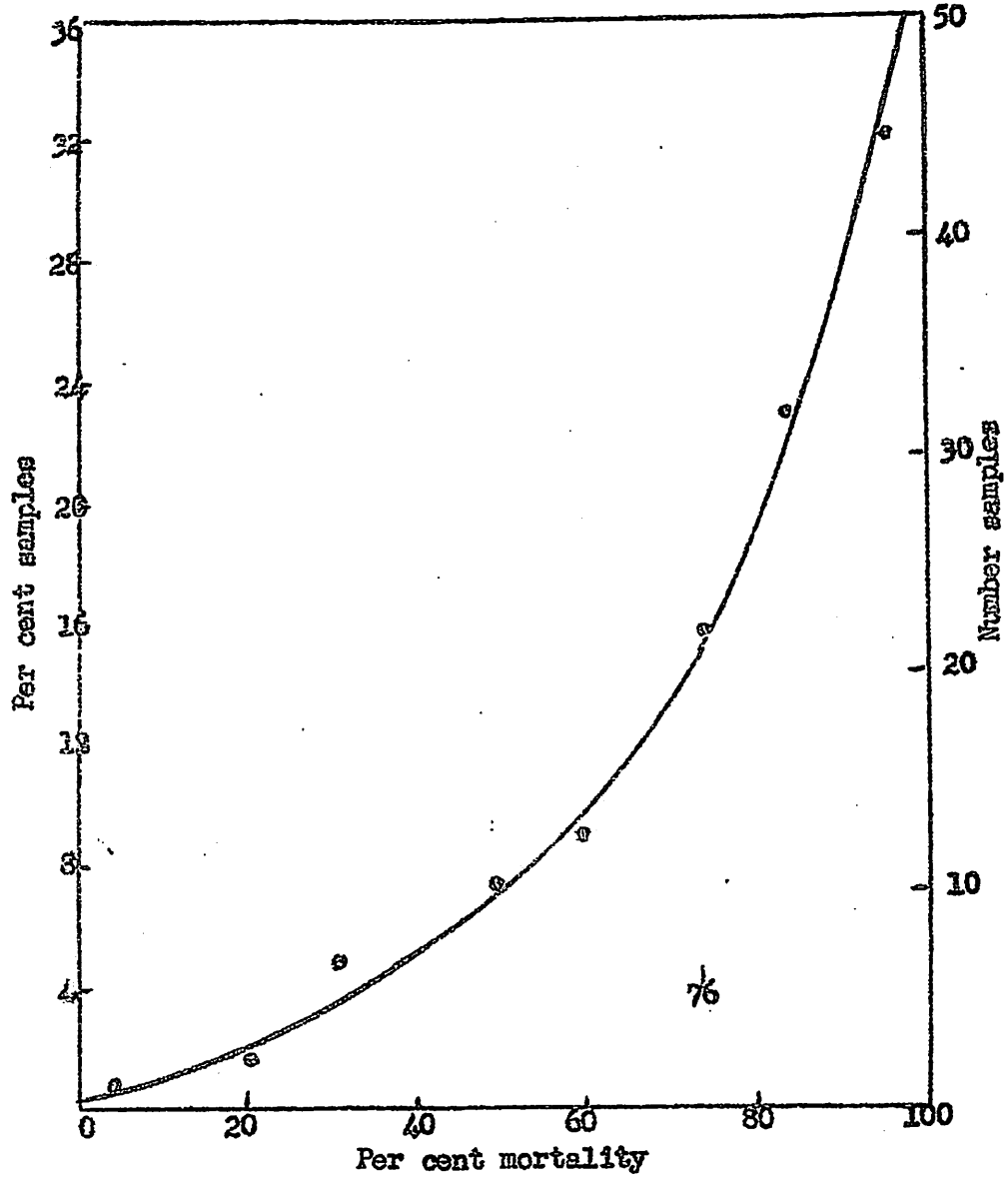
Graph 2.



Graph 3.



Graph 4.



ing selected, heavy infestations in order to determine the relationship between these heavy infestations and egg mortality. So the true figure would probably be closer to 80% mortality of the eggs in the field. In these dead eggs, fungi or bacteria could have been the primary cause of mortality or could have been simply secondary invaders which found the dead eggs a favorable medium in which to develop. Dr. Steinhaus and his group at the University of California have identified many of the organisms cultured from dead eggs, and all of them are forms which are normally saprophytic, and not pathogenic. However, even saprophytic forms may become pathogenic when introduced directly into the eggs by ovipositing parasites, and it seems quite certain that the majority of eggs which die do so as a result of inoculations of microorganisms by O. oophilus.

This graph (5) represents the summary of those samples. This bar represents 100% of all of the eggs that were in the samples: 76% did not hatch at all; of the remaining 24% which did hatch, 30% produced D. dorsalis and 70% O. oophilus, with the other parasites present only in incidental numbers. Represented in terms of percentage of total eggs, 76% were killed, 17% produced O. oophilus and 7% produced D. dorsalis. This 7% of course is prior to the action of other mortality factors.

Mr. Flitters: These were taken from guava fruits?

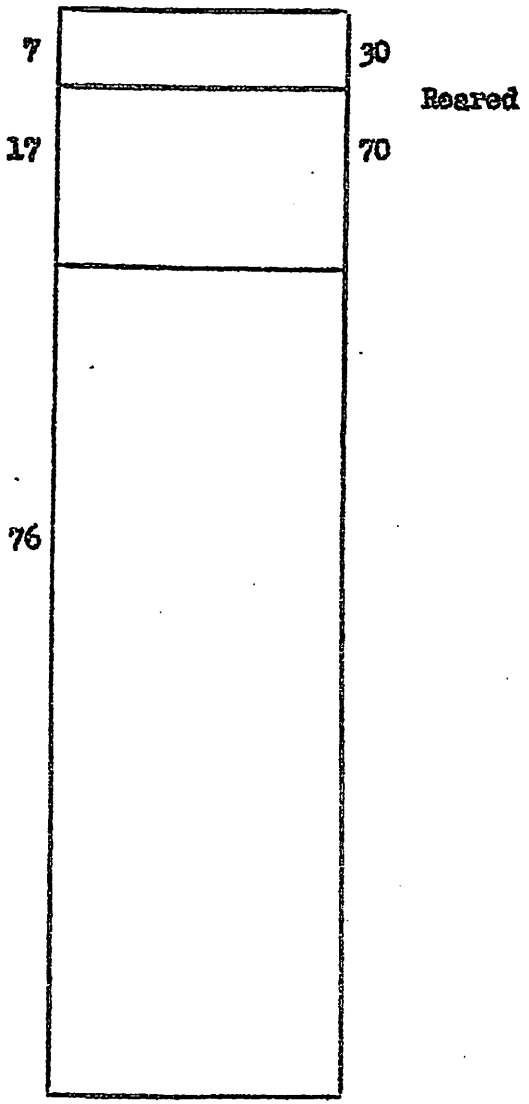
Dr. Newell: Yes, and only from the island of Oahu.

This next graph (6) represents the relationship between the true percentage parasitism and the hatch of the eggs. As the true percentage parasitism rises from 0 to 100%, the hatch of the eggs falls from roughly 100% to as low as 0%. It is very important when talking about percentage parasitism to consider whether you are talking about parasitism based on rearing (as we usually speak of per cent parasitism), or about per cent of parasitism of the original egg population, because, although a value of 76% parasitism was obtained on the basis of rearing, actually O. oophilus was parasitizing at this time 76 plus 17 or 93% of all of the eggs in the fruit.

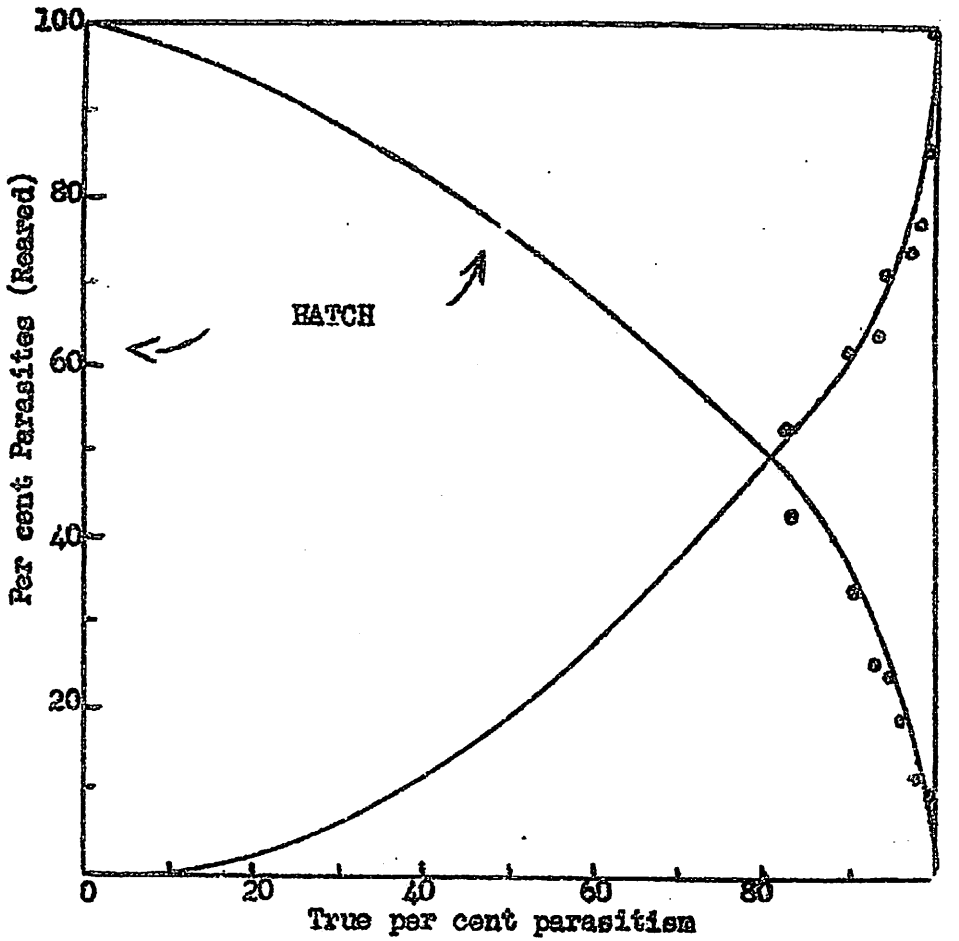
There is also a very consistent relationship between the true percentage parasitism and the percentage parasitism as determined by rearing. As the true percentage parasitism rises from 0 to 100%, the percentage parasitism by rearing also rises from 0 to 100%, but at a considerably different rate.

In this graph (7) I have attempted to show the relationship between the factors of true parasitism and percentage parasitism as determined by rearing. This is really a modified bar graph in which each column represents 100 eggs. If we take this bar here, for example, when the true parasitism is 91% the parasitism by rearing is only 63%. Only about 35% of the eggs hatch, and the rest represent egg mortality. If we compare this with the samples in which the true parasitism averaged 97%, we see that the parasitism as determined by rearing rises to 75%, and the hatch drops to 19%. Therefore, very slight changes in the true percentage parasitism result in more marked changes in percentage parasitism by rearing, and very great changes in hatch.

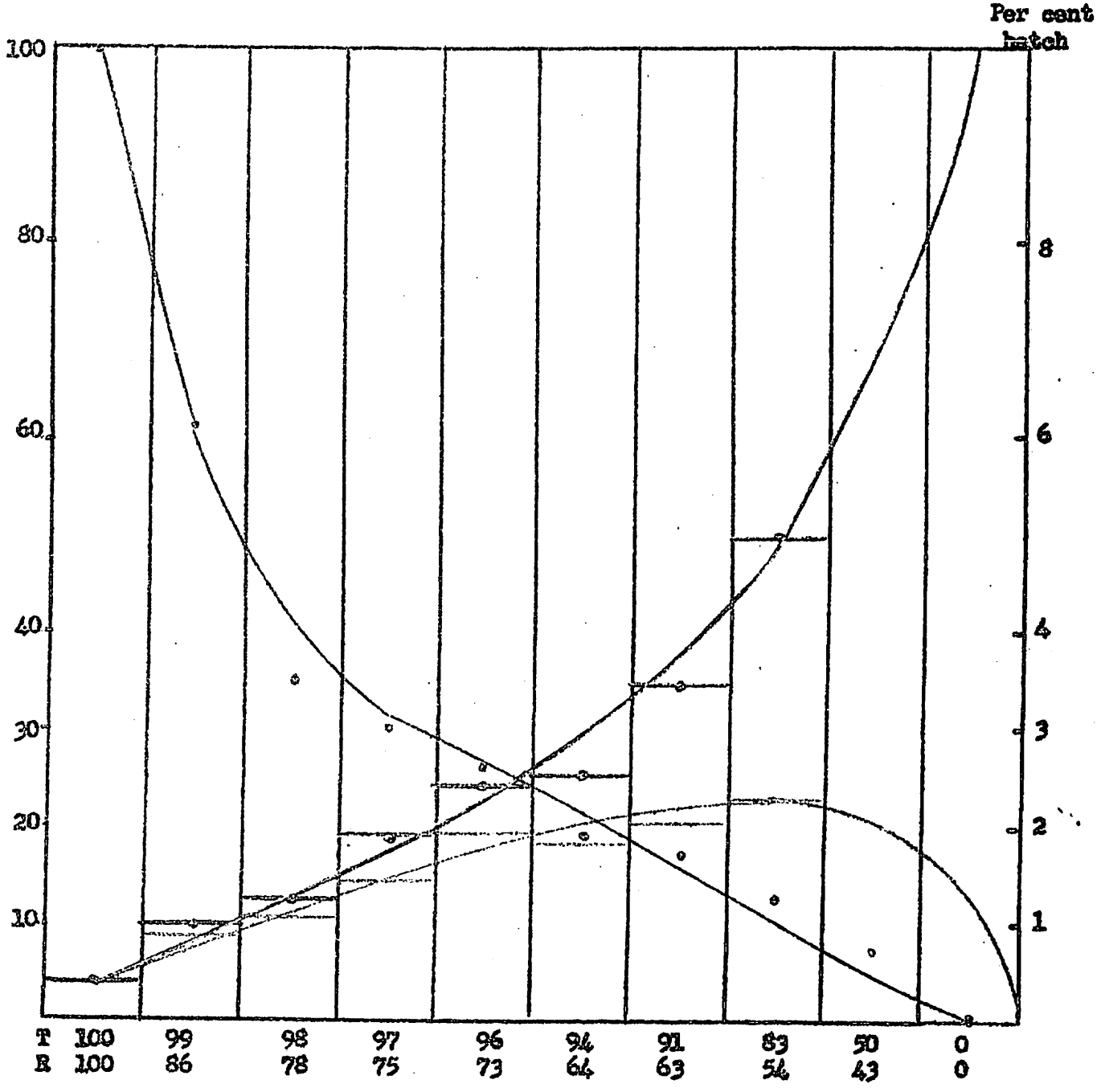
Graph 5.



Graph 6.



Graph 7.


Per cent hatch
100
80
60
40
30
20
10
8
6
4
3
2
1
T 100 99 98 97 96 94 91 83 50 0
R 100 86 78 75 73 64 63 54 43 0

In view of this we might ask ourselves, then, whether the slight changes that have occurred in the parasitism picture are adequate to produce the increases which have occurred in infestation and adult abundance. While there are factors involved other than per cent mortality and parasitism of eggs, I think that the comparison will be of value anyway. Note here, now, the per cent parasitism in 1951 and 1952 dropped from 81.4 to 71.4 per cent. Now, if you picked up two small samples of fruit and the parasitism as determined by rearing differed by only 10%, you may or may not regard such a difference as significant. But, these figures are based on large collections and they are undoubtedly reliable. Now, if we go back to this last graph, we see that when the parasitism by rearing drops from about 81% to about 71%, the hatch would increase from approximately 12 to 25 per cent. In other words, just about a doubling of the infestation, just such as was noted in field collections from 1951 to 1952. On the other hand, if we go from a mortality of 81.5% down to a mortality of 52.6%, such as we had in the first half of 1950, the per cent hatch would increase from 12% to approximately 60%, which is a gain of 5 times. In other words, this would represent an increase in infestation from 2.5 larvae per fruit to 12.5 larvae per fruit. While the correspondence between observed and calculated differences in infestation in 1950, 1951, and 1952 is almost too good to be entirely true, there is no doubt that a change in parasitism of the magnitude that has occurred here on Oahu could, in itself, account for the observed increases in infestation and trap catch.

This other line here (green) shows the proportion of parasitized flies produced at the corresponding levels of hatch. At a true percentage parasitism of 50%, 0.75 parasites per D. dorsalis would be produced. At a true parasitism of 98%, approximately 3.5 parasites per D. dorsalis would be produced. In other words slight changes here can produce very significant changes in the proportion of O. oophilus to D. dorsalis, and those changes are, of course, of great importance in the balance between host and parasite.

(Note: The following point was not brought out at the Kailua Meeting but is added here because of its importance in evaluating the effect of Opius oophilus. One highly significant inference that may be drawn from the study on egg mortality is that in a population sustaining average egg mortality of 70 per cent, if O. oophilus were suddenly eliminated today, the infestation would drop to 30% of the present level within three days. All samples so listed contained an average of 7.4 larvae per fruit, but they contained 24.0 eggs per fruit, practically all of which would have hatched without the activity of O. oophilus. This 300-fold increase in one generation would continue into the second generation before other factors could drop it, and the equilibrium level of the population would undoubtedly be somewhere between 5 and 25 times as great as the present population. The egg mortality is, in reality, the key to the evaluation of the importance of Opius oophilus.)

We have not confined our attention to O. oophilus although it is obviously the dominant mortality factor in D. dorsalis populations here on Oahu. We have also conducted studies on mortality in fruit on the ground and we find there a critical point regarding mortality. If we start out with a sample of tree fruits and determine the survival of larvae in those from the time they fall on the ground until the time the parasites and flies emerge we find that on the average 80% of the larvae do not develop. In other words, taking the small residue of 5 to 7% which is left over after the parasites have finished their work, 80% of those die before they ever emerge from the puparium. Without going into too much detail on this I will simply point out briefly that our studies have shown that

most of this is due to asphyxia or it is due to malnutrition of the larvae or production of toxic substances by the decomposition of the fruit. The results, although based on field experiments which were done under rather difficult conditions, are very consistent (graph 8). This bar represents one series of experiments done on the other side of the Pali, while this one represents a series of experiments done in the lower Waimanalo area. The three lines here represent 3 separate experiments which were done in lower Kailua, down where it is rather hot and dry, while these three represent the corresponding experiments in the upper Waimanalo area where it is cool. You can see that there are distinct local differences in mortality. Down here in Kailua where it was generally warm and dry, the larvae came through in better shape than they did up in the Waimanalo area where it is much wetter and cooler and where conditions favor the development of fungi and the very rapid breakdown of fruit by fungi of the genus Mucor. We found that the most effective factor in larval mortality is the fungus Mucor. Under rather moist and cool conditions a guava which falls to the ground becomes immediately innoculated with this because it is present everywhere and becomes converted to a veritable mycelial ball within a period of 24 to 48 hours. If you break this guava open you will find indications of all sorts of compounds which cannot be anything other than detrimental to the larvae--carbon dioxide, alcohol, aldehydes, etc.

This last graph (9) is a refugee from a previous policy meeting. We were interested in studying the effect of predators and ran some experiments on the other side of the island in which we excluded predators from frames in which we had guava samples. Of course, we had checks in which predators had access to the frames. We then compared the emergence in those two types of frames. In those frames from which the predators were excluded we found that only about 24% of the larvae came through, 76% died before they ever matured, whereas in the frames in which the predators were admitted the emergence was 16%. That would indicate a reduction of approximately 30% in the potential emerging population, due to the action of predators.

Dr. Pemberton: How long were the frames exposed?

Dr. Newell: Three to five weeks, or until all emergence had taken place. These experiments were run in areas where predators had pretty favorable conditions. In some of the other areas--such as the upper Waimanalo area--the predators are few because conditions are unfavorable, and those that are present are not very active.

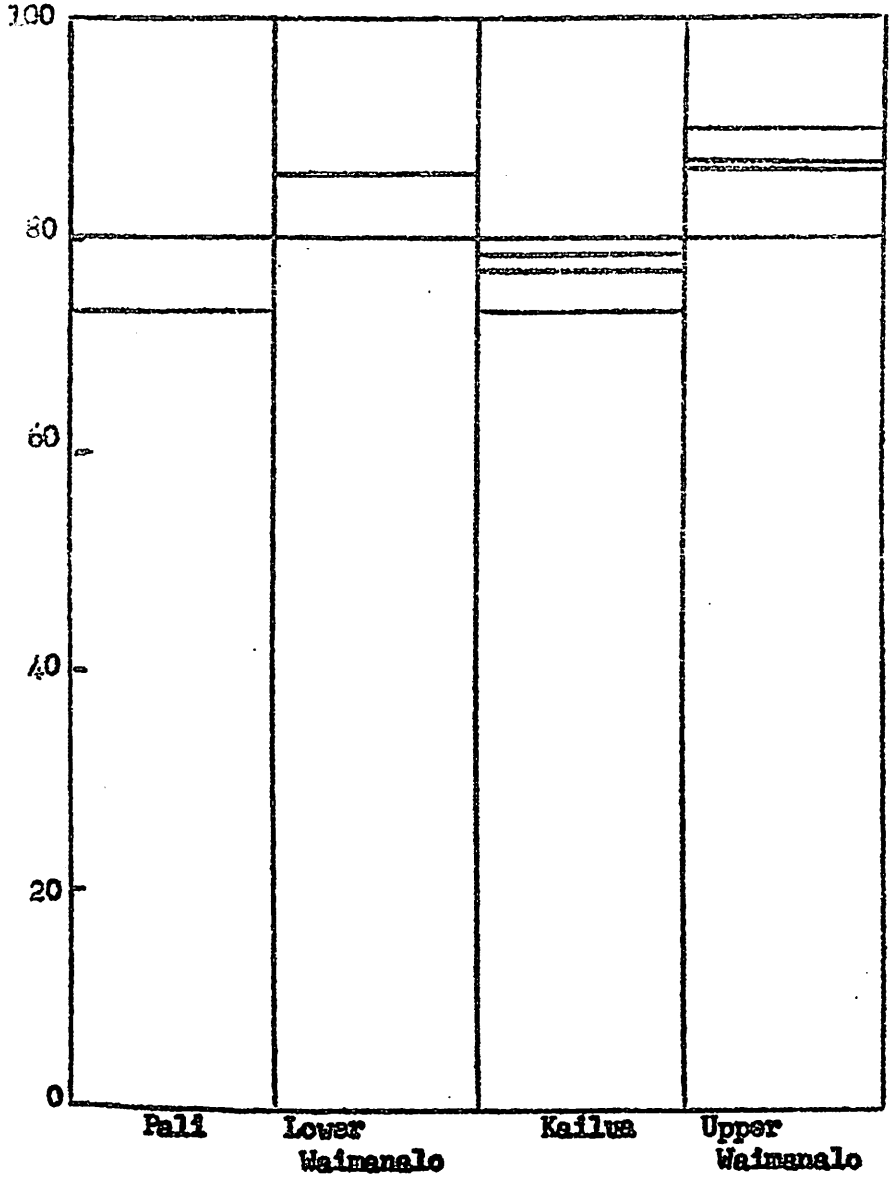
Mr. Clausen: Were there any predators of any consequence in addition to ants?

Dr. Newell: None of any importance. We saw occasional earwigs or cockroaches, but there was no evidence that these were of any importance.

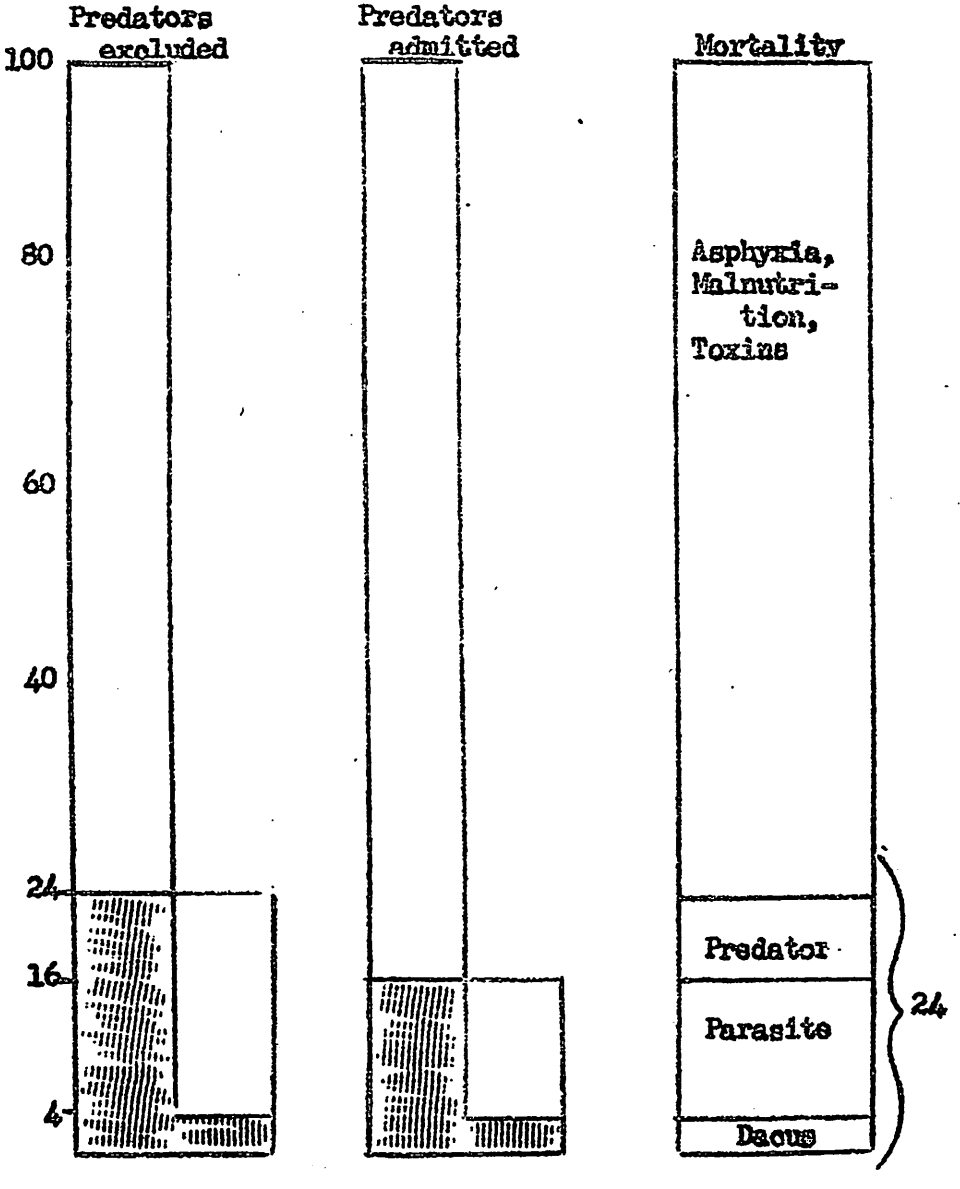
Q. Is the Mucor you mention the same as found in eggs?

Dr. Newell: No. The fungi associated with the eggs were species of Penicillium. I might say in that connection that in the case of the organisms producing egg mortality the bacteria are probably more effective than fungi.

Graph 8. Mortality of Larvae and Pupae on Ground



Graph 9. Mortality of Larvae and Pupae from Fruits Exposed in Frames.



Dr. Messenger: Have you determined the degree of mechanical trauma on eggs?

Dr. Newell: No. It is likely that trauma is of some importance, at least in cases of repeated parasite attacks. However, single attacks by parasites are evidently capable of producing mortality, when oviposition is followed by infection of the host egg, and living larvae may contain two or three eggs and larvae of O. oophilus.

Mr. Christenson: Were the parasitized eggs more susceptible than the non-parasitized eggs?

Dr. Newell: Yes. If you catch fruit flies in the field and cage them on growing guava fruits in the field, 95% or more of the eggs will hatch. If you admit parasites to them 5 to 100% of the eggs will be killed. Bacteria and fungi are introduced almost entirely by Opius oophilus--almost 99.9%.

Mr. Mashler: Doesn't the fly introduce these?

Dr. Newell: Apparently not. When ovipositing field flies are caged on growing fruits protected from parasite attack, the eggs are not killed by microorganisms.

Mr. Keiser: How would the per cent of natural mortality increase between the 1st, 2nd, and 3rd instar larvae?

Dr. Newell: I can't answer that question off hand but I would say that the factors which inflict larval mortality after O. oophilus has had its licks are more or less proportional throughout all stages of larval development.

Mr. Keiser: Notwithstanding the 93% control in eggs the other 7% could prove to be very important economically.

Dr. Newell: Definitely.

Dr. Messenger: That figure of 76% mortality of eggs--how long a period does it cover?

Dr. Newell: The data were compiled over a period of two years, 1951-1952.

Dr. Messenger: Was there a trend?

Dr. Newell: I would hesitate to say anything about the trend, although the average mortality was down slightly in 1952. There were approximately 70 samples each year, but they were not taken in such a way as to give figures on survival which could be compared on a year-to-year basis.

Dr. Messenger: Do you think you would be justified in using that figure without re-evaluation?

Dr. Newell: No, it must be continually revised, because any factor which results in an increased hatch would markedly affect the percentage parasitism determined by rearing. Actually if these curves are determined accurately enough you could almost use them to get a pretty good idea what average egg mortality was on the basis of rearing. However, this could be done only in comparing large quantities of data gathered over a period of time. In any single sample in which the percentage parasitism was say 70 per cent by rearing the mortality could range anywhere from 9% to 99%.

Mr. Steiner: Do you associate your higher egg mortality with multiple egg laying?

Dr. Newell: I think that undoubtedly comes into the picture.

Mr. Steiner: That would be about the only reason for that curve wouldn't it?

Dr. Newell: No, not necessarily, but it is almost certainly a primary factor. Egg infection is seemingly possible following single ovipositions. Epidemiological factors are probably involved, for when practically all the stings in an area are infected, the probability that a parasite will introduce a lethal charge of bacteria or spores into an egg are far greater than when most of the stings are clean.

Mr. Gow: Is your true per cent parasitism taken from all of the eggs that fail to hatch?

Dr. Newell: Yes, that is right.

Mr. Steiner: In other words they were actually parasitized eggs?

Dr. Newell: Yes. We know from experimental work that for all practical purposes any dead egg means a parasitized egg.

Q. How do you differentiate between disease and parasitization?

Dr. Newell: We don't except for the fact that we know that almost every egg killed by pathogens was parasitized.

Mr. Gow: Does that figure include your 5% natural infertility?

Dr. Newell: I have not included the 5%.

Mr. Gow: That has been deducted?

Dr. Newell: No, it hasn't. No correction for non-viability has been introduced. (Note: This amounts to less than 5%. Experiments have shown that O. cephilus does not differentiate between infertile and fertile eggs, hence, the infertile ones would actually sustain the same degree of attack as the fertile ones.)

Mr. Steiner: Why do we get 2-3 times as many larvae from green tree-picked fruit as from ripe or ground ones?

Dr. Newell: I think the ripe and green fruits differ in susceptibility to fungi. Green fruit does not break down as rapidly as ripe fruit.

Mr. Steiner: That is what we attribute it to but these figures would put a different slant on it.

Dr. Newell: Yes, it would because changes in rates of parasitism can take place in a very short time--a few days. Green tree fruits are still being worked on by parasites, and presumably have not sustained maximum parasitism and egg mortality.

Dr. Messenger: Your Mucor contamination from dropped fruits, can it be introduced into dirty holding trays?

Dr. Newell: Yes, very definitely. Virtually all holding trays are heavily contaminated with Mucor spores.

Mr. Steiner: Not as much so as the ground. The trays dry out in between uses.

Dr. Messenger: Green fruits in holding trays would not be as susceptible to decomposition as ripe?

Dr. Newell: That is right.

Mr. Christenson: This has been a very interesting discussion. I had planned to have a break but somehow overlooked it. A very important part of Biological Control has been the propagation and release and recovery work that the Territorial Board of Agriculture and Forestry has been carrying on. Mr. Chock will tell us about it.

Mr. Chock: At the last meeting of this policy committee held about a year ago, it was reported that there were in propagation seven species of parasites of the fruit flies. These consisted of five braconids, Opius formosanus, O. novocaledonicus, O. compensans, O. tejensis and O. kraussii; one cynipid, Trybliographa daci and one eulophid, Syntomosphyrum indicum.

In the discussion, the question of discontinuing the breeding of some of the species was brought up. It was decided then to leave this matter to the discretion of the Board of Agriculture and Forestry. Although we were planning work on several new projects at the time, we have managed to continue the propagating of all of the above species. However, this does not mean that production of all of the species were carried on the same level as previously. Unfortunately, pressure of other duties made it necessary for us to reduce the number of placements on all the species. A few thousands of parasites more or less released do not change the situation one way or the other, but it is more important to release continually at fairly regular periods even if the numbers might be smaller.

During the twelve month period, our insectary propagated 423,953 parasites and released 344,396 in the Territory. See table 1.

By requests, there were many shipments of parasites sent to the United States, Guam, and other foreign countries as follows:

Species	Country	No. released
Opius longicaudatus	Guam	825
	Australia	535
	Total...	1,360
Opius oophilus	Guam	675
	Australia	315
	Fiji (parasitized pupae)	23,700
	Italy	260
	Greece	1,455
	Total adults	2,705

Table 1.

PARASITE PROPAGATION

1952	No. 1*	No. 2*	No. 3*	No. 4*	No. 5*	No. 6*	No. 7*
July	2,735	2,755	1,313	1,165	654	314	5,000
August	3,045	3,365	2,115	1,835	418	381	9,800
September	1,340	1,650	1,035	700	547	432	9,600
October	3,763	3,167	1,872	1,759	400	270	16,080
November	3,072	2,684	2,903	2,510	594	468	15,700
December	2,731	2,897	2,425	3,285	569	443	44,100
1953							
January	3,895	3,930	2,660	3,485	821	339	24,950
February	3,560	3,290	3,880	3,600	932	585	56,715
March	1,495	1,085	1,865	2,170	1,500	230	52,200
April	2,815	2,655		4,937	723	229	13,000
May	2,115	2,025		7,546	282	425	19,600
June	2,540	2,520	____	11,076	275	1,362	14,600
Total ...	33,106	32,023	20,118	44,168	7,715	5,478	281,345

Grand Total 423,953

*No. 1 - Opius formosanus
*No. 2 - " novocaledonicus
*No. 3 - " compensans
*No. 4 - " taiensis
*No. 5 - " kraussii
*No. 6 - Trybliographa daci
*No. 7 - Syntomosphyrum indicum

Species	Country	No. released
O. incisi	Guam	150
	Philippines	100
	Total ...	250
O. watersi	Guam	300
Opius #1 India	Guam	150
O. formosanus	California	2,187
	Idaho	337
	Oregon	460
	Guam	260
	Bolivia	150
	Total ...	3,394
Opius novocaledonicus	Idaho	105
	Oregon	130
	Guam	495
	Bolivia	200
	Total ...	930
O. compensans	Idaho	130
	Oregon	140
	Guam	460
	Total ...	730
O. taiensis	Idaho	100
	Oregon	105
	Guam	455
	Australia	160
	Total ...	820
Dirhinus giffardii (Australia)	Guam	150
Syntomosphyrum indicum	Guam	8,000
O. fletcheri (Guam)	Parasitized puparia	600
	Adults	42

RECOVERY OF PARASITES

Species	Date	Locality
Opius longicaudatus	Oct. 6, 1948	Nuuanu, Oahu
O. cophilus	Dec. 1, 1948	Kaneohe, Oahu
O. vandenboschi	Dec. 1, 1948	Kaneohe, Oahu
O. incisi	Dec. 22, 1948	Kualoa, Oahu
*O. watersi (India #5)	Aug. 8, 1950	Hanapepe, Kauai
O. kraussii	July 2, 1951	Kula, Maui

*Reared by Steve Au on Momordica. I believe this same parasite was also reared from momordica at another time by Mr. Marucci from fruits growing near the fruit fly laboratory. All these parasites are definitely established, except O. watersi. The latter has never been recovered again. The only species in current propagation not recovered to date is the cynipid.

Recovery of Parasites (cont'd)

O. formosanus	Aug. 10, 1951	Kohala, Hawaii
O. novocaledonicus	Sept. 6, 1951	Lihue, Kauai
O. compensans	Sept., 1951	Iao Valley, Maui
O. taiensis	January, 1952	Makiki, Oahu
S. indicum	April 1, 1952	Makaka, Oahu
T. dacicida	April 3, 1952	Makaka, Oahu

About 2 weeks ago Mr. Flitters brought us some specimens for identification and Dr. Fullaway and I looked them over and found some interesting figures. Some of those specimens were reared on parasites such as Opius novocaledonicus, O. formosanus, and O. taiensis, reared out of Medfly puparia. It looks as though these Opius types are getting along in Medfly.

Mr. Christenson: I think that might be worth a little additional comment. Mr. Miyabara and Mr. Yamada on Maui have developed some skill in identifying Medfly puparia--i.e., separating them from oriental fruit fly puparia. They are using characters which seem rather definite. There are gentle swellings or raised areas surrounding the base of each of the anterior spiracular organs and a definite concavity between these raised areas on oriental fruit fly puparia. In the examination of several thousand puparia in mixed lots they have only made one mistake. The records Mr. Chock mentioned are from these puparia.

Mr. Clausen: Can you tell me the total number of species of parasites released?

Mr. Chock: I can't but I think Dr. Fullaway can because there are some species released and not established and we have not kept track of them unless we go back into the records.

Dr. Messenger: Of all of the parasites which you have released have you brought them through on flies in the laboratory?

Mr. Chock: Yes.

Dr. Messenger: How about those that you brought in but were unable to rear. Do you destroy them?

Mr. Chock: It depends upon the number received. If we have a good number there are always some released and others held for breeding.

Dr. Messenger: Do you consider it justifiable to release parasites if you don't know whether it will come through on the fly?

Mr. Chock: Yes, we hope they will come through in the field.

Dr. Newell: Do you have any records of picking up watersi?

Mr. Chock: That is a rare thing. Although we donated over half of a million of that parasite to the Territory we have only recovered it twice. It was one parasite that we reared very well.

Dr. Pemberton: Was it reared on dorsalis here?

Mr. Chock: That's right.

Mr. Flitters: You are not getting too many back from kraussii are you?

Mr. Chock: No, as a matter of fact since cophilus is doing so well you can gather parasites in the field but occasionally we rear some. We all know they are here. For instance, now, take dacicida. We have been breeding that parasite for a long time and had liberated such great numbers we finally decided to discontinue rearing it because we hadn't recovered any. However, we have now recovered it in a number of places and today you can pick them up at any time.

Mr. Flitters: Only in Momordica, isn't that right?

Mr. Chock: No, I wouldn't say only on Momordica. I think it was reared out of fig, or something. If I remember correctly it was reared by our man on Hawaii from guava.

Mr. Christenson: If there are no further questions and as this concludes our program for this morning we will adjourn until 2 o'clock.

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Afternoon session - 10/1/53

Mr. Christenson: The program for this afternoon is entirely concerned with the different phases of chemical control. I will ask Mr. Steiner to present the different speakers.

Mr. Steiner: One objective of this project is the development of practical, effective, and safe insecticidal treatments that can be used in Hawaii to protect fruits and vegetables from fruit fly attack. Others include the development of suitable methods for eliminating incipient fruit fly infestations should they occur on the mainland, practical treatments for control there should eradication attempts fail, chemical procedures to reduce the hazards of adult fly introduction to the mainland via ships or planes and finally the development of lures and trapping methods for determining the limits of incipient fruit fly infestations, or for use as direct controls.

We recognize our responsibility to develop effective methods for the control of fruit flies with a minimum destruction of their natural enemies where such are capable of materially contributing to control. However, we also have the responsibility of developing more severe treatments for possible use where effective biological control methods are inoperative or where eradication may be demanded regardless of cost to beneficial insects.

That we still have a local control problem despite the remarkable performance of the introduced parasites should be evident from this morning's discussions. Local increases in fly abundance that result in serious damage from one or more of the species are a common occurrence. The commercial production of certain fruits and vegetables free of fly injury is impossible under present infestation conditions without the use of insecticides.

In the development of a successful oriental fruit fly control program we must contend with:

(1) An insect that may live many months under favorable conditions.

(2) An insect that, in the 10 or more days required to reach sexual maturity, may move many miles from its place of emergence or from parasites, insecticides, or other environmental factors unfavorable to it, and that can find the earliest maturing fruits in new locations or the food elements essential to its development.

(3) An insect that may oviposit in available host fruits within a few minutes after arrival, that generally selects fruits ready to be harvested, or soon to be harvested, on which there is a severe limitation as to the amounts (or type) of poisons that dare be used.

(4) An insect that deposits many eggs at a single site at a depth that escapes nearly all known safe insecticides.

(5) An insect that, when bent on oviposition, cannot be diverted by any known attractant or repellent except possibly under very artificial conditions.

(6) An insect that can readily be transported long distances, that can ride the windshield of automobiles for many miles at speeds up to 70 m.p.h., that on comparatively rare occasions can find hiding places in planes and escape recommended aerosol treatments.

(7) An insect that in the Islands has a sufficiently wide range of hosts within flight range to insure continuous reproduction. Such hosts may include not only immature or mature growing fruit but drops on the ground or quality produce in the markets or in transit. The injury may result in wormy fruit, in accelerated breakdown of tissues around the oviposition site, in deformed fruits with calloused areas or in failure to set, and damage may occur on hosts in which the fly cannot survive, and finally,

(8) An insect that must be reared from the hosts to properly assess its abundance, its damage, and the effectiveness of its parasites under various control programs, and also one that varies tremendously in population density from fruit to fruit so that unusually large samples must be held to avoid errors in data interpretation.

Until an insecticide safe enough to be used at effective dosage levels on ripening fruit, and effective enough to kill ovipositing flies that make their first contact upon arrival at the fruit is found, we will have no dependable safe spray program for universal usage. However, if a bait as attractive to females as methyl eugenol is to males can be found, control would be greatly simplified.

Mr. Gow, who is in immediate charge of our lure and repellent research, will discuss his phase of the problem.

Mr. Gow: Screening Tests for Attractants and Repellents. A few materials were screened in field tests early in this investation before the development of a practical olfactometer but most of the screening tests have been made in the

olfactometer. In all, 607 materials consisting of 484 chemical compounds, 71 essential oils, and 52 other chemical mixtures have been tested against D. dorsalis. In January, 1952, it was decided to introduce D. cucurbitae and C. capitata into the olfactometer cage and maintain populations of these two species whenever they were obtainable from the rearing section. Of the materials screened against D. dorsalis, 209 have also been screened against D. cucurbitae and 127 against C. capitata. All of these tests have been made using a quantitative technique involving trapping of flies attracted, sex counts, and statistical analysis of the results.

Materials tested by this technique can be classified into five classes: attractants, where the test material is found to be attractive per se; enhancers, where the material enhances the attractiveness of the standard fermenting lure but does not attract flies by itself; repellents, which decrease fly catches when used in traps with water alone; obscurants, which reduce the catch of the standard lure; and neutral, which have no significant effect on fly catches, either when combined with water or with the standard lure. Results of the screening tests are summarized in the accompanying table.

	D. dorsalis	D. cucurbitae	C. capitata
Materials tested	607	209	127
Attractants - Both sexes	132	30	21
Males	47	16	19
Females	6	1	0
Enhancers - Both sexes	20	2	0
Males	6	2	2
Females	0	0	2
Repellents	30	10	8
Obscurants	264	116	39
Neutral	128	43	51

Most of the materials screened were tested at only one concentration (0.1%). It was considered desirable to make a preliminary screening of a large number of materials by such a method, since it was believed that any outstanding attractant would be indicated as attractive at this concentration.

However, with any material to be tested for attractiveness concentration likely to be attractive is always the initial unknown. Most insect attractants, according to the literature on this subject, pass through concentration peaks and tend to become less attractive or even repellent as the concentration is allowed to exceed the peak value. Therefore, although none of the materials tested and found attractive in this program have shown attraction for female fruit flies as high as that of the standard fermenting lure, it is easily possible that some of them may be valuable attractants at some other concentration level than that used in testing. We believe that the time has come when screening tests on new materials should be suspended and those materials shown attractive in initial tests at the 0.1% level should be retested in olfactometer concentration tests over a hundred-fold range of concentration.

Mr. Steiner demonstrated that the attractiveness of eugenol methyl ether, commonly called methyl eugenol, to D. dorsalis males is such as to class it with the male gypsy moth attractant and the geranoil-eugenol Japanese beetle attractant as one of the three outstanding insect attractants. In olfactometer tests we were able to show that female D. dorsalis are attracted to methyl eugenol in considerable numbers, its failure to attract females in the field probably being due to low sensitivity of females that enables them to detect it over distances of only a few feet. Iso-eugenol, iso-eugenol methyl ether and eugenol allyl ether also displayed a high level of attraction for males while vanillin, which is closely related in chemical structure, was shown both here and elsewhere to be a non-sex specific fruit fly attractant for several species.

It was therefore decided to test all available compounds which had any similarity to the chemical structure of the eugenol- vanillin compounds. So far we have been able to obtain and have screened in olfactometer quantitative tests 124 such compounds. A considerable number of these showed a low-level attraction for both sexes of D. dorsalis and some for D. cucurbitae but none gave indication of outstanding attractiveness at 0.1% concentrations. The compounds in this study which were attractive have not yet been subjected to concentration tests. It is probable that any new materials to be included in this study will need to be synthesized either here or elsewhere.

In addition to our quantitative olfactometer screening tests a considerable number of tests have been made by a qualitative olfactometer technique suggested by Dr. Haller. These tests are made by applying a spot of the material to be tested in solution in acetone or other suitable volatile solvent to a piece of paper and exposing on a rotating wheel in the olfactometer. It is highly probable that any outstanding attractant would be revealed by this technique. Steiner first noted the attraction of methyl eugenol to D. dorsalis males by spotting test materials on replicated filter paper disks in a stand of wild guava. The method, however, has several drawbacks. There is no control over concentration, and it was found on testing materials that had shown attractiveness to both sexes of D. dorsalis in quantitative tests that only males were attracted in spot tests. Indications are that D. dorsalis females will not crowd into a group of males clustered on a spot; often in such cases a few females were found around the outskirts of the cluster. Also, a number of materials which showed a fair attractiveness in quantitative tests failed to show any attraction in qualitative tests. Furthermore, while these tests were capable of indicating attraction, they proved valueless in indicating repellence.

All of the "E" series of coded compounds which have been furnished to this laboratory by the Bureau were tested by this method which was especially suited for these tests due to the small quantities of such compounds available after being used for routine insecticide screening tests. Of the "E" series, 443 compounds were tested against D. dorsalis with 9 showing attraction; 423 tested against D. cucurbitae showed no attractants; and 380 tested against C. capitata showed 10 attractants. The compounds indicated as attractive by these tests should be retested in quantitative screening tests.

Three materials showing considerable promise according to olfactometer tests were field tested. These were castoreum, diethyl phthalate, and chlorthion. All three gave disappointing results in the field. Herein is probably indicated a serious limitation in the olfactometer technique where a large population of flies is confined within a few feet of the traps used in testing. An attractant having no "reach" or distance effect may show up as quite good in olfactometer tests when it will prove worthless in the field. This was demonstrated in the case of methyl eugenol which caught up to 28% female D. dorsalis in olfactometer tests, while field tests showed catches of less than 0.3% females. However, if olfactometer

tests are used only as preliminary to field tests to eliminate non-attractive materials, this is not a serious drawback since we still have every reason to believe that any attractant which is good in the field will show up as good in the olfactometer.

Olfactometer Tests on Repellents

A technique has been devised for testing repellents of D. dorsalis in the olfactometer wherein orange sections are painted with the test materials and exposed in replicate on the rotating olfactometer wheel. After several hours' exposure, the sections are examined to determine whether oviposition has or has not occurred. We have found that we may make such tests simultaneously with quantitative screening tests using traps by hanging the glass traps well below the petri dishes containing the orange sections. All of the materials indicated by screening tests as true repellents for D. dorsalis have been tested by this method. None has prevented oviposition at concentrations less than 100%.

Referring back to the table presenting the results of screening tests, it will be seen that 264 materials were found to be obscurants for D. dorsalis. It is probable that a considerable number of these are also true repellents but failed to show as such because, in order to be classed a repellent, a material must produce a significant decrease in catch compared to that found in traps containing only water. This catch is always small since water has apparently no attraction. Often the LSD values found by statistical analysis are much larger than the water catch, in which case a true repellent would not be so indicated. Moreover an obscurant might effectively prevent oviposition even though it had no true repellent effect. Olfactometer tests on a considerable number if not all of these materials classed as obscurants is indicated.

Development of SM-14 Lure

Initial tests undertaken by Mr. Steiner on bait sprays together with advice from Finney and Hagen of the California laboratory on apparent responses of caged flies to yeast hydrolysate indicated that this material might be very attractive. Field tests showed it to be usually more attractive than the standard fermenting lure, although such tests proved to be somewhat erratic. Attractiveness of this material was in line with attractiveness of other proteinaceous materials previously found by numerous other investigations of fruit fly baits. This attractiveness of proteinaceous materials had usually been attributed to production of ammonia. However, tests with ammonia against D. dorsalis indicated that it had an attractiveness far too low to account for the attractiveness of yeast hydrolysate.

Since this material is a rich source of B vitamins, all of the B vitamins were tested in the pure form at concentrations comparable to those obtained in the yeast hydrolysate lure. None of these tested either singly or in combination showed any attractiveness except choline chloride. However, the attractiveness of choline was not great enough to account for the attraction of the yeast hydrolysate. A commercial B vitamin complex preparation sold under the name of "Lederplex" showed outstanding attractiveness, but this material contains a considerable amount of liver extract which makes it proteinaceous in character.

Other protein hydrolysates and a number of other similar materials such as fermentation by-products and various liver extracts were tested. Of course, soy hydrolysate appeared to be best and addition of a complete mixture of B vitamins to soy hydrolysate considerably improved its performance. However, behavior of this lure in both field and olfactometer tests continued to be erratic. This was thought to be due to varying microflora picked up by these baits.

It was found that a combination of the antibiotics streptomycin and tyrothricin prevented putrefaction in the proteinaceous lures but did not prevent development of a micro flora. Baits so protected proved superior to unprotected baits. The antiseptic zephiran chloride was apparently effective in preventing development of microflora of all types. Baits protected by this material were considerably inferior to unprotected baits, so it was concluded that microbiological activity is necessary to best functioning of proteinaceous baits, and that the effect of addition of B-vitamin complex is to exert a beneficial selectivity on the types of microflora developing in the baits.

Eighteen traps containing Lederplex and eighteen containing Lederplex plus antibiotics were exposed on rotating trap suspensions. Each suspension held also a trap containing the standard fermenting lure for purposes of comparison. These traps were inspected daily over a period of eight days. Two traps produced outstanding fly catches which improved steadily from day to day. The baits from these two traps were turned over to Miss Maeda of Mr. Finney's University of California laboratory for isolation of the microorganisms therein and the preparation of pure cultures. Thirteen strains of bacteria and one yeast were isolated therefrom.

Field and olfactometer tests were made with soy hydrolysate baits which were given large inoculations with very active pure cultures of these various microorganisms. One bacterium, since determined to be a species of Proteus, gave consistently superior results throughout this series of tests. This bacterium we have designated as bacterium No. 14.

Investigation of the effect of varying pH in the culture on production of attractants showed equally good performance of pH values ranging from 5.5 to 10.5. It was found that addition of carbohydrate in the form of dextrose inhibited production of attractants indicating that the attractants were produced by breakdown of the proteins by the bacteria. Studies were made on effect of varying the concentration of the soy hydrolysate and a concentration in the neighborhood of 1% proved best.

We next investigated the possibility of using soy meal unhydrolyzed and prehydrolyzed chemically. It was found that the unhydrolyzed soy meal gave results equal to those obtained with the much more expensive soy hydrolysate.

It was found that preculture of the soy meal with bacterium No. 14 in shallow cultures with a large surface exposed to air produced a great increase in attractiveness accompanied by the development in the culture of a strong red coloration probably due to culture under aerobic conditions. Attempts to increase aeration by bubbling sterile air through the culture failed since the culture foamed to such an extent that it could not be contained in a flask. However, deep cultures which were mechanically stirred throughout the culture period in such a manner as to continuously force air into the culture gave results equal to those from the shallow cultures but not superior. Shallow culture under an atmosphere of oxygen did not result in any improvement in production of attractants.

Extensive studies involving both field and olfactometer tests were made to determine best conditions of culture. It was found that the best concentration for culture is 10% soy meal and that best concentration for exposure of the lure is obtained by diluting the culture to 1% just before taking to the field. The best period for preculture was found to be one to three weeks. Heavy inoculations of the soy meal culture consisting of 75 cc. of a 24-hour old culture of bacterium No. 14 in trypticase-soy broth was found to produce the best results. It is probable that the bacteria cannot hydrolyze the soy meal proteins until it has had a chance to produce proteolytic enzymes in the trypticase-soy broth.

Since the soy meal contains about 20% carbohydrates and addition of carbohydrates had been found to inhibit attractant production, it was attempted to remove the carbohydrates from the soy meal by prefermentation with yeast. However, this failed to increase production of attractants. Postfermentation by yeast after culturing with bacterium No. 14 proved interesting since it rapidly decreased the attractiveness of the soy meal lure from 8 times that of the standard fermenting lure to a level just equivalent to that of the standard, showing that the nature of the soy meal attractants is such that they are rapidly consumed by the yeast. This suggests that the attractants are either carbohydrates or nitrogen-containing compounds.

Attempts to preserve the soy meal culture by storing under refrigeration or by quickfreezing resulted in loss of attraction. However, since the permissible time of preculture was found to range from one to three weeks, the material may be shipped considerable distances in the form of the concentrated culture.

The proteinaceous soy meal lure prepared by culture with bacterium No. 14 we have designated as SM-14 lure.

We have found over a period of 3 years' study that the effectiveness of the proteinaceous lures as compared with that of the standard fermenting lure exhibits a seasonal variation. During the late spring, summer, and early fall the proteinaceous lures range from six to ten times as attractive as the fermenting lure. In the late fall, winter, and early spring the attractiveness of the proteinaceous lures drops to about the same level as shown by the fermenting lure. We do not know yet which lure varies or whether both have a seasonal variation.

A considerable number of other meals were tested as baits by culture with bacterium No. 14. Some were decidedly inferior to soy meal and none showed any superiority.

We have found recently that the soy meal culture may be treated with as much as 20% of its volume of clorox immediately before dilution to produce the lure. This results in no loss of attractiveness, removes the objectionable odor of the SM-14 lure, and probably decreases the tendency of the lure to attract blowflies, which have on occasion so packed the traps as to render them ineffective.

Chemical studies are in progress with the ends in view of concentrating and isolating the attractants, and, if possible, determining their chemical nature. It has been found that distillation at room temperature under high vacuum removes some repellents and that the attractants remain with the undistilled residue and are therefore non-volatile. Removal of the bacteria by centrifuging does not decrease attractiveness. The attractants have been found to be alcohol and acetone soluble as well as water soluble so are not proteins, polypeptides or any of the common amino acids. They are not soluble in ether or petroleum ether. The attractants pass through a cellophane membrane which indicates that the molecules are smaller than protein or polypeptide molecules. They are practically

completely removed from solution by ion-exchange resins and are held in both the cation and anion exchange resins indicating that we are dealing with two or more attractants or a single amphoteric material.

Attempts to use the SM-14 lure on poison feeding stations similar to the canec pieces used successfully with methyl eugenol by Mr. Steiner have failed. The material has been found to lose its attractiveness when dried, but again becomes attractive when remoistened. Use of humectants such as glycerol, propylene glycol and calcium chloride maintained the material in a moist state but did not preserve the attractiveness indicating that water must not only be present but also free to evaporate.

The fact that the SM-14 attractants are not volatile and the necessity for the presence of freely evaporating water to maintain attractiveness suggests that the non-volatile attractants are being carried out into the air by a cold steam distillation, i.e., that the escaping water molecules are pushing molecules of attractants out of the surface of the lure into the air. This mechanism is also suggested by the fact that pure sucrose solutions which are freshly prepared and non-fermenting are significantly attractive although the vapor pressure of sucrose itself is so low as to be negligible.

Studies with Fruit Extracts

Very early in this work tests were made with various fruit juices which were allowed to ferment. None of these proved superior to the raw sugar-vinegar fermenting lure. Recent tests with alcoholic and water extracts of orange, guava, mango and kamani nuts have indicated considerable attractiveness which is apparently reduced when fermentation is allowed to take place. In a very recent field test the juice pressed from green cucumbers was found to have an attractiveness for both D. dorsalis and D. cucurbitae quite comparable to that of the SM-14 lure for the first day, and that the attractiveness of this juice dropped on subsequent days. An olfactometer test with fresh cucumber juice as compared with juice fermented for 24 hours by addition of yeast showed this same effect. Apparently, as is the case with the SM-14 lure, the attractants are consumed by the yeast. Juice expressed from yellow-ripe and overripe cucumbers failed to show a high level of attraction during the initial 24 hours of exposure in the field.

An alcohol extract of olapa (Cheirodendron gaudichaudii) leaves proved fairly attractive in the olfactometer indicating that attractants may not be confined to the fruit but may also be found in other portions of the plant. This indicates that other leaf extracts should be investigated.

Mr. van Zwaluenberg: Is this seasonal variation in SM-14 correlated with temperature?

Mr. Gow: Only insofar as temperatures are lower in winter than summer. We think that it is correlated with something nutritional and that perhaps the flies are not as hungry for protein in the winter as they are in the summer. Of course they are not going to the SM-14 lures for proteins--they are going to some decomposition product which may serve as a signal to them that there is protein available. Incidentally this SM-14 lure has a terrific stench. It has an odor that is almost fecal. We recently found that if we treated it with a 1-2% clorox it would destroy the objectionable odor and make it smell just like clorox, and it is still attractive to the flies.

Q. Does it attract only the male?

Mr. Gow: No, it attracts both males and females.

Dr. Hardy: Do you have any idea what the Australians are doing along this line?

Mr. Gow: Not extremely recently.

Dr. Hardy: No. What I am referring to is that recently I received a collection from there and a number which were collected in bait traps were females. This is extremely unusual.

Mr. Gow: They have been using non-sex-specific lures in Australia for a number of years. I know that they did a lot in lure work a number of years ago. Among them they developed the so-called "Jarvis" lure, which is a combination of ammonium carbonate and vanillin, which, as you know, has been fairly attractive to our fruit flies, but it does not take just females, it takes both sexes.

Dr. Carter: Have you tried oil of clove?

Mr. Gow: Yes.

Dr. Carter: It is used in Ceylon and dorsalis came to it.

Mr. Gow. The chief component of oil of cloves is eugenol. We have tested two types of oil of cloves and found that they were male attractants. We also know that eugenol is a male attractant.

Dr. Newell: Do you have any idea what attracts dorsalis to these small green coconuts outside the laboratory building?

Mr. Gow: No.

Dr. Messenger: How does the orange-peel extract compare to cucumber extract?

Mr. Gow: I would say that the cucumber was 6 to 8 times as attractive. The other fruit extracts that I mentioned were in about the same class as the fermenting lure. At this time the SM-14 was about 6 times as good as the fermenting lure and the cucumber extract was as high as the SM-14 for the first 24 hours, and then it dropped down to the level of the fermenting lure,--probably became nothing but a fermenting lure after the first day.

Dr. Newell: Have you tried anti-ferments in cucumber lures.

Mr. Gow: Not in the field, but we have in the olfactometer. However counts on this olfactometer test have not yet been completed.

Mr. Steiner: I think you realize the complexity of this lure problem. We have a long way to go. Mr. Gow has come a long way. He has done considerably more work in this field than has been done heretofore, I think, by anybody working on lures.

When this project was initiated in 1949 we were advised that Mokihana (Pelea anisata) was attractive to male flies. We found that alcohol extracts yielded the equivalent in terms of flies caught of about 16 ml. methyl eugenol per pound of foliage. Our Division of Insecticide Investigations in Washington also prepared extracts that were very attractive and, while they did not identify the attractive ingredients, they were able to determine that the Mokihana extracts did not contain methyl eugenol.

Recently Dr. Paul Scheuer of the University of Hawaii Chemistry Department has become interested in the chemical phases of the problem of identification of the attractants in Mokihana. He will tell us of his work at this time.

Dr. Scheuer: During the summer of 1952, H. L. Haller of the Department of Agriculture was here on a visit and in a conversation with him he pointed out to me what Mr. Steiner has just mentioned, that early tests several years ago had shown that Mokihana showed a very high level of attractiveness to fruit flies and he suggested that it might be a good chemical problem to try and identify its active principle or principles. During July of this summer, I started to work on this problem.

Mokihana, the botanical name of which is Pelea anisata Mann., belongs to the Rue family or Rutaceae, a family to which the citrus plants also belong. It is a perennial which grows on the island of Kauai, exclusively, although related species are found on this island. It is found on the plateau of Kokee at an elevation of approximately 3,000 to 4,000 ft. It is not a very plentiful plant and collections entail a fair amount of labor. With Mr. Christenson's and Mr. Flitter's help we have been able to make three collections to date of about 10 lb. each, and have ground the leaves and seeds as well as the small twigs. Except for small tests we have largely steam-distilled the ground material and have obtained the essential oil by extraction with chloroform. The yield was very small--approximately 1% essential oil per weight of plant.

The crude oil, which is a rather mobile, yellowish oil, was taken up in dry petroleum ether and adsorbed on a column of activated alumina. The major fractions were: (1) a colorless oil having an odor resembling that of safrole; (2) a colorless oil have an odor resembling that of anise (and of course it is this particular odor from which the botanical name of the plant is derived); (3) is an almost colorless oil, slightly yellowish with an odor resembling, although not closely, that of oranges; (4) a viscous yellowish oil and the odor is relatively unpleasant--I would just describe it as acrid. The first 3 fractions comprise about 60% of the oil, fraction 4 about 5%. In addition there are left on the column 4 bands which cannot be eluted even with very polar solvents and when the column is extruded and cut there are isolated in very small amounts three solids--the fourth band simply turned out to be an impurity. All of these solids have odors resembling vanillin.

When samples of the crude oil as well as of the fractions were given to Mr. Gow to be tested in his olfactometer, it proved that the crude oil was--if anything--a fruit fly repellent. The chromatographed fractions 1, 2, and 3 were also mostly repellents. After some time in the olfactometer there were attracted a few flies but not very many. The acrid fraction 4 did not prove very promising in the olfactometer test--it proved to be about as attractive as oil of citronella. None of the solids have been tested since there hasn't been enough material.

There is a discrepancy between the early work on the basis of which this work was undertaken and what we have found so far. We have found nothing which resembles the early promise of a material which is present in large amounts and which has or had greater attraction than methyl eugenol.

I have only one suggestion to offer and that is that apparently the dry conditions of this past year have caused the Mokihana to have very few seeds and all of us who have been up there to make collections can testify to that point. So it is possible, although not being a botanist I would not say probable, that the total amount of essential oils is definitely very much lower than it was during those early tests a few years ago; that the concentration of the attractive fraction is very, very low or probably it is not present at all.

I might say that these fractions are not completely pure and of course the work ahead is to work up larger quantities of the material and obtain large enough samples of the various fractions so that chemical studies can be made. As far as chemical studies are concerned they have so far only been carried out with one of the non-attractive materials—the one which is present in largest amounts, which made it feasible to work with.

Are there any questions?

Mr. Gow: Perhaps Mokihana is not as attractive this year as in the past. I had a sprig of it in the olfactometer for a few days and there was no response. When it was dried out there were a few flies on it.

Dr. Scheuer: There is no question that the attractiveness increases as one proceeds through the fractions; and of course—what comes off the column first are the most non-polar compounds—they go right through; they don't stick to the alumina. So the fractions get more polar as one goes along. The more polar ones are generally the less volatile. After these things have evaporated the less volatile components have a chance to get into the play. I think these observations check very well.

Mr. Christenson: Changes in the ratios of obscurants or repellents that might be present because of changes in growing conditions might change the amount of attractiveness.

Mr. Steiner: It might be too that comparisons were made a little differently this time than originally.

Dr. Scheuer: We extracted 50-g. samples with several solvents to see whether the steam distillation procedure might not possibly account for the discrepancy. We made acetone, ethanol and petroleum ether extracts and they did not prove superior to the steam distillation material that we are getting now and, in addition, solvent extracts make the chemical work considerably more difficult.

Mr. Keiser: Is there any attraction in the water soluble phase?

Dr. Scheuer: I don't know, we have never tested it.

Mr. Keiser: If the olfactory senses of the oriental fruit fly is as strong as we have been led to believe the attractive material might be water soluble.

Dr. Messenger: Frank Hinman had some leaves on his desk that were more attractive when dry than when fresh. Why not dry them out first?

Dr. Scheuer: The result would be the same. We now get a crude oil which comprises all fractions--it is not attractive. Then we separate and obtain one fraction which is good. I think that's exactly the same thing. Fractions 1, 2, and 3 are volatile and present in relatively large amounts and obscure the attractant and after they have evaporated the less volatile components have a chance to act.

Dr. Messenger: I was wondering if it would simplify your problem to have these other factors eliminated.

Dr. Scheuer: Apparently #4 is the best one we have found unless there is something in the solids which we have not tested at all as yet. I must confess I am interested in all of the chemical constituents of Mokihana.

Mr. Balock: Five years or so ago the fresh leaves were very attractive and retained their attractiveness even when dried out.

Dr. Scheuer: I have no answer for that. I do know that no flies followed me when I carried the leaves; none followed me when I ground them up. I have heard that story that you refer to that when that first batch came in all of the flies on the island were following it.

Mr. Steiner: Are there any other questions? - - - Thank you, Dr. Scheuer.

The possibility that exposure to certain insecticides will lead to increased resistance cannot be overlooked in the development of any control program. Although we cannot devote as much time or go into the subject as deeply as those specializing on house fly resistance, we felt it was important to determine if D. dorsalis could in a reasonable number of generations develop any substantial resistance to insecticides. We also consider it important to study the range of tolerance to specific representative insecticides likely to be encountered among our island flies from different locations or from different hosts.

Our early selection work was done in this project by Messrs. Frank Hinman, Oliver Stout and J. R. Holloway. For a few generations it was assigned to the Physiology Proj. under Dr. Roan and Miss Maeda, and is now again in Chemical Control under Miss Maeda's immediate supervision.

Miss Maeda: Efforts to control the fruit fly population locally are being made through the use of insecticides and in the event of mainland outbreak chemical control methods will be necessary for an eradication program. In any situation, the question of resistance to chemicals, as known in the house flies, will have to be studied to avoid any building up of resistance either by using insecticides alternately or by using a compound with an insecticide to prevent resistance.

Selection studies were undertaken to determine the extent to which resistance is likely to develop in the oriental fruit flies and also to observe the mechanisms involved in development of resistance in order to counteract or prevent it.

Oriental fruit flies are being selected for resistance to two types of insecticides--parathion and DDT.

DDT-Resistance--Selection of one strain of laboratory-reared oriental fruit flies was started late in 1950 by exposing the sexually mature flies in small test cages covered with Petri dishes with different concentrations of 50% wettable DDT residues. Any flies surviving a 50% mortality level after 48 hours of exposure were recovered and used to propagate the following generation. The larvae were not treated. Comparisons between the selected and untreated laboratory flies were made at the LD_{50} levels based on the dosage mortality curves obtained by topical treatment. When topically treated, these flies had attained a 2- to 4-fold resistance by the 10th generation and except for a very slight increase has remained about the same after 23 selected generations. See figure 1.

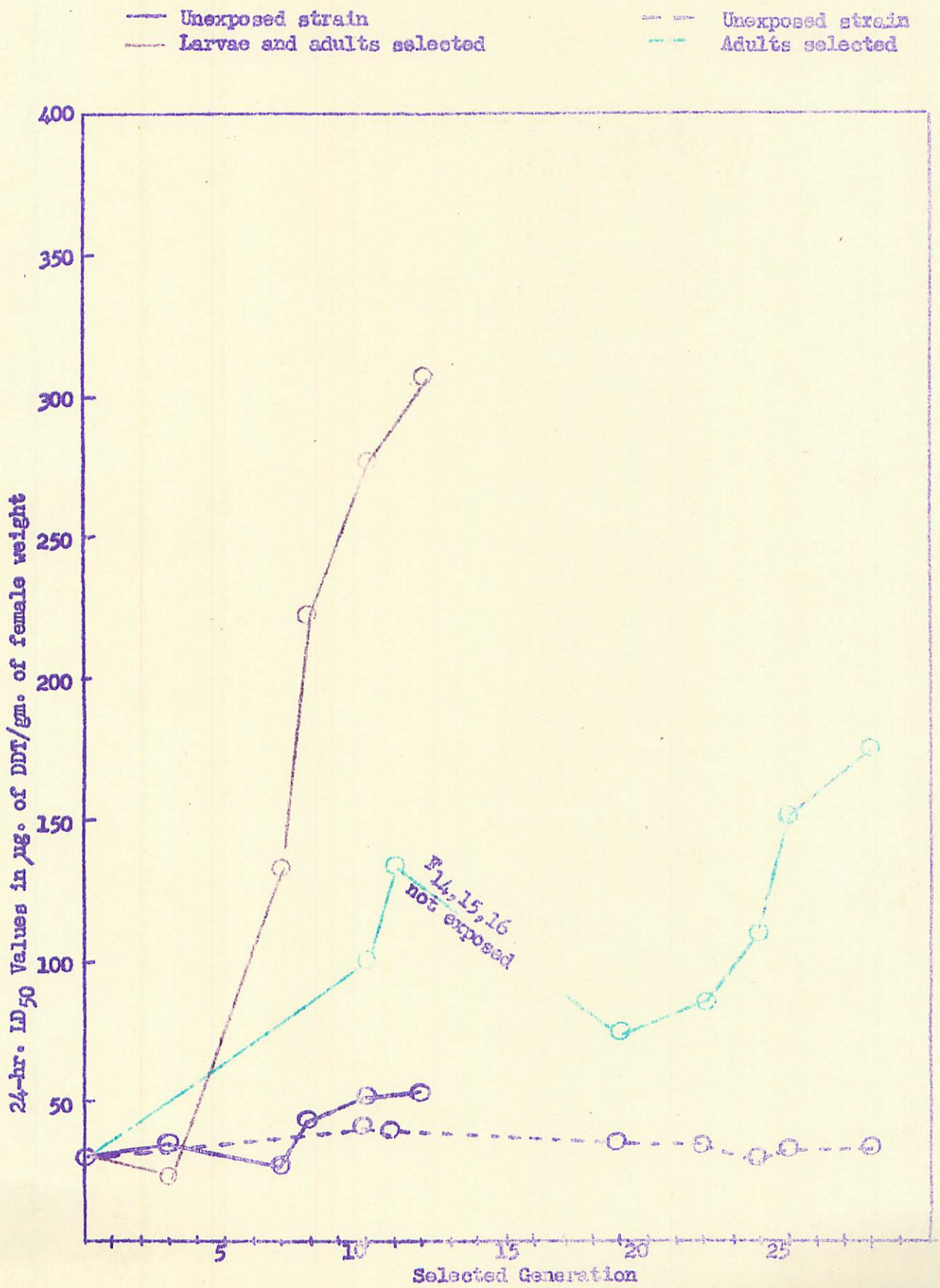
DDT-derivative, chlorinated hydrocarbons and phosphate compounds were tested topically and residually to investigate whether this strain of flies has developed cross-tolerance to these compounds. Topical test results showed that these DDT-resistant flies have also acquired resistance to methoxychlor, aldrin, dieldrin, heptachlor, chlordan, toxaphene and dilan. This strain has not built up any tolerance to phosphates (parathion and EPN) and to isodrin and endrin (isomers of aldrin and dieldrin).

It is interesting to note that this strain through partial selection as a result of exposure to DDT residues only has attained a low be definite degree of resistance to DDT and has also acquired resistance to compounds closely related to DDT.

In another strain, both the larvae and the adults are being selected to observe how rapidly the flies will acquire resistance under maximum exposure to DDT. The larvae were reared in a medium containing DDT. The concentration of DDT was increased gradually each generation to allow only 10-20 per cent of the larvae to survive, based upon the number of introduced eggs. In order to achieve this larval recovery, it was necessary to start with thousands of eggs. Eggs were collected for 4-hour periods over a 3-day period and incubated at different temperatures to induce egg hatch at the same time. Collection of large numbers of eggs eased the culturing procedure and also provided greater number of larvae and adults of uniform age each generation. At the start of the selection 10 to 15 p.p.m. DDT in the medium gave 10 to 20 per cent larval survivors. At present after ten selected generations, 170 p.p.m. DDT is required to achieve the desired selection.

Instead of selecting mature adults in small test cage lots, for this strain, sexually immature (3 days after emergence) flies were exposed in several 12-liter flasks completely coated internally with recrystallized technical DDT. Thousands of flies were handled in each flask. The adults were selected by at least two exposures to the toxicant (1 hour each day for two days) to minimize the daily variation among individual flies. Total treatment was calculated to give 80 to 90 per cent mortality. After 12 selected generations, these flies have

Figure 1. — DDT-RESISTANT ORIENTAL FRUIT FLY



developed a 6 to 7 fold resistance. The selection of both the larvae and the adults seems to have accelerated the development of resistance. This strain has been treated just about a year now and though it has not developed resistance to the degree reported for some house fly strains the use of DDT as a field control on fruit crops would not be practical against a population having this much resistance.

The Potential Resistance of the Oriental Fruit Fly to Parathion.--The larvae and the adults of the oriental fruit fly are being selected by culturing the larvae in a medium with parathion and exposing the adults in 12-liter flasks as mentioned previously for the DDT selection. Unlike the DDT strain the amount of parathion in the medium was increased only 0.005 to 0.01 p.p.m. each generation. Both the larvae and adults are very sensitive to even a slight increase in parathion dosage.

In another strain only the larvae are being selected to determine whether drastic larval treatment alone will contribute any protective effect in the adults' response to parathion and also to observe the rate of resistance acquired if any by selecting different stages of these flies. Larvae in fruit might contact absorbed parathion or related phosphate systemics. The larval stage would be unlikely to contact DDT except at time of pupation on soil under DDT-sprayed trees.

The two strains have been treated for parathion resistance for 15 generations (a little over a year) without any appreciable tolerance developing.

Periodic determination of the cholinesterase activity of all 4 selected strains are being made to observe any changes in the activity of this enzyme coincidental with the development of resistance. So far there has been no appreciable change in the characterization of these enzymes obtained from these resistant strains.

Field Resistance.--Wild fruit flies emerging from infested fruits collected from different parts of the islands are being evaluated for variations in resistance to parathion and DDT. The preliminary results of the topically treated wild and laboratory oriental fruit fly indicate in one case a tolerance of only two-fold to both parathion and DDT in flies collected from papaya from Waimanalo. Flies from guava collected at the same time and place were only half as resistant as the papaya-bred flies.

Mediterranean fruit flies from Hilo showed no tolerance to the insecticides. Melon flies from one location showed a tolerance of 2 times to DDT but no tolerance to parathion. To date, the wild flies from different parts of the islands show a very slight and possibly insignificant tolerance to DDT and parathion.

Mr. Steiner: Are there any questions?

Late in 1949 Dr. Robert Metcalf of the University of California spent a few weeks on this project in screening a number of new compounds topically and in assisting in acquainting our personnel with this technique. Most of our early tests were made by Mr. Hinman and Mr. Holloway and were not intended to set up dosage-mortality curves for each material but rather to compare the residual effectiveness at reasonable dosage levels with that of a standard. Practically all known insecticides available in 1949-1950 had been so tested by them.

Later in 1950-51 Dr. Walter Ebeling, also of the University of California, in cooperation with the University of Hawaii evaluated many of these materials against D. cucurbitae.

Late in 1951 Mr. Keiser was transferred to our staff and since then he and Mr. Holloway have continued the screening both by topical and by residual techniques of new proprietary preparations as well as several hundred coded compounds received from our Division of Insecticide Investigations.

They have not been able to give full time to this phase of the investigation since they also have assisted in laboratory evaluation of field spray treatments and in studies dealing with disinsectization methods for packing plant and transport facilities.

Mr. Keiser will discuss certain phases of the screening program.

Mr. Keiser: The laboratory screening of insecticides and other studies carried on wholly in the laboratory or partly in the field constitute an important phase of the work in the preliminary evaluation of insecticides, their comparative toxicities to different fruit fly species, indications of modes of action (contact, stomach poison and/or fumigant), and effectiveness of residual deposits after indoor and outdoor weathering.

In laboratory residual studies, technical and emulsifiable products are dissolved in or diluted with xylene, and 2 milliliters of the proper concentration are pipetted into a 100 millimeter Petri dish. Wettable powders are suspended in water, and the same volume (2 ml.) is applied per dish. Six concentrations (2 cages - 50 flies per cage at each concentration) are used for securing an adequate dosage-mortality curve. In topical tests, the technical and emulsifiable products are dissolved in or diluted with acetone, and one microliter of the proper concentration is applied to the thorax of the individual flies. Six concentrations are also used for securing an adequate dosage mortality curve (20-60 flies at each concentration).

Table 1 lists LD-50's and 95's for representative compounds screened against D. dorsalis. Parathion was the best, when evaluated both topically and residually at the 50 and 95 per cent levels. Geigy 22008 and 22870 were also highly satisfactory. Endrin was somewhat more toxic when tested topically than residually. Malathon technical and wettable powder performed about the same residually. However, Diazinon technical was about 10 times as toxic as the wettable powder. The latter material did not give consistent results and may have deteriorated in storage or transit. Conversely, DDT wettable powder was approximately 10 times as effective as the technical material in xylene, when tested residually in the laboratory.

In tests conducted to determine the optimum number of flies per Petri dish cage, 25-50 flies were found to be most feasible for use in these laboratory residual studies. For example, with DDT at 19.2 mg/cm^2 glass surface, 25 D. dorsalis gave mortalities of 46 per cent; 50, 42 per cent; 100, 20 per cent, and 150, 6 per cent. Need for sufficient surface per fly to pick up toxicant. Similar results with parathion. D. cucurbitae gave same results.

Table 1.—Comparative effectiveness of different insecticides against adult D. dorsalis when tested under laboratory conditions (24-hour counts)1/.

Insecticide		Micrograms toxicant per fly (topical)		Micrograms toxicant per sq. cm. of glass surface (residual)	
Name	Formulation	LD-50	LD-95	LD-50	LD-95
Parathion	96 tech.	0.01	0.04	0.07	0.31
Endrin	6.5 Em.	.01	.04	.88	1.6
Geigy 22870	100 tech.	.02	.1	.08	.90
Isodrin	6.5 Em.	.02	.07	-	-
Geigy 22008	100 tech.	.03	.1	.18	1.0
Geary 21/199	10 tech.	.03	.2	1.5	8.5
American Cyanamid 4124	100 tech.	.04	.2	-	-
Dieldrin	15 Em.	.04	.1	-	-
Dieldrin	25-50 WP	-	-	.21	.44
Malathon	89-97 tech.	.05	.1	.90	2.4
Malathon	25 WP	-	-	.80	2.5
Diazinon	100 tech.	.06	.2	.60	6.0
Diazinon	25 WP	-	-	6.7	14.7
Aldrin	25 Em.	.06	.2	-	-
American Cyanamid 3456	100 tech.	.09	.4	-	-
Chlorthion	50 Em.	.1	.5	.85	3.1
Geary 13/59	10 tech.	.1	.6	.75	2.0
Geigy 24483	100 tech.	.2	1.5	3.3	35.0
Geigy 23224	100 tech.	.4	3.0	-	-
NPD	85 Em.	.6	2.1	-	-
DDT	50 WP	-	-	3.0	7.9
DDT	100 tech.	1.0	4.1	28.0	178.0
Perthane	25 Em.	1.0	3.5	-	-
Rhothane	25 Em.	1.8	6.0	-	-
Geigy 24027	100 tech.	3.0	12.0	-	-

1/ Topical tests—dissolved or diluted in acetone; residual WP as water suspensions; all others in xylene.

Flies are sometimes under anesthesia up to 20 minutes when counted for insertion into cages. Tests were run at different intervals of anesthesia, using DDT and parathion. The results showed no significant differences up to 80 minutes of anesthesia for either D. dorsalis or D. cucurbitae. When tested at 160 minutes, mortalities were depressed for both DDT and parathion. Check flies were anesthetized up to 280 minutes with little or no significant effect on mortalities.

In our topical tests, both sexes treated, sex studies showed the male to be slightly more tolerant than the female. This is in contrast to Musca domestica, where the female is reportedly more tolerant to insecticides.

Whenever possible, fruit fly species other than dorsalis are also tested with different insecticides. As noted in table 2, chlorthion was very much less effective against D. cucurbitae than against D. dorsalis. As far as we know, this is the first instance of specificity of such magnitude for one species as compared with another, when both are so closely related as to be in the same genus. This was also noted when chlorthion was used as a residual.

In the course of laboratory residual studies with the newer Geigy compounds, in case any of these are substituted for G-22008 in methyl-eugenol test stations 2-hour counts were made to note the rapidity of cation by deposits on glass. These showed that D. cucurbitae was hardly affected during this period, although 24-hour mortalities of this species were as high or higher than those of D. dorsalis. A detailed test with parathion (fig. 1) showed only 3 per cent kill for cucurbitae as compared with 30 for dorsalis after 3 hours, and 14 and 56 after 4 hours, even though parathion was more toxic to cucurbitae (99) as compared with dorsalis (88) after 24 hours.

A third laboratory procedure in determining the effectiveness of different insecticides against fruit flies is testing fumigant action. The apparatus devised consists essentially of 2 Mason jars held together at the openings by a cap constructed of 2 rings soldered together. Two circular disks of window screening are held in place between jar and ring on each side. The insecticide or sprayed foliage is placed in the larger jar, and the smaller jar, containing 50 flies is coupled upside down to the large jar for the required exposure period. This jar is then removed and held with flies for a 24-hour observation period. Food and water may be furnished the flies after exposure.

In 2 laboratory tests, aldrin showed a very high fumigant quality as compared with parathion. Dieldrin was second in this respect. Extreme care was taken to prevent insecticidal particles from reaching flies, as parathion is so toxic. Also, exposure periods were only 1 and 3 hours. Therefore, in the field, air movement may spread particles and this may be more important than actual gaseous dispersion. Also, the flies would be exposed to the fumes constantly with no period for possible recovery as in the laboratory. A third study indicates a high degree of fumigant action by Systox and almost none for chlorthion, when tested in this manner.

A special apparatus was constructed for use in evaluating the effectiveness of insecticidal residues on foliage gathered from guava trees treated with different insecticidal formulations under field conditions, and subject to natural weathering. Four twigs are gathered from each replicated plot, and placed in florist tubes to prevent wilting until they are transferred to the laboratory. Each twig contains approximately 12 to 13 leaves, so that about 50 leaves are used from each replicated plot, or 200 from the four replicates of a particular

Table 2.—Comparative LD-50's of different insecticides against two fruit fly species, when tested under laboratory conditions.1/

Insecticide	Micrograms insecticide per fly (topical)		Micrograms insecticide per square centimeter (residual)	
	D. dorsalis	D. cucurbitae	D. dorsalis	D. cucurbitae
Parathion	—	—	0.06	0.06
Diazinon	—	—	0.2	0.2
Malathon	0.05	0.05	—	—
Chlorthion	0.12	1.20	0.85	19.0

1/ 24 hours' exposure.

Table 3.—Comparative effectiveness against adult D. dorsalis of insecticidal residues on guava foliage gathered from field-sprayed plots. 1952.

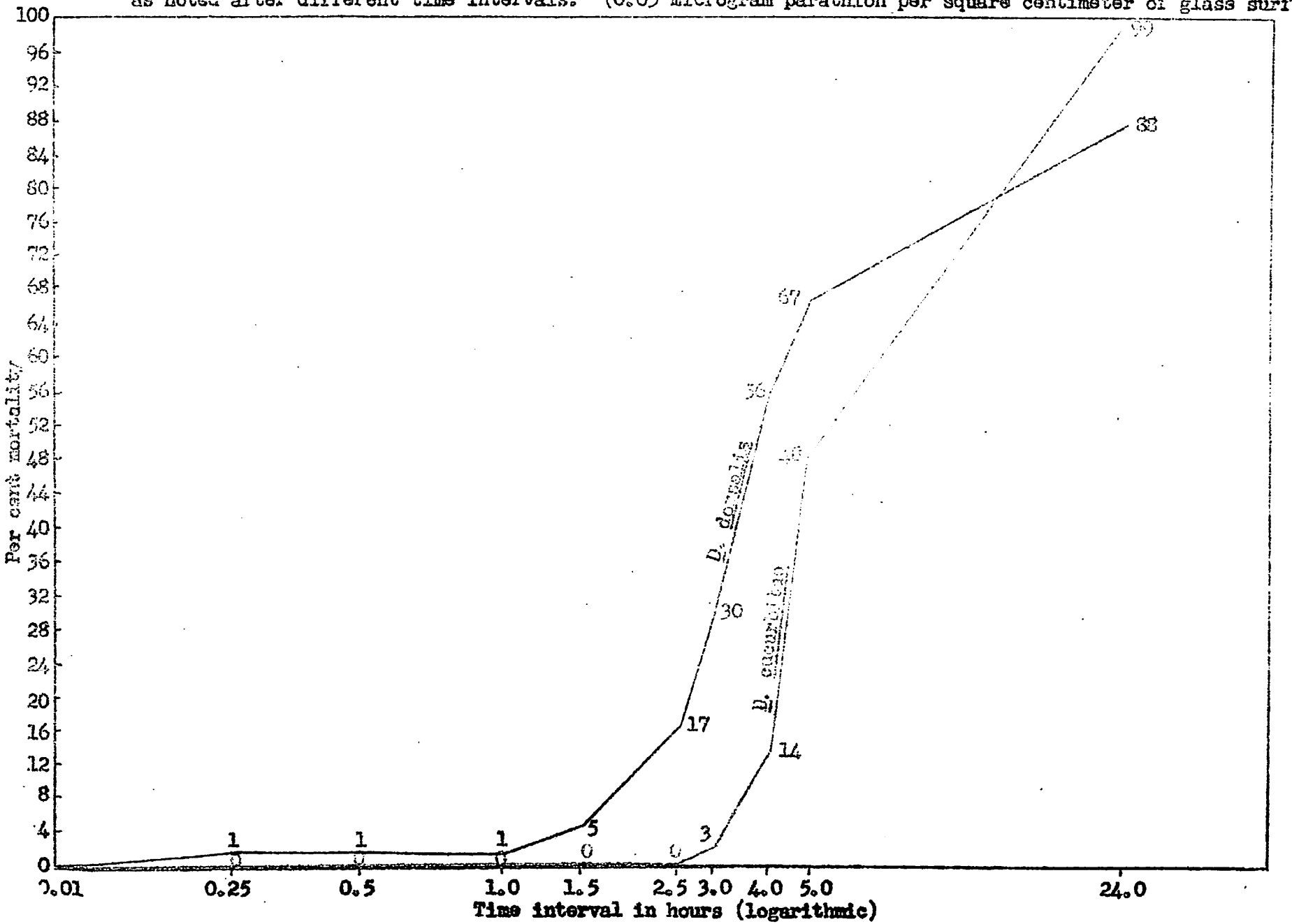
A. Wahiawa test area, large canopy-type trees. Sprayed from underneath.

Treatment		Per cent mortality (24 hours) from laboratory exposure of guava foliage gathered specified numbers of days after second and third treatments					
Ingredients	Pounds toxicant per acre	1	4	7	12	15	19
DDT 50 WP	10	92	95	87	61	77	80
Methoxychlor 50 WP	20	96	94	76	94	65	76
Isodrin 50 WP	2-1/2	93	94	58	58	61	24
Parathion 25 WP	5	100	99	89	86	21	27
Dieldrin 25 WP	2-1/2	100	99	77	40	14	14
Malathon 25 WP	5	99	63	37	2	1	-
Systox 33 Em.	2	75	18	4	5	2	-

B. Tripler test area, small scrub-type trees. Sprayed from outside.

Treatment		Average per cent mortality (24 hours) from laboratory exposure of guava foliage gathered specified number of days after second and third treatments				
Ingredients	Pounds toxicant per acre	0	4	7	11	13-14
EPN 300	6	99	87	55	21	6
Dieldrin 25 WP	6	100	88	39	26	7
DDT 75 WP	12	99	76	32	10	8
Methoxychlor 50 WP	24	88	78	26	18	7
Parathion 25 WP	6	100	69	16	6	5
CS-708 40 Em.	12	82	52	31	21	8
Lindane 25 WP	6	100	41	8	4	1
Heptachlor 25 WP	6	100	41	7	3	4
Malathon 25 WP	6	100	69	16	5	5
Cumulative rain (inches).		0	0.43	1.28	2.25	3.41

Figure 1.--Comparative toxicity of parathion to fruit flies exposed to laboratory residual deposits on petri dishes as noted after different time intervals. (0.03 microgram parathion per square centimeter of glass surface.)



experiment. The four twigs are placed beneath a 9 by 12 inch cage, and kept fresh by having the stems in water beneath the canoe board on which the cage rests. The stems lead through a modified florist tube to the water below, and the rubber cap with a hole takes stems of various thicknesses without affording an opportunity for fly escape. From 30 to 50 flies are placed in each cage and fed sugar water on a cotton pad for the 24-hour exposure period.

Table 3 shows the comparative effectiveness of field-sprayed guava foliage insecticidal residues against D. dorsalis when tested in the laboratory. At Tripler, EPN was the best, followed by dieldrin, DDT, methoxychlor, CS-708, and parathion at the particular dosages used. Similar collections were made from the Wahiawa test area, also sprayed by the project leader for overall evaluation. The results showed DDT, methoxychlor, and parathion were best in the order given. The duration of effectiveness was greater than at Tripler, probably due to spraying from ground up (under surface) at Wahiawa, and larger canopy-type trees affording greater protection from weathering. Also there was no rain of any consequence during the test period.

Tests with DDT and parathion combined with different fungicides sprayed on guava showed no adverse effects when foliage residues were tested in the laboratory, except for DDT plus Bordeaux mixture. In that combination, toxicity was significantly depressed between 6 and 9 days of field weathering. The other fungicides tested were wettable sulfur, Fermate, and a neutral copper compound.

A study was made at the request of the Plant Quarantines Division to find a suitable indoor spray for packing sheds. The sprays studied (fig. 2) were applied to disks of representative indoor building surfaces. These were tested as cage tops in a manner similar to residual deposits in Petri dishes. DDT suspension 75 WP at 0.5 lb. per gallon gave 100 per cent kill up to 132 days after treatment, when the experiment terminated. DDT emulsion and Dilan emulsion followed in order of effectiveness. Those insecticides with and without fumigant qualities showed interesting results with the different building surfaces tested (fig. 3). Unpainted plywood, for example, showed significantly longer duration of effectiveness than painted plywood when treated with lindane or chlordane. Deposits on aluminum and galvanized iron sheeting for both these insecticides were ineffective after a short duration. The absorbent surfaces, as unpainted plywood and canoe were effective for much longer duration because they probably g ve off fumes for a considerable period of time. Also, all surfaces were sprayed at once until run off began from about half. Therefore, absorbent surfaces may have retained more deposit than the others. With the DDT emulsion spray, the non-absorbent surfaces such as aluminum, glass, and galvanized iron sheetings showed best residual deposits, while the absorbent surfaces such as canoe the least. Window screening, either galvanized iron or plastic, was not as satisfactory with DDT, lindane, or chlordane emulsion, as with DDT suspension spray (wettable powder).

(10 minute intermission)

Figure 2.--Comparative effectiveness of insecticidal residues on representative indoor building surfaces, against D. dorsalis.

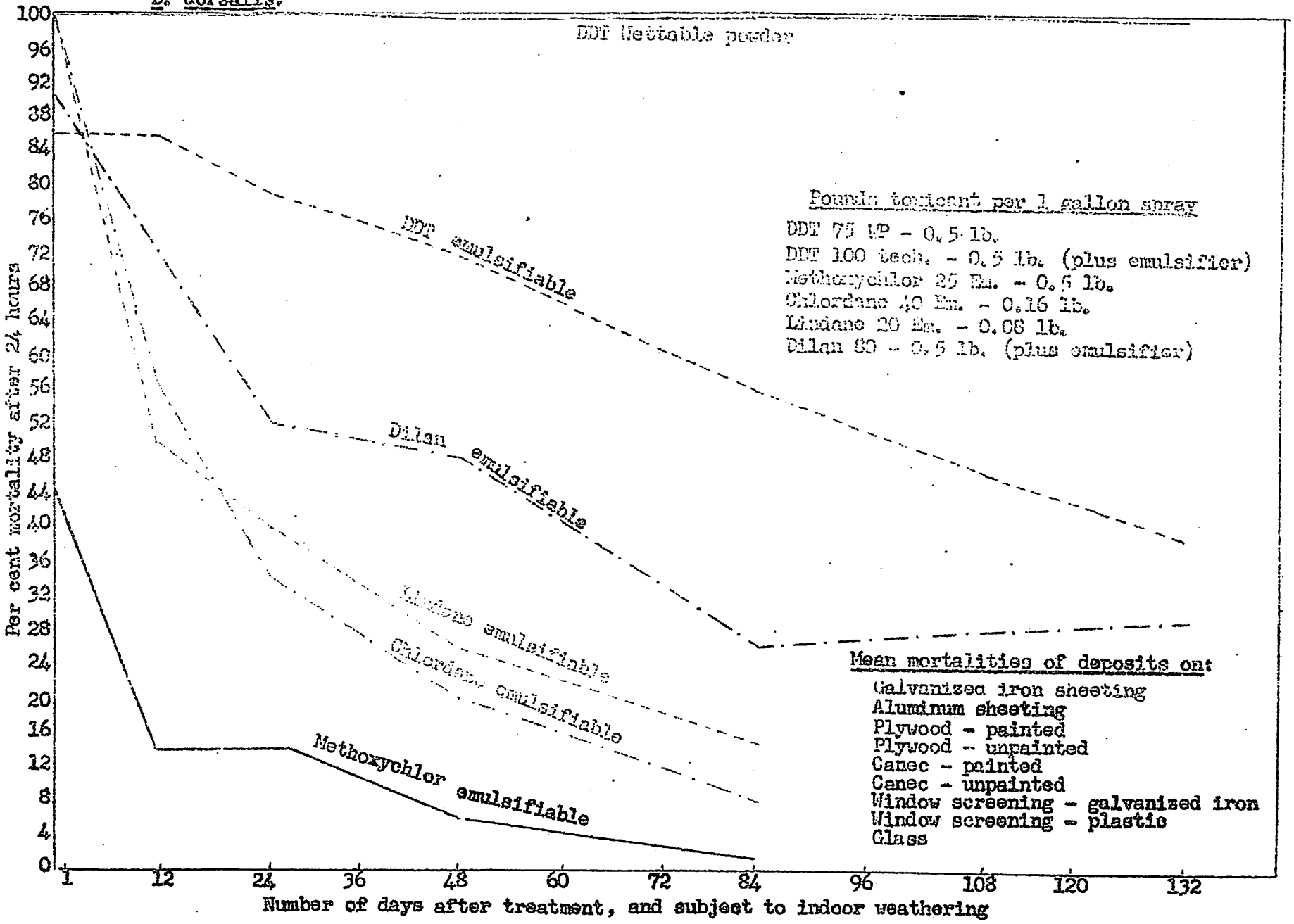
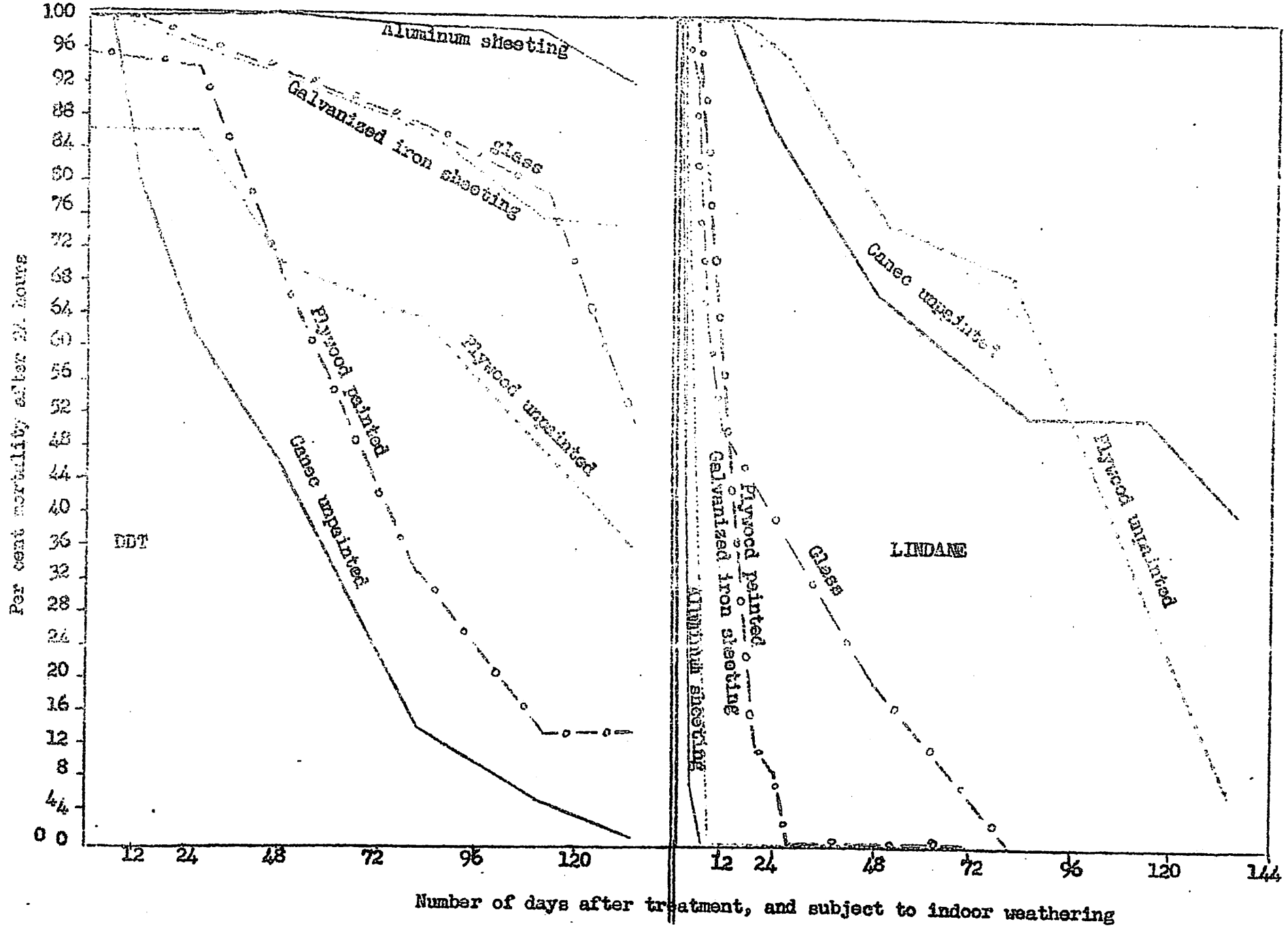


Fig. 3. Comparative effectiveness of DDT and lindane emulsion spray residues on representative indoor building surfaces, against adult D. dorsalis.



Mr. Steiner: Status of Chemical Control Research.

Although we have developed insecticide programs that will function well under certain conditions, they all have weaknesses that only repeated testing and continued study can bring to light. Even so, here in the Islands we do not have the range of conditions likely to be encountered in the event of a mainland outbreak and so cannot fully evaluate all factors likely to influence insecticide efficiency. Extreme temperature and humidity fluctuations and effect of insecticides and fungicides required for the control of other pests are only 2 of many examples.

There will probably be no end to the information that can be developed about any biological organism. With the rapid advances being made in new chemical development any cessation of our efforts, to develop new chemical controls would mean that we would rapidly lose ground in fruit-fly control research.

Our field tests have been too extensive to discuss in detail. Following this discussion is a listing of most of the spray treatments we have tested in the past two years and following this are examples of certain types of field experiments.

No one experiment can stand alone in evaluating an insecticide treatment. Our fruit sampling problem is quite different from Dr. Newell's. His 100 4-fruit sub-samples make up a single sample intended to represent a large area. There is little if any correlation between size of area sampled and size of sample needed. We also must obtain large samples, sometimes from very small areas, if we are to accurately ascertain the infestation index at any one time or place.

For example, 15 to 20 normal sized mangoes will fill a holding box. In a series of four 40-fruit samples collected from a single tree we had mean infestations ranging from 10.5 to 36 larvae per pound and standard errors ranging from 19 to 32 per cent of the mean. Single fruits produced from zero to 66 larvae. At the range of infestations usually encountered we should have a minimum of 150 fruits in most guava or mango samples. This is impossible since replication and frequent sampling would multiply the amount of fruit to be held too greatly. We therefore compromise by collecting enough fruit to fill a holding box, usually 50 guava, 15 to 18 mangoes, 5 papayas, etc., and obtain 1 to 3 such samples from each replicate each sample date. With periodic sampling between sprays, and the application of several sprays at intervals we can pool the data for several samples representing each time interval after spraying to determine length and extent of effectiveness. With continued testing under different conditions we gradually expose the weak and strong points of the insecticides so used.

The size of fruit plantings available often limit number of replicates, or treatments, or frequency of sampling. The length of harvest or ripening period limits the number of sprays that can be applied. Fruit flies present or arriving in an area when fruit begins to ripen may deposit most of their eggs in a short time. This may be followed by a declining infestation before the next brood appears, that will be mistakenly attributed to the spray treatment unless pre-spray infestation data is accumulated over a long enough period to determine if such a break will occur. Since the results will not be apparent until later all experiments set up on a scale large enough to avoid much reinfestation from outside should span a period long enough to allow at least 2 broods to develop.

These are only a few of the important reasons for our apparent repetition of specific or related spray formulas in various experiments.

The formulas in the listing come from nearly 20 different series of field tests usually involving 3 or more sprays at 2 week or longer intervals and involving nearly 1000 acres of small-plot spray coverage and the holding of many tons of fruit, occasionally up to 6 tons for a single experiment.

Bait Sprays

The most promising spray treatments available at present are combinations of parathion or malathion (new name for malathon) with certain enzymatic hydrolysates of yeast, first tested by this project in 1950.

Our data on melon and Medfly were obtained incidental to that on dorsalis. These species were found together on several occasions and at present both dorsalis and cucurbitae are abundant in the guava area used for our bait-spray development.

A detailed study of formulas is still being made in replicated field tests where small areas of guava foliage are treated and trays maintained underneath to catch dead flies. Some of the findings follow:

(a) Parathion 25 WP and malathion 25 WP (1953) are the two most promising toxicants tested. 1952 Malathion is less effective and may be repellent. Sodium fluosilicate, tartar emetic, chlorthion Em., diazinon 25 WP, and C-22008 are also much less effective. Slowly acting toxicants cannot be tested by the tray method.

(b) Rains reduce effectiveness rapidly. In dry weather, applications will attract flies 3 weeks or longer.

(c) A ratio of 1 part protein to 2 parts insecticide formulation is generally best since too much parathion is repellent. Malathion (1953) has not depressed catches when used at 5 lb. per pound of protein.

(d) The attractant is generally lost before the toxicant.

(e) Coarse, concentrated sprays, well distributed are more effective over long periods than dilute full coverage sprays because of less rapid loss of constituents. The 94 per cent control effected by 2 lb. malathion 25 WP plus 1 lb. yeast hydrolysate on mangoes (example 1) was accomplished with a 1-man-operated pickup truck, mounting a 7 g.p.m. sprayer and 2-nozzle boom, one nozzle pointing upward into the trees on each side. Spraying time was only 6 minutes per acre.

(f) Sugar should not be used in the formula for melon fly control. Present indications also are that it may not be needed for dorsalis control. The variable performance experienced in our tests is believed due to effects of competition from natural food sources. Where scale is abundant, sugar has detracted from the performance of the bait spray. More study on this point is needed. While the bait sprays have never been very attractive to parasites the omission of sugar should make them even less so.

(g) Cheaper proteins have been found but they also require more study. A partially hydrolyzed yeast protein at $1.50 per pound (instead of $2.20 to $3.60 for the 2 fully hydrolyzed products) was used on Maui in 1953 where it gave 100 and 98 per cent control of dorsalis on mangoes at 1 and 2 lb. per acre/application in combination with 4 or 2 lb. respectively of parathion 25 WP. The cost was less than $16 per acre for the season. In 2,700 ripening mangoes picked 4 days to 2 weeks after each spray only 5 were wormy (9% wormy before first spray). On Sept. 2, 3 weeks after the last spray, only 1/2 per cent of 200 fruit was wormy compared to 17.5% in the unsprayed orchard. In the field-tray tests we have had returns in terms of dead flies appearing on the trays at the rate of 2,000,000 per pound of protein applied (40 lb. of flies). The return of females per pound of protein used in a recent 3-week test following 1 application was at the rate of 384,000 dorsalis and 580,000 cucurbitae.

(h) The adult flies have a strong urge to search foliage for food. Bait sprays on detached fruit or other surfaces as close as 18 inches from foliage will not attract flies. Even the effectiveness on foliage is lost if the leaves wilt but remain in position. Thus while bait sprays may bring flies from some distance the flies will feed on them most effectively if the deposits are on the growing leaves. The use of absorbent surfaces such as cellulose sponges impregnated with the formula and attached to twigs among leaves has given good results but is less practical than direct application to foliage.

(i) The partially hydrolyzed yeast protein is less hygroscopic than the fully hydrolyzed materials but unlike the latter it is not fully soluble in water. It will cake if moist air gets to it but it can be shipped in larger containers. At the suggestion of Mr. Christenson we have tried and had good success with dry-mix formulations of this product plus either parathion or malathion wettable powders to provide a single formulation requiring nothing but the addition of water.

(j) Bait sprays on trees subject to rapid reinfestation will not prevent fly oviposition. It must be realized that in using the bait spray we most likely kill only hungry or feeding flies and can have little hope of distracting a well fed female full of eggs and bent on ovipositing. Later she can be expected to feed and die. Results to date indicate that low-toxicant bait sprays are not likely to function well on small plantings of non-isolated hosts.

While bait sprays used on a backyard tree might pull in one's neighbor's flies it is probable that those attracted would all be most interested in feeding and so the general level of population would be reduced to the equal benefit of both neighbor and user. The value of such treatments are difficult to check. We need to set up single-tree plots widely dispersed to avoid interplot influence, and adequately replicated in some uniformly infested large host area. (see example 4)

We have not been successful in devising a field tray or laboratory technique for testing slow-acting toxicants. Some regular tests have been made in the field, and dieldrin, among the materials tested, seems most promising. When used at only 1/2 lb. toxicant per acre in a bait spray, dieldrin doesn't greatly reduce parasitization.

Sugar reduces the residual toxicity of most insecticides; hence, when its need became questionable, we set up a series of tests on 3-acre guava plots replicated 3 times and sprayed 3 times at 2-week intervals. (See example 3) Dieldrin and parathion, each at 0.5 lb. toxicant per acre with 0.75 lb. yeast hydrolysate, gave 94 per cent control of dorsalis compared to 87 per cent for twice as much DDT and 91 per cent for 50 per cent more CS-708. Aldrin failed completely in other tests and lindane, which was effective the first week, was worthless later.

Non-Bait Sprays

In this discussion I should like to give the good and bad features of those insecticides that might be available and adapted for control operations. This evaluation is based on the results of field tests as given in the attached listing plus our previous experience from 1949-1951.

We have consistently found wettable powders more effective than emulsifiables for use as residual toxicants and therefore have worked almost exclusively with them since 1952.

Parathion 25 WP.—At 2 or more pounds toxicant per acre, its foliage deposits often have good residual action for a week or more and generally are 100 per cent effective for 1 to 4 days.

It is the best known toxicant for bait sprays and is excellent for use with methyl eugenol. Its fumes or airborne particles from spray deposits are outstandingly effective in killing flies not contacting sprayed surfaces up to 4 days after sprays—it is equaled only by dieldrin in this respect. It requires less than half as much toxicant as DDT for comparable results despite its shorter residual action.

Parasitization is only partly depressed in sprayed areas. Residues on fruit sprayed one day before picking rarely exceed 2 p.p.m. and with the usual bait spray formulas, only 0.5 p.p.m. It has given outstanding results in most tests. It shows less differential toxicity among the 3 species of flies than DDT and is more suitable therefore for mixed populations. Fruit flies have shown no indication of increasing resistance to parathion. It may be combined effectively at reduced dosages with slower-acting toxicants like DDT or dieldrin.

It is one of the quickest-acting toxicants available for field use against adult flies and will kill many larvae or eggs already in fruit.

It is an outstanding soil toxicant for periods up to 30 days after application at rates of 5 lb. or more per acre.

It is outstanding as an aerosol fog, and wind-borne fogs will kill flies at 1/8 to 1/4 mile from the discharge point at application rates of 1/4 ounce per acre but is not presently considered safe for such usage.

It is toxic to presumed important insect sources of essential food elements for fruit flies. I refer to certain scale, mealy bugs, aphids, etc. We have noted that in long-term tests parathion becomes relatively more effective after 3 or 4 sprays. DDT improves as a result of residue accumulation and improved

spray coverage resulting therefrom. Parathion accumulates very little but residues that may be harmless to flies as long as they do not feed can kill as soon as they are consumed. We need to determine if this extra kick results (1) from the destruction of essential food sources to reduce oviposition and lower tolerance to insecticides as a result of dietary deficiencies, or evacuation of flies from the area in search of the missing elements, (2) if instead, all food sources become poisoned, or (3) if the soil accumulations reach a point where flies ovipositing in drops or emerging from the soil succumb to fumes or deposits from residues on the soil or low-growing vegetation.

Malathion 25 WP.--Equal to parathion in protein hydrolysate bait sprays at least for 1 week after application for both dorsalis and cucurbitae. Its shorter residual action when used alone is likely to make it of little use in small-scale applications except for its initial contact effect.

It is safer than parathion to the spray man and from the residue standpoint.

The 1953 formulation needs more study in non-bait sprays. It seems to have a pronounced attraction for blow flies.

Systox.--In the early small-scale tests when Systox gave excellent results, we obtained evidence of systemic action by a technique where we artificially infested media made from guava pulp. The technique had serious faults and the results were not considered completely reliable. Good field control on small plots could have been due to repellency since Systox has no surface residual action on foliage after 1 or 2 days' exposure.

The indications of good systemic action have recently been verified by an improved laboratory technique where a pad of 100 eggs is applied to the cut end of single guavas from the test plots at intervals after sprays and the larvae dissected from the fruit 6 days later.

After 2 lb. toxicant per 100 gal. were applied in 3 monthly sprays, guavas retained enough toxicant to produce 100 per cent control of applied larvae for 7 weeks after the last spray and still had a substantial effect 3 months after the spray when fruit was ripening which at time of spraying was in the bloom or bud stage. The action from dosage levels above 1 lb. per 100 gal. develops soon enough after a spray to kill some larvae or eggs already in the fruit. Its value on other crops has not been determined. There are indications, as yet unconfirmed, that parasites either do not attack or cannot survive in larvae in Systox-sprayed fruit. The juices from fruit toxic to larvae are relatively non-toxic to adult flies.

Systox and possibly other systemics might prove very useful in giving long-time control of flies breeding in non-edible hosts or in marketable crops in the event any are proven sufficiently non-toxic for such use.

Systox has some fumigant action against adult flies.

G-22008.--This Geigy Company compound is the best known toxicant for use with methyl eugenol. It is completely soluble therein, thus eliminating the need for other ingredients. It has very rapid stomach poison effect, thus preventing loss of attractant by fly consumption. Needs more evaluation in regular field tests.

It is equal to parathion in fog sprays, giving long-distance kill at very low application rates. (Not considered safe.)

EPN-300.--Similar to parathion in many ways. Shows longer residual action on foliage to adult flies, but its fumes or air-borne particles are less toxic to flies not contacting sprayed surfaces. Less effective than parathion in bait sprays. Results in limited field tests, erratic.

Dieldrin 25 WP.--Effective in large-scale bait sprays on basis of limited evidence. Probably most outstanding insecticide for large-scale use in regular foliage applications at application rates of 1 lb. or more per acre. As a soil toxicant, may remain highly effective for several months at dosages as low as 5 lb. per acre. Residues from sprays applied to foliage may kill pupating larvae months later in the soil beneath the sprayed trees. Fresh foliage applications result in a sufficient concentration of fumes or air-borne particles to kill all flies in the area several days after spraying. Has unusually long residual toxicity but because of its slow rate of action this characteristic is of value chiefly in large-scale operations. Results in small-plot tests have been erratic with good evidence that ovipositing flies may either be attracted into the sprayed area or having contacted the poison are stimulated to deposit many eggs before succumbing to its slow but sure action. Increased infestations sometimes are associated with small-scale use but are not likely with large-scale spraying.

Its present rating as an insecticide too dangerous for use on food crops would limit it as a fruit fly control to soil applications, possibly in low dosage bait sprays to inedible portions of the host, or as a regular spray to non-edible hosts. Parasitization is depressed more by this insecticide than any other except possibly aldrin. It is very toxic in fog-type sprays making wide swaths possible but is less effective than parathion or G-22008. Emergence of pupae are depressed greatly which adds to its value for large-scale operations.

Outbreaks of Amorbia emigratella followed the use of dieldrin and aldrin in guava areas infested by the Argentine ant but not elsewhere.

Aldrin 25 WP.--Most useful as a soil toxicant. Almost as effective as dieldrin. Not dependable as a host spray except for large-scale use since, like dieldrin, it may result in increased local infestations. Its length of residual action is shorter than that of dieldrin and it has almost the same adverse effect on parasites.

Fumigating effect very good.

Isodrin 25 WP.--Very promising as residual toxicant but not sufficiently studied.

Lindane 25 WP.--Effective bait-spray toxicant at low dosages for periods up to 1 week. Less effective than parathion, dieldrin, or aldrin in the killing effect of its fumes or air-borne particles. Of little value as a residual toxicant at economical application rates. Depresses parasitization much less than dieldrin. The emulsifiable is useful as a residual toxicant on absorbent wall or ceiling surfaces for controlling flies in enclosures but of little value on non-porous substances.

DDT-WP.--May be used as 50 or 75 per cent wettable powders. It has long-time residual action but is much less toxic than parathion or dieldrin. Must be used at application rates that are likely to leave objectionably heavy residues on

on edible fruits in the smaller sizes. If dorsalis acquires a 3- to 5-fold tolerance to this insecticide, DDT will no longer have any practical value in fruit fly control on food crops because of the residue hazard. As a residual for treating interior surfaces of packing plants, etc., it is unexcelled. At 0.5 lb./gal. it has left deposits that remained highly effective for 6 months. DDT sometimes depresses parasitization in field-sprayed plots more than most insecticides other than dieldrin or aldrin.

It is generally highly effective against dorsalis at application rates of 4 or more pounds toxicant per acre. It can be supplemented by the addition of EPN, parathion, or malathion.

Emulsifiable DDT is much less effective as a residual toxicant than is the wettable powder formulation.

CS-708, WP or Em.--The performance of this material has generally been good, though erratic. It has rather long residual action but on a cost basis is less practical than DDT. Like DDT its use on mangoes has resulted in substantial increases of mites. It rates next to DDT (among the materials tested) as a residual for use on wall surfaces, porous or otherwise.

Methoxychlor WP-50.--The wettable powder formulation at high concentrations may be very useful for small area control operations where cost is not an important factor and where more toxic insecticides would be unsafe for use. It should be applied with the minimum of water needed to get good coverage without run-off in order to conserve the large amounts that must be used.

Miscellaneous Insecticides.--Materials that have generally given poor control in tests of one or more types include Heptachlor, metacide (except as a toxicant in bait sprays where it works well), DuPont's NPD, Aramite, and chlordane.

Control Suggestions.--On the basis of present knowledge, in the event of a mainland outbreak of D. dorsalis the following steps would be most likely to insure eradication, if the infestation is not too widespread.

(1) Immediate placement of methyl eugenol-G-22008 baited traps in suspected areas with a more concentrated placement of 10 to 20 per square mile out from known infestations in order to delimit such areas.

(2) The application of dieldrin as a soil poison in all known infested host areas at 5 to 10 lb. per acre wherever such applications could safely be made. Substitute soil toxicants would be BHC, Lindane, aldrin, or parathion at similar application rates. (DDT is completely ineffective.)

(3) The application of bait sprays using parathion 25 WP where possible (or malathion 25 WP otherwise) at rates of 4 lb. formulation per acre plus 1 lb. of one of the enzymatic yeast hydrolysates previously mentioned in coarse but well-distributed low gallonage sprays to all host and nearby ornamental or forest vegetation in the area shown by the traps to be infested. Such sprays should be applied at 2-week intervals until all traps within approximately 1 mile have failed to catch additional flies for a reasonably safe interval. The application rate should be increased where vegetation is very dense or trees large.

For use in commercial fruit plantings in the islands against any one or more of the 3 species, the parathion bait spray is most practical. For cucurbitae control on border trap crops or for direct application to cucurbits, tomatoes, melons, or squash, the malathion formula appears most promising but is in need of field testing beyond our current passion fruit experiment which involves a mixed population of dorsalis and cucurbitae.

For use on backyard trees, the heavy methoxychlor WP-50 sprays appear most useful.

Large-Scale Tests of Methyl Eugenol-Poison Bait Stations for Control of D. dorsalis.

A promising and unique method of fruit fly control under investigation consists of the destruction of male flies before they are able to fertilize newly emerged females by attracting the males to poisoned methyl eugenol feeding stations where they are killed. The first large-scale test of this method conducted in Opaeula gulch on Oahu was concluded in 1952 after 28 months of operation. Guava infestations within this 1/4 to 1/2 mile wide gulch--protected for 1.5 miles along its rims with 55 poisoned feeding stations--averaged only 4 larvae per pound of guava from February 12 to May 12, 1952. This was 76 per cent less than the average infestation in surrounding, untreated gulches and approximately the same as the reductions obtained in previous guava crops.

Because of the need for additional replication and information on the effectiveness of the male annihilation method in other environments, new tests were run on Hawaii from January, 1952, to early May, 1953.

One of these consisted of a 6-square mile treated area on the wet Hamakua coast extending from sea level up the slopes of Mauna Kea for 2-1/2 miles to the forest line at an elevation of 2100 feet. The other involved a small area of isolated guava in a comparatively dry environment on the south slope of Kilauea at an elevation of 2500 feet.

In the Hamakua experiment, 180 feeding stations, later increased to 215, were distributed along the windward rim of gulches and the coastal pali, and in the other host areas scattered along the extensive sugar cane fields. The feeding stations were canec squares, each treated at monthly intervals with 30 ml. of methyl eugenol containing 3 per cent G-22008.

In an experiment of this kind if the fly population tends to evaucate an area before the females become very old the visible effect of male annihilation on the infestation should begin to develop almost immediately, otherwise the full effect will not be evident until all fertile females have died which may take several months.

In the Hamakua experiment we set up 2 permanent sampling sites in or near the middle treated gulch (Kaula) at each of 300, 700, 1100, 1500, and 1900 ft. elevations, and at comparable sites in areas 1-1/2 to 3 miles northwest and also southeast of the treated area. Picked guava samples (usually 50 fruit) were taken from these 30 sites 37 times, or from 2 to 3 times monthly except in June and July, 1952, when there was no crop.

SOME RESULTS OBTAINED WITH VARIOUS SPRAY FORMULAS IN FIELD TESTS COMPLETED SINCE 1951

CHEMICAL CONTROL - L. F. Steiner, Project Leader

These data are intended to illustrate the variability in performance experienced at various dosage levels, types of experimental design, and on different hosts. Dosage rates were purposely held low enough to permit comparisons between treatments, hence general control recommendations would call for higher application rates than listed herein for most of the treatments.

The per cent change in treated area from that in the controls (for which we may use pre- and post-spray infestation data, or untreated replicated plots, or nearby comparable areas) represents the means of all samples taken at periodic intervals after each spray for the period shown under "Time." This usually coincides with the spray interval although in some instances sprays were spaced farther apart with infestations shown only for the first 2 weeks after each.

The results of several representative field experiments are given in Examples 1 to 7 inclusive which follow the data given below.

Key:
- YH: Yeast hydrolysate, NBC.
- PH: Protein hydrolysate, MRT.
- PHYP: Partially hydrolyzed yeast protein, MRT (experimental).
- SC: Small plots contiguous or close. Less than 50 ft. diameter.
- SD: Small plots dispersed. Less than 50 ft. diameter.
- R: 5-20 trees to single row plots generally separated by unsprayed controls.
- Water: Refers to gal. per acre in spray.
- Sugar: Raw cane sugar.
- Em: Emulsifiable.
- 25 WP: Wettable powder with 25 per cent active ingredient.

Formulation and Additive	Pounds active ingredient per acre	lv./lb. fruit in control	% change in treated	Sprays			Plots		Host
				Time wks.	No.	Water	Acres	Repl.	
PARATHION 25 WP BAIT SPRAYS									
Parathion, PH, sugar	2,2,20	5.6	-99	2	3	200	SC	4	Guava
Parathion, YH, sugar	2,1,5	5.3	-98	2	3	100	7 1/2	1	Mango
Parathion, PH, sugar	1.5,0.5,6	12.9	-87	2	4	20	1	2	Mango
Parathion, YH, sugar	1,1,5	1.1	-100	2	3	135	7 1/2	1	Mango
Parathion, YH	1,1	8.3	-99	2	3	135	7 1/2	1	Mango
Parathion, PHYP	1,1	2.4	-100	2	3	27	7 1/2	1	Mango
Parathion, YH, sugar	1,1,5	4.4	-97	2	3	27	3	3	Mango
Parathion, YH, sugar	1,1,5	1.8	-96	2	2	16	3	1	Guava
Parathion, PH, sugar	1,2,10	5.0	-81	2	6	300	SD	5	Guava
Parathion, PH, sugar	0.6,0.75,7.5	13.9	-93	2	5	25	1	1	Banana
Parathion, PH, sugar	0.6,1.5,12	13.5	-64	2	3	100	SD	5	Papaya
Parathion, PHYP	0.5,2	4.8	-98	2	3	135	7 1/2	1	Mango

Formulation and Additive	Pounds active ingredient per acre	Av./15 fruit in control	% change in treated	Sprays Time wks.	Sprays No.	Sprays Water	Plots acres	Plots Repl.	Host
PARATHION 25 WP BAIT SPRAYS (cont'd)									
Parathion, YH, sugar	0.5,1.5	9.0	-93	2	3	100	6 1/2	1	Mango
Parathion, YH, sugar	0.5,0.75,3	15.8	-84	2	3	8	3	3	Guava
Parathion, YH	0.5,0.75	16.1	-94	2	3	8	3	3	Guava
Parathion, YH, sugar	0.5,0.5,2.5	11.7	-96	2	3	6	3	3	Guava
Parathion, YH, sugar	0.25,0.5,2.5	20.3	-73	2	3	4	6	1	Guava
Parathion, PH, sugar	0.25,0.5,5	16.6	-91	3	3	4	5	2	Guava
BAIT SPRAYS OTHER THAN PARATHION									
Malathon 25 WP ('53)+ YH	0.5,1	23.6	-94	1	5	40	7 1/2	1	Mango
Dieldrin 50WP, YH	0.5,0.75	15.8	-94	2	3	8	3	3	Guava
CS-708 25WP, YH	0.75,0.75	19.3	-81	2	3	8	3	3	Guava
DDT-60 Em, sugar	3,7.5	13.9	-71	2	4	25	1	1	Banana
DDT-75WP, YH	1,0.75	16.4	-87	2	3	8	3	3	Guava
Lindane 25 WP, YH, Sugar	0.25,0.5,2.5	20.3	-21	2	3	4	6	1	Guava
Aldrin Em, YP, sugar	1,1.5	1.8	-7	2	2	16	3	1	Guava
PARATHION 25 WP									
Parathion	6	1.8	-90	2	2	600	0.33	4	Guava
Parathion	5	5.6	-98	2	3	200	SC	4	Guava
Parathion plus Nat'l Sticker	5,4	5.6	-99	2	3	200	SC	4	Guava
Parathion	3	12.9	-93	2	3	40	0.5	2	Mango
Parathion	2.5	4.4	-95	2	3	27	3	3	Mango
Parathion	2	5.0	-98	2	6	300	0.33	5	Guava
Parathion	1.5	13.9	-80	2	4	25	0.25	4	Banana
Parathion	1.5	13.9	-79	2	4	300	0.25	4	Banana
Parathion	1	6.9	-82	2	3	6	3	3	Guava
Parathion	1	13.9	-67	3	3	100	R	3	Guava
Parathion	1	104.0	-65	2	1	400	R	4	Guava
Parathion	0.6	13.5	-64	2	3	100	SD	5	Papaya
Parathion (To Soil Only)	1	104.0	-63	2	1	400	R	4	Guava
SYSTOX									
Systox Em.	2	5.0	-97	2	6	300	SD	5	Guava
Systox Em.	2	5.6	-98	2	3	200	SC	4	Guava
Systox Em.	2	13.9	-91	3	3	100	R	3	Guava
Systox Em.	1	13.9	-84	3	3	100	R	3	Guava
Systox Em.	0.7	104.0	-59	2	1	400	R	4	Guava
Systox Em. (To Soil Only)	0.7	104.0	-12	2	1	400	R	4	Guava

Formulation and additive	Pounds active ingredient per acre	lv./lb. fruit in control	% change in treated	Sprays			Plots		Host
				Time wks.	No.	Water	acres	Repl.	
DIELDRIN 25 WP									
Dieldrin	6	1.8	-75	2	2	600	0.33	4	Guava
Dieldrin	3	12.9	-98	2	4	40	0.5	2	Mango
Dieldrin	2.5	5.6	-98	2	3	200	SC	4	Guava
Dieldrin	2	5.0	-97	2	6	300	0.33	5	Guava
Dieldrin	1.5	23.1	-97	4	3	100	SC	4	Papaya
Dieldrin, Parathion 25 WP	1.5,0.5	5.0	-96	2	6	300	0.33	5	Guava
Dieldrin	1.5	13.9	-40	2	4	25	0.25	4	Bananas
Dieldrin	1	13.5	-80	2	3	100	SD	5	Papaya
Dieldrin	0.5	21.5	-89	3	3	8	4	2	Guava
Dieldrin	0.25	13.9	-81	2	4	25	0.25	4	Banana
ALDRIN									
Aldrin 25 WP	2	5.0	-86	2	6	300	0.33	5	Guava
Aldrin 25 WP	1.5	13.9	-57	2	4	25	0.25	4	Banana
Aldrin 25 WP	1.5	13.9	-47	2	4	300	0.25	4	Banana
Aldrin Em.	1	1.8	-42	2	2	16	3	1	Guava
Aldrin-Xylene-Helix oil- Fog	45 gm.	42.3	+ 4	2	4	0	65	1	Banana
DDT									
DDT 75 WP	12	1.8	-91	2	2	600	0.33	4	Guava
DDT 50 WP	10	5.6	-98	2	3	200	SC	4	Guava
DDT 50 WP	6	12.9	-96	2	4	40	0.5	2	Mango
DDT 50 WP, EPN 300 WP	5,0.5	12.9	-95	2	4	40	0.5	2	Mango
DDT 75 WP	4	5.0	-95	2	6	300	0.33	5	Guava
DDT 50 WP	4	5.0	-94	2	6	300	0.33	5	Guava
DDT 75 WP	4	13.9	-60	3	3	100	R	3	Guava
DDT 75 WP	4	23.1	-90	4	3	100	SC	4	Papaya
DDT 50 WP, EPN 300 WP	3,0.4	4.4	-92	2	3	27	3	3	Mango
DDT 50 WP, Dieldrin 25 WP	3,0.2	13.9	-69	2	4	25	0.25	4	Banana
DDT 50 WP	3	13.9	-82	2	4	25	0.25	4	Banana
DDT 50 WP	3	13.9	-82	2	4	300	0.25	4	Banana
DDT 75 WP	2.2	13.5	-50	2	3	100	SD	5	Papaya
DDT 50 WP	1.5	19.4	-82	3	3	8	4	2	Guava
DDT-Xylene-Helix oil (Fog)	180 gm.	35.8	+ 4	2	4	0	35	1	Banana
CS-708 (Dilan)									
CS 708 -40 Em.	12	1.8	-62	2	2	600	0.33	4	Guava
CS 708--LC 80+ Malathon 50 Em+ Triton B-1956	4+0.75	4.4	-93	2	3	27	3	3	Mango
CS 708, 50 WP	4	5.0	-90	2	6	300	0.33	5	Guava
CS 708, 25 Em.	2	12.9	-92	2	4	40	0.5	2	Mango
CS 708, 25 WP	1.5	23.1	-87	4	3	100	SC	4	Papaya
CS 708, 25 WP	1	13.5	-58	2	3	100	SD	5	Papaya

Formulation and Additive	Pounds active ingredient per acre	Lv./lb. fruit in control	% change in treated	Surveys			Plots		Host
				Time wks.	No.	Water	acres	Repl.	
METHOXYCHLOR									
Methoxychlor 50 WP	24	1.8	-75	2	2	600	0.33	4	Guava
Methoxychlor 50 WP	20	5.6	-98	2	3	200	SC	4	Guava
Methoxychlor 50 WP	10	23.1	-95	4	3	100	SC	4	Papaya
Methoxychlor 50 WP	4	23.1	-87	4	3	100	SC	4	Papaya
Methoxychlor 50 WP	4	13.5	-51	2	3	100	SD	5	Papaya
Methoxychlor 50 WP	2	13.5	-26	2	3	100	SD	5	Papaya
MISCELLANEOUS INSECTICIDES									
G-22008 50 Em.	3	12.9	-95	2	4	40	0.5	2	Mango
G-22008 50 Em.	2	5.0	-83	2	6	300	SD	5	Guava
EPN 25 WP	6	1.8	-72	2	2	600	0.33	4	Guava
EPN 25 WP	1.5	13.9	-67	2	4	25	0.25	4	Banana
Lindane 25 WP	6	1.8	-94	2	2	600	0.33	4	Guava
Malathon 25 WP ('52)	6	1.8	-80	2	2	600	0.33	4	Guava
Malathon 25 WP ('52)	5	5.6	-99	2	3	200	SC	4	Guava
Malathon 25 WP ('52)	0.6	13.5	- 2	2	3	100	SD	5	Papaya
Heptachlor 25 WP	6	1.8	-68	2	2	600	0.33	4	Guava
Heptachlor 25 WP	1	13.5	-52	2	3	100	SD	5	Papaya
Metacide 32 Em.	2	5.0	-85	2	6	300	SD	5	Guava
Metacide 32 Em.	1	13.9	-66	3	3	100	R	3	Guava
Aramite 15 WP	0.6	13.5	0	2	3	100	SD	5	Papaya
Isodrin 25 WP	2.5	5.6	-98	2	3	200	SC	4	Guava
DuPont NPD 25 WP	1	13.9	+54	3	3	100	R	3	Guava

EXAMPLE 1 (Large Plot--Single)
CHEMICAL CONTROL PROJECT - FIELD TEST SUMMARY

Host: Mango

Location: Molokai - H.S.P.A.

Period: 6/3-8/27/53

Plot size: 7 1/2 acres

Replicates: 1

Application Method: CH-400 with fixed single nozzle boom directed upward into trees on each side of middles.

Spray Interval: 1 week

Controls: Pre-spray X

Rem. plots

Adjacent comparable area: X

5 sprays applied

7/2, 9, 15, 23, 31

Formulation and pounds per acre/application in 40 gal. water	Larvae per lb. fruit in controls	Mean per cent change in treated area--1 week after each of 5 sprays	Remarks
NBC yeast hydrolysate - 1	adjacent		Weighted on basis of 5 Mapelehu, 2 Haden, and 1 mixed variety sample.
Malathon 25 WP (1953) - 2	9.5	-64	
	pre-spray		Samples of 13-17 picked fruits collected 1 week after each spray usually 5 from Mapelehu, 2-3 from Haden, and 1-2 from mixed varieties.
	23.6	-94	

Four weeks after final spray the infestation averaged 17.2 and 26.6 larvae per pound in control and treated areas respectively, with 34 and 52 per cent of the fruit producing larvae.

Male fly catches per trap hour in restricted output methyl eugenol traps averaged:

	Pre-spray	Avgs. 7 days after each spray	1 wk. after final spray
Treated area	143	29	102
Control "	69	63	84

Prevailing wind direction from treated to control area.

EXAMPLE 2 (Large Plots Replicated - Commercial Mango)
CHEMICAL CONTROL PROJECT - FIELD TEST SUMMARY

July-Sept. 1952 Report, p. 82

Host: Haden Mango

Location: Honolua, Maui

Period: June 19 - Sept. 25 '52

Plot Size: 3 acres

Replicates: 3

Application Method: MB-100 from 1 side of rows generally against wind.

Spray Interval: 2-3 weeks

Controls: Pre-spray X

Repl. plots

Adjacent comparable area:

3 sprays applied at 2-3 week intervals.

Trees stripped of mature fruit 3 times weekly.

9 samples per treatment per week. Average 15 fruits and 10 lb. per sample.

Formulation and pounds per acre/application in 27 gal. water 1/2 gal. per tree	Larvae per lb. fruit in controls	Mean per cent change in treated area--2-14 days after each of 3 sprays	Remarks
	4.4		Mean of 48 10 lb. samples
Bait Parathion 25 WP 4 Yeast hydrolysate 1 Raw sugar 5		-97	Adjacent to 9 acres unsprayed controls
Parathion 25 WP 10		-95	
CS 708 80 LC 5 Malathon 50 EM 1.5 Triton B-1956 0.125		-93	
DDT 50 WP 6 EPN - 300 1.5		-92	
Unsprayed (replicated)		-86	Adjacent to parathion plots
Unsprayed (large area)		-29	

Cost of the bait-spray averaged $30.00 per acre for labor and materials and averaged less than 1 cent per pound of mangoes harvested. Average price at orchard - 25¢ lb.

EXAMPLE 3 (Large Plots Replicated - Guava Gulches)
CHEMICAL CONTROL PROJECT - FIELD TEST SUMMARY

April-June 1953 Report

Host: Guava
Location: Wahiawa Gulches
Period: 3/17 - 6/30/53
Plot Size: 3 acres
Replicates: 3
Application Method: MB-100 blown and wind drifted across plots from gulch rims.
Spray Interval: 2 weeks
Controls: Pre-spray
Repl. plots
Adjacent comparable area X
Two or 3 of the 7 unsprayed gulches nearest each sprayed replicate used as controls.
Sprays applied 4/30, 5/14, 5/28/53

Formulation and pounds per acre/application with 12 oz. yeast hydrolysate and 3 gal. water	Larvae per lb. fruit in controls	Mean per cent change in treated area			Remarks
		1st week	2nd week	Mean after sprays	
1. DDT 75 WP 1.33 lb.	13.6-19.2	-88	-86	-87	88% less than in pre-spray period
2. CS-708 25 WP 3 lb.	16.4-22.2	-90	-72	-81	76% less than in pre-spray period
3. Dieldrin 50 WP 1 lb.	15.0-16.6	-92	-95	-94	94% less than in pre-spray period
4. Parathion 25 WP 2 lb.	13.8-18.5	-95	-93	-94	92% less than in pre-spray period
5. Parathion 25 WP 2 lb. Raw sugar 3 "	14.1-17.4	-89	-80	-84	83% less than in pre-spray period

Percentage parasitism 1 and 2 weeks after each of the 3 sprays averaged 60, 70, 41, 57, and 51 under the 5 treatments and 73 per cent in the controls.

Infestations in Post-Spray period 3-5 weeks after last spray averaged 28.2, 32.3, 31.7, 21.8, and 33.0 lv./lb. in the controls for the 5 treatments and 33.6, 47.2, 1.1, 13.0, and 27.0 in the respective treatments. Note the long residual action of dieldrin.

EXAMPLE 4 (Small Guava Plots Contiguous vs Single Trees Dispersed)
CHEMICAL CONTROL PROJECT - FIELD TEST SUMMARY

Oct.-Dec. 1951 Report, p. 133

Host: Guava

Location: Trinler Hospital

Period: 7/30-10/24/51

Plot Size: 0.33 acre

Replicates: 3

Application Method: CE-600
2 gms 30 g.p.m. from sprayer. Area vs. single tree coverage.

Spray Interval: 2 weeks

Controls: Pre-spray

Repl. plots: 3

Adjacent comparable area:

Six sprays applied 7/18, 8/1, 8/15, 8/29, 9/12, and 9/26.

Three 50-fruit samples from all ripe picks and drops per replicate collected once weekly.

Crop season extended from July 4 to Oct. 24.

Total of 101,000 or 7 tons held for data herein.

Formulation and pounds per acre/application		Larvae per lb. fruit in controls 6 to 13 days	Mean per cent change in sprayed area 1st week	2nd week	Mean after spray 6	Larvae per lb. 9-4 weeks after spray 6	Per cent parasitization spray season
Whole area sprayed w/300 gal/acre							
Parathion 25 WP	8	4.3 5.4	-100	-96.4	-98.2	9.4	33
Dieldrin 25 WP	8	do.	- 97.7	-96.4	-97.0	3.0	0
Dieldrin 25 WP + Parathion 25 WP	6 7	do.	- 98.9	-96.4	-95.6	5.0	0
DDT 75 WP (Geneva)	3.33	do.	- 97.7	-92.9	-95.3	30.0	29
DDT 50 WP (Texas)	5	do.	- 97.7	-89.3	-93.5	20.2	43
GA-708 50 WP	8	do.	- 93.0	-87.5	-90.2	0.6	28
Dieldrin 25 WP	8	do.	- 90.7	-82.1	-86.4	1.3	30
Single tree surrounded by unsprayed							
3 sample sites per 0.33 acre replicate sprayed. Application rate per unit of guava same as above.							
Parathion 25 WP Raw sugar Protein hydrolysate	4 30 2	4.3 5.6	-93.0	-69.6	-81.3	3.3	49
Delnav 22000 50 Em.	4 pts.	do.	-88.4	-76.8	-82.6	0.6	29
Metacide 32 Em.	6 pts.	do.	-83.7	-85.7	-84.7	4.7	19
Systox 31.5 Em.	6 pts.	do.	-97.7	-96.4	-97.0	0.6	80

EXAMPLE 5 (Very small plots non-contiguous, heavy applications, confined gulch)
CHEMICAL CONTROL PROJECT - FIELD TEST SUMMARY

April-June 1952, p. 129

Host: Guava

Location: Brodie - Wahiawa

Period: 5/19-7/16/52

Plot Size: 50 ft. dia.

Replicates: 4

Application Method: CH-300 Bean 4 g.p.m. Tall trees sprayed with gun from below.

Spray Interval: 2 weeks

Controls: Pre-spray X (not)
Repl. plots X suitable)

Adjacent comparable area:

Sprays 5/28, 6/11, 6/26

Samples of 40 picked fruit collected from each replicate at 4-5 day intervals following each spray.

Plots non-contiguous separated by unsprayed guava. 40 plots in 6 acre gulch.

Formulation and pounds per acre/application in 200 gal. water		Larvae per lb. fruit in controls Mean of 20 pre-spray samples	Mean per cent change in treated area. Mean after sprays	Remarks
Malathon 25 WP	20	5.6	-99.6	The mean infestation 3 weeks after the last spray had increased to 60 per cent of the pre-spray level and ranged from zero in parathion (alone) and methoxychlor plots to 14.6 lv./lb. in the dieldrin plot.
Parathion 25 WP	20	do.	-99.6	
+ National Sticker	4			
Parathion 25 WP	8			
Protein hydrolysate	2	do.	-99.2	
Raw Sugar	20			
DDT - 50 WP	20	do.	-98.5	
Dieldrin - 25 WP	10	do.	-98.4	
Parathion 25 WP	20	do.	-98.2	
Systox 31.5 Em.	6 pt.	do.	-98.1	
Isodrin 25 WP	10	do.	-98.1	
Methoxychlor 50 WP	40	do.	-97.7	
Unsprayed		do.	-93.5	

Mean reduction 5 and 9 days after spray 1:

5 plots - Chlorinated hydrocarbons and Systox	-92.8
4 plots - Parathion and Malathon	-99.9
1 " - Unsprayed	-66.3

Reliable comparisons of effectiveness prevented by interplot fly movement and fumigating action of 7 of the 10 treatments.

EXAMPLE 6 (Passion Fruit)
CHEMICAL CONTROL PROJECT - FIELD TEST SUMMARY

Host: Passion Fruit

Location: Waimanalo

Period: 8/26-9/23/53

Plot Size: 0.33 acre

Replicates: Single plot

Application Method: CH-400
2 fan-shaped nozzles on broom-
hand operated.

Spray Interval: 1 week

Controls: Pre-spray: X

Repl. plots

Adjacent comparable

area:

Passion fruit vines growing on tall iron frames shaped like trees.
Sprays applied 8/26,9/2,9/10,9/18,9/24,10/2
Fruit examined at 2-week intervals.

Melathion 25 WP 3 lb. Partially hydrolyzed VP 1 lb. Water 120 gal.		Per cent fruit injured	Remarks
Pre Spray 8/26	Mature fruit	68	
	Immature 1-1-1/2" dia.	67	
2 weeks after spray	Mature	73	Immature at 1st spray.
	Immature	15	Some immature at 1st spray.
4 weeks after spray	Mature	15	Some immature at 1st spray.
	Immature	0	All fruited since 1st spray.

Fly control should also increase production.

Flies, both dorsalis and cucurbitae, oviposit in fruit at different ages. The larvae hatch, work awhile in the rag, then die. The fruit becomes deformed if the oviposition was early and it may fail to set or to fill with pulp and juic

EXAMPLE 7 (Small plots replicated, closely spaced and subject to immigrating flies.)
CHEMICAL CONTROL PROJECT - FIELD TEST SUMMARY

April-June 1953 Report

Host: Papaya

Location: Expt. Station-Waimanalo

Period: 12/20/52 - 4/23/53

Plot Size: 4 trees center of 4X4 tree square

Replicates: 4

Application Method: CH-400 7 g.p.m. Bean

Spray Interval: Monthly

Controls: Pre-spray

Repl. plots

Adjacent comparable area: X

4 locations within similar block 100 yards away.

Sprays applied 1/30, 2/26, and 3/26

3/4 gal. per tree.

Formulation and pounds per acre/application and per 100 gal.		Larvae per lb. fruit in controls	Mean per cent change in treated area				Remarks
			1st mo.	2nd mo.	3rd mo.	Mean after sprays	
Mean Pre-spray indices in Control area		17.8					
in Plot area		21.4					
DDT 75 WP	5.33	23.1	-88	-89	-99	-90	Spray applied to fruit on 4 trees at center of each 16-tree replicate.
Methoxychlor 50 WP	8	23.1	-85	-88	-96	-87	
Methoxychlor 50 WP	20	23.1	-96	-89	-100	-95	
Dieldrin 25 WP	6	23.1	-97	-96	-99	-97	
CS 708 25 WP	6	23.1	-95	-74	-87	-87	

Monthly mean infestations in the control areas and per cent difference in treated are given in the table on the next page.

Mean differences after March, 1952, indicate no control at the lowest level where on-shore trades kept us from getting adequate width of dispersion from the traps placed at the lowest levels. Mean differences at the higher elevations ranged from 66 to 82 per cent. When fruit production in the fall crops was at its peak (in September and October), excellent control (from 70 to 100 per cent) was shown at all levels. Starting in December and building to a peak in January, there was a heavy influx of flies into the upper elevations of treated as well as untreated areas. These came from above or across the mountain since the increases appeared first at the highest border traps. Presumably, this was either a natural overflow from the more heavily infested controls or mass movement from other parts of the island. At any rate, it temporarily reduced the indicated control within the treated area. As the crop approached its end in 1953, infestations in general were much higher than at the end of the crop in May, 1952.

It is highly significant that the January to April mean infestations at the five elevations in 1953, as compared to the same period in 1952 before the control effect was fully operative, were 188 per cent greater in the control areas but only 64 per cent greater in the treated area.

The respective increases at 300 ft. were 133 and 60 per cent; at 700 ft., 160 and 43 per cent; at 1100 ft., 200 and 21 per cent; and at 1900 ft., 305 and 190 per cent. At 1500 ft., the absence of a crop in the treated area in January and February, 1952, makes such a comparison impossible.

Four months after discontinuance of the experiment samples from the first of the summer crop indicated that the populations had already leveled off with a mean of 45 larvae per pound at the 300, 700, and 1100 ft. levels in the former treated area compared to a mean of 33 larvae per pound at the same elevations in the controls. The crop above 1100 ft. was not yet ripe.

The indicated control figures are highly conservative. C. capitata in the treated area at 700 to 1500 ft. exceeded that in the controls. With opihilus parasitization all credited to dorsalis in the absence of reliable data on the extent to which it parasitizes capitata, the recorded dorsalis infestation was probably excessive. On numerous occasions in the treated area, only capitata and opihilus emerged. If opihilus were divided proportionately, 100 per cent control would have been indicated several times at the intermediate levels. Mean parasitization (attributing all to dorsalis) ranged from 60 to 64 per cent for the 5 elevations in the control areas and 46 (1500') to 87 (1100') per cent in the treated.

The cost of the Hamakua operation, exclusive of strictly research items, averaged 25 cents per acre per year.

The much smaller Kilauea experiment failed to produce any consistent reductions in infestation because of frequent unanticipated movement of flies into the small test area. This site on the south slope of Kilauea was in an area of changeable

METHYL EUGENOL-G-22008 BAIT STATIONS FOR D. DORSALIS CONTROL THROUGH ANNIHILATION OF THE MALE FLY POPULATION.
Ookala, Hawaii

Month	Mean D. dorsalis Larvae Per Pound in Control Areas and Per Cent Difference in Treated									
	Elevation 300'		700'		1100'		1500'		1900'	
	Larvae	Per cent	Larvae	Per cent	Larvae	Per cent	Larvae	Per cent	Larvae	Per Cent
Jan. '52	17.2	+131	17.1	-35	3.5	NC	1.1	NC	1.2	-100
Feb.	10.2	+204	7.7	-90	2.3	+117	2.2	NC	2.1	- 86
March	4.2	+317	7.8	-81	1.7	- 99	2.7	-100	3.6	- 87
April	38.9	- 12	15.4	-25	5.2	- 27	0.6	- 33	1.7	+ 59
May	29.5	+177	29.8	-83	4.5	- 69	1.4	- 71	0.2	+100
June-July	NC (No crop)									
August	25.0	- 12	33.5	-93	4.4	- 89	1.6	-100	0	---
Sept.	17.5	- 75	3.2	-94	0.6	+200	2.3	- 99	0.2	-100
Oct.	19.1	- 59	5.2	-73	2.0	- 70	1.0	- 98	0.4	-100
Nov.	4.9	+151	2.4	-67	3.0	- 80	0.8	- 82	1.0	-100
Dec.	3.0	+ 43	1.8	-72	6.0	- 87	2.3	- 83	0	-
Jan. '53	10.5	+235	5.0	+ 4	17.0	- 51	13.0	- 75	6.2	- 95
Feb.	37.1	- 44	19.2	-62	6.8	- 90	6.8	- 59	10.2	- 82
Mar.	27.0	- 4	47.9	-84	6.2	- 77	3.8	- 66	5.2	- 21
Apr.	96.6	- 2	49.4	-71	19.1	81	23.0	- 93	9.8	- 59
Infestation at peak of fruit production underscored.										
Mean after March '52	26.1	+ 15	18.4	-74	6.4	- 69	4.9	- 82	3.2	- 66

wind direction and adjacent to the Kau desert on one side and the southeast slope of Mauna Loa on the other. Catches of male dorsalis up to 1500 per day were made by traps located more than 1/2 mile from the nearest hosts. During the 16 months, more than 16,000 were caught in a trap on the southwest rim of Kilauea caldera at 3900' in an area of no vegetation except an occasional fern. More than 165,000 were taken at 3600' in an area of ohia trees, lava, and fern, 1/2 mile or more from the nearest fly hosts. In December, January, and February more than 400,000 flies were taken in the 28 traps used for this experiment. It is believed that these flies indicate mass movement from the heavily infested guava in the Kalapana-Puna area 15 to 25 miles east of Kilauea.

The method as now developed must be used on whole populations for the best results and we have surveyed the islands of Guam, Rota, and Saipan in the Marianas with the object of determining if an eradication test would be feasible in that area. D. dorsalis is present in ample numbers on all 3 islands. At the end of the dry season in June, 10 traps on Rota took 1300 flies in 20 hours. Forty-five on Guam took only 3600 in 6 days but with the advent of the rainy season there, have since taken nearly 100,000 flies according to Mr. G. D. Peterson, Entomologist. Saipan's infestation was intermediate between those of Guam and Rota. We consider Rota a sufficiently promising site for serious consideration.

Development of Methods for Eliminating Fruit Flies in Planes, Ships, and Export Facilities.

Tests, largely by Keiser and Holloway, with the assistance of Plant Quarantine personnel and cooperation of the Navy, were made to re-evaluate presently used aerosoling methods for mainland-bound planes.

Twelve experiments were conducted utilizing 17 MATS R5D 4-engined (DC-4) planes in on-the-ground tests at Hickam Airfield. Peet-Grady tests were also conducted. More than 66,000 of the 86,000 flies used were marked and released inside the planes.

Without going into detail we wish to state that these studies did not provide a clearcut basis for any simplification of the present treatment procedures. On the contrary, the results emphasized the importance of and need for both the pre-loading or Agricultural spray (30 gm. G-651/1000 cu. ft./10 min.) and the post-loading or Public Health treatment. The tests also revealed the importance of employing the utmost care possible when applying the aerosol and oscillating the nozzles in a manner to achieve the best possible spray distribution. Some flies were alive in planes (14 out of 10,000) 20 hours after they had been subjected to both the standard treatments.

(Meeting adjourned until tomorrow)

POLICY COMMITTEE MEETING (cont'd)

Open Session - Held October 2, 1953, at 8:30 A.M. in the
Pineapple Research Institute
Assembly Room

Mr. Christenson: Good morning. This morning will be devoted to commodity treatment problems and quarantine problems. Our first speaker is Mr. Balock, who will speak on current objectives and progress in the development of commodity treatments to destroy fruit fly infestations.

Mr. Balock: The objectives of commodity treatments are, as Mr. Christenson said in the title of the talk, to develop effective and practical treatments to eliminate fruit fly infestations in commodities without injuries and thereby permit their shipment to fly-free areas. The development of a commodity treatment program falls more or less along these lines: (1) Screening of materials to determine their lethal actions to insects; (2) The effectiveness of such treatments when applied to fruits; (3) The development of dosages for use under commercial conditions; (4) The testing of commodities for tolerance to these treatments; and (5) The question of residues following treatments.

During the past 4 years the following lines of approach have been investigated either by our laboratory or through cooperating agencies: heat, cold, fumigation, dips, pressure, radio frequency as reported by Prof. Hubert Frings of the Pennsylvania Agricultural Experiment Station through a grant provided by the H.A.E.S., dielectric heating as investigated by Mr. Christenson and Dr. Carter in Schenectady, in the General Electric Plant, I believe, accelerated electrons as investigated by Mr. Yoemans and others of the B.E.P.Q., and the application of gamma rays from radioactive cobalt in cooperation with Dr. George Burr of the H.S.P.A. Several of these treatments have shown no promise, others like dielectric heating, accelerated electrons and gamma rays did not appear economically feasible at the present time.

Satisfactory treatments have been developed, however, using vapor-heat and fumigation for papayas, Cavendish bananas, Zucchini squash, bell pepper, tomato, and string beans. Recently ethylene chlorobromide has shown good promise and also aqueous dips with EDB. Emphasis at the present time is being directed along these lines: (1) fumigation with EDB; (2) fumigation with ECB; (3) tests with methyl bromide for use on tomatoes; (4) refinement of the vapor-heat process by the use of shorter exposures at higher temperatures; and (5) the use of aqueous dips.

During the course of studies to develop a satisfactory dosage with EDB for naked fruits, approximately 20,000 fruits of various kinds such as papaya, guava, tomato, zucchini squash, cucumber, and string beans were used. Over a quarter of a million immature stages of the fruit flies were tested in these fruits. These studies resulted in a treatment that was approved for fumigation of most island commodities when packed in open-slatted boxes without packing.

Once this treatment was approved our efforts were directed to the fumigation of packaged commodities. Mr. Maehler, in charge of our local Federal Plant Quarantine office, has estimated that 80% of the supervising activities in connection with commodity treatments are involved with packing procedures. Savings to shippers

by the use of the pre-packed method would result in considerable saving of labor and also in the reduction of injury because of less handling of fruits and vegetables. Since papayas are the major export of the islands requiring treatment, now that pineapples are allowed to move without any restrictions, the tests were first started with this commodity. Ripe, field-infested and cage-infested fruits were first wrapped in citrus paper and then packed in wood excelsior in field cartons following the packing procedure used by local export firms. The fumigation was carried on in fumigation chambers of 10 ft., 100 cu. ft., 240 cu. ft., and 376 cu. ft. capacity. The loading ratios remained constant at about 50 to 60 per cent of the free-air space in the chambers and cartons were stacked directly one on another with 3/4 inch space only between stacks. Temperatures were maintained constant at 70° F. with a variation of approximately ±1°.

In figure 1 are shown the results for the first test. Curve A gives the mortality for unpackaged fruits fumigated in open, slatted boxes. Twenty-five tests are represented here with fruit fly populations of 141,000 individuals. Data for dosages of 1 to 4 milligrams per liter were obtained in 10 cu. ft. chambers. The data at 8 mg. per liter are from five tests in a 240 cu. ft. chamber. At this upper dosage no survivors are recorded in a population of over 67,000 individuals. In order that we might place the minimum slope of the mortality curve, the mortality here is calculated as 1 survivor out of 67,000 individuals although none was obtained experimentally. Curve B represents the mortality in 68 tests in 10 cu. ft. chambers with papayas in sealed cartons. In these studies 132,000 fruit flies were used. The upper point at 6 mg./liter was calculated here again as 1 survivor although none was obtained out of approximately 13,000 individuals.

Mr. Maehler: What do you mean by pounds per 1000 cu. ft.?

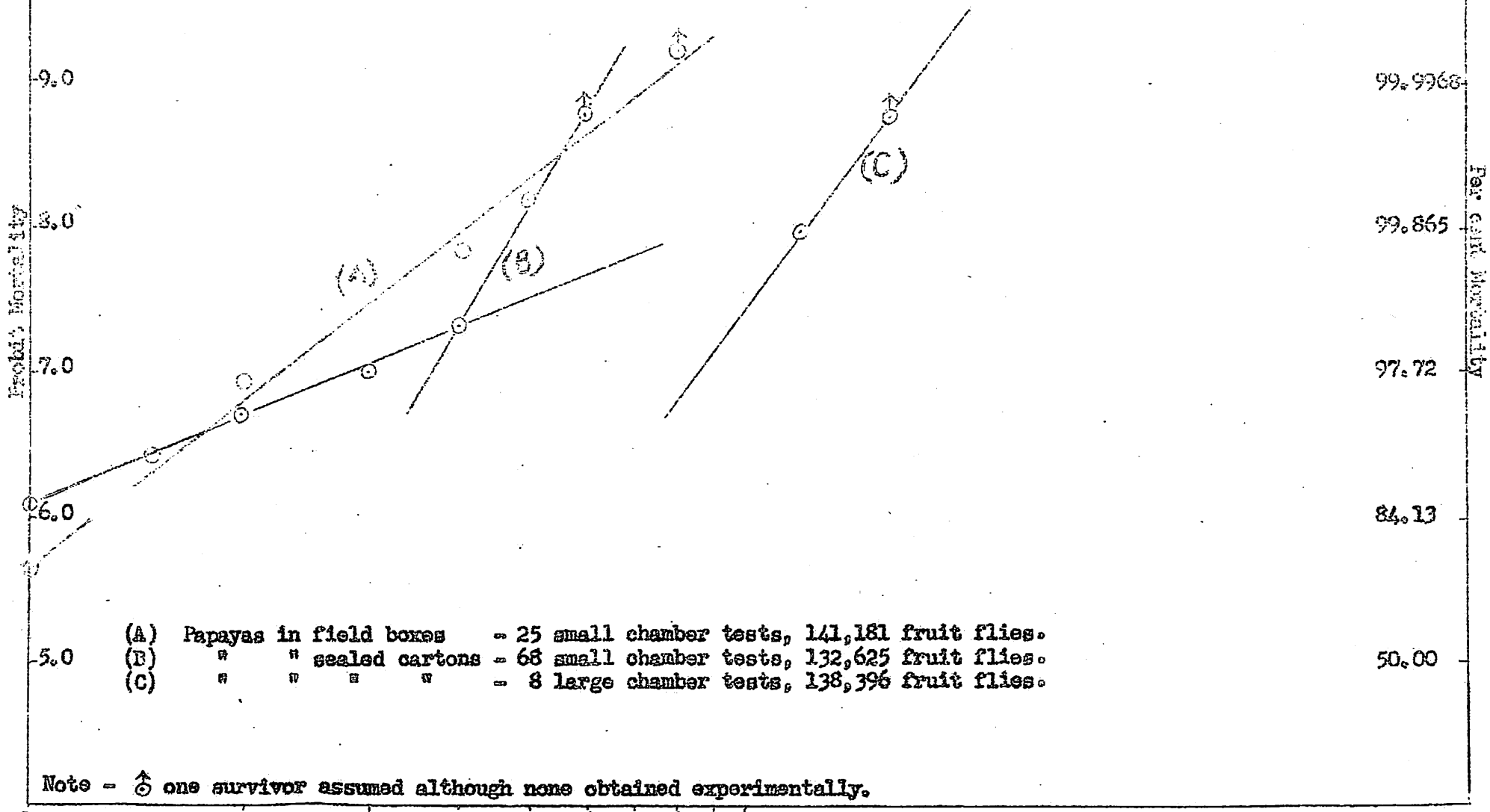
Mr. Balock: I am sorry. I should have expressed dosage as pounds too, but they would be easy to convert if you figure that 1 mg./liter can be calculated as 1 oz. per 1000 cu. ft., so 8 mg./liter would be equivalent to 1/2 lb.

Curve C presents mortalities from 8 tests with papayas fumigated in large chambers of 100, 240, and 376 cu. ft. The mortality at 12 mg/liter was calculated from 198 survivors out of a population of over 125,000 in 7 tests. The mortality was complete in 4 of these tests and survivors occurred in 3 others. One hundred and fifty-seven of the 198 survivors occurred in a single test. Mortality at 16 mg./liter was complete but here again the data are calculated as one survivor from a total population of over 13,000 eggs and larvae in a single test.

The difference in curves B and C was not expected since all of the conditions were maintained constant except for the size of the chambers. The results suggest that more tests in larger chambers be made in order to establish more accurately the slope of this curve which is based on extremely limited data.

Mr. Christenson: The differences in those curves, could that possibly be because of differences in gas circulation patterns in the two different types of chambers and the amounts of EDB getting into the cartons?

Figure 1 Fruit fly mortality in papayas wrapped in tissue and packed in wood excelsior in sealed cardboard cartons and fumigated with ethylene dibromide for 2 hours at 70° F. compared with results in open field boxes.



(A) Papayas in field boxes - 25 small chamber tests, 141,181 fruit flies.
(B) " " sealed cartons - 68 small chamber tests, 132,625 fruit flies.
(C) " " " " - 8 large chamber tests, 138,396 fruit flies.

Note - ⊙ one survivor assumed although none obtained experimentally.

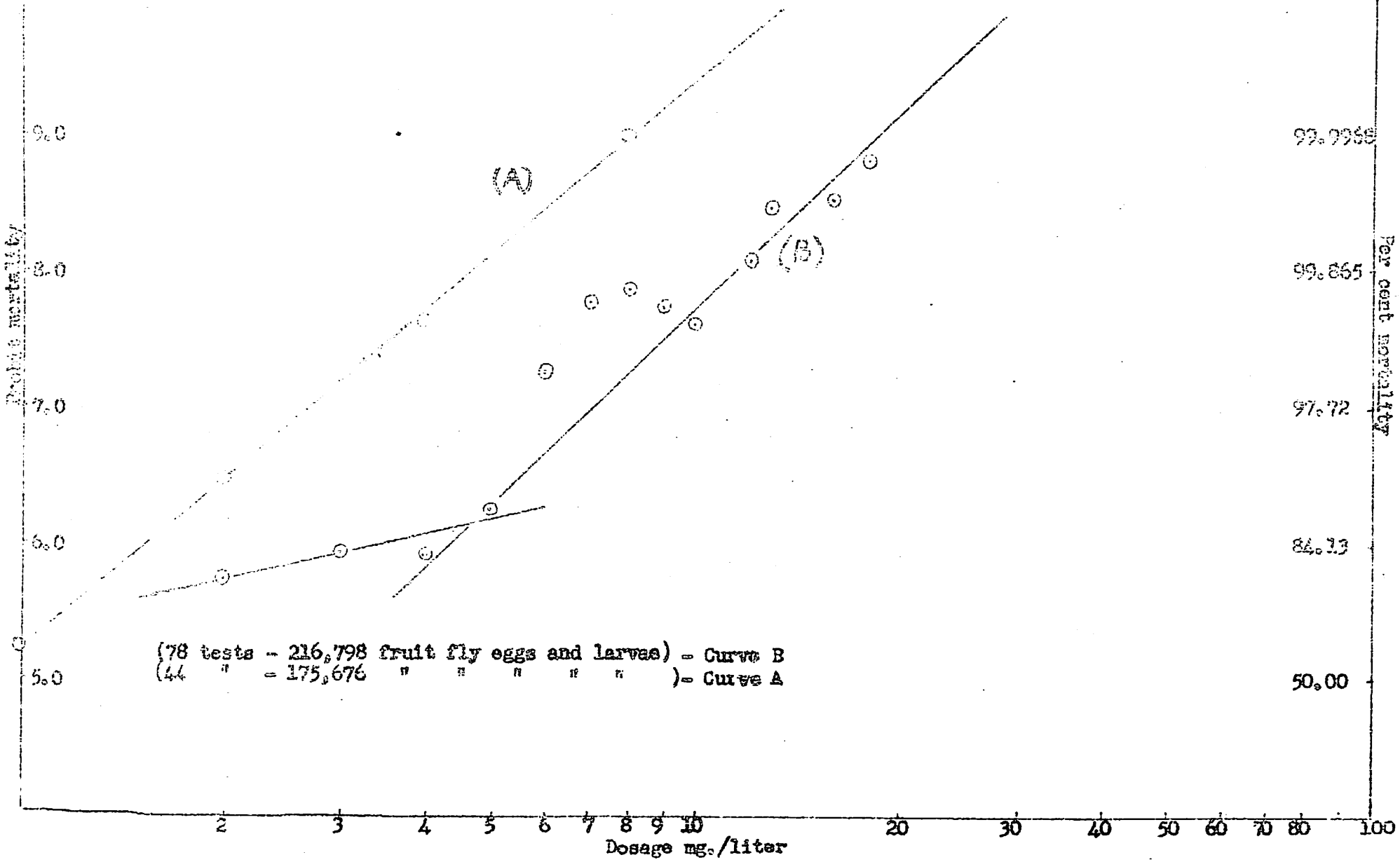
Mr. Balock: That could well be. We have plotted the survivors in the various locations in the chambers by marking the stacks of the boxes and the cartons as they were taken out after fumigation so that we could determine exactly where in the chamber individuals survive. It doesn't seem to be related particularly to position, and if there was a position difference in any chamber you might expect it to be constant. We have an arrangement whereby the air is circulated through a duct from bottom to top. It is thrown out over the commodities and sucked in through a duct at the bottom and circulated back through. We have found no relation between the position of the cartons and mortality. It is possible that the differences are due to unequal penetration or uneven penetration of the fumigant into these cartons requiring longer fumigation perhaps to reach equilibrium. We feel, however, if we can maintain the exposure constant at 2 hours and then develop a mortality curve we should reach some dosage where we can get complete kill.

I will next discuss what we have done so far with ethylene chlorobromide. These studies have been delayed because we still have urgent problems to solve with EDB. ECB is not quite so toxic to fruit flies as is EDB, but it is tolerated to a much greater extent by most commodities. Fumigation tests in 10 cu. ft. chambers with naked fruits in field boxes have indicated that ECB is practically as effective as EDB under these conditions. However, when tests were conducted with fruit packed for shipment in sealed cartons the difference in effectiveness was extremely wide. The results are shown in figure 2. Comparison of curves A and B in figures 1 and 2 will give you some idea of the relative effectivess of both compounds under the two methods of packing tested in 10 cu. ft. chambers. Curves A for naked fruits in field boxes are nearly identical, but curves B for fruit in sealed cartons show that the mortalities are very dissimilar and when both curves (Curve B, fig. 1, and Curve B, fig. 2) are compared, for example, at a probit of 9, which we are using as our security probit (mortality of 99.9968) the difference in dosage required at this level of mortality for ECB is about 2 to 3 times as much as for EDB. No tests have been conducted as yet in large chambers so we don't know whether these differences will be so wide when these tests are run.

I will next go over some of the results that we are getting with fumigation of tomatoes with methyl bromide. Tomatoes will not tolerate even very small amounts of EDB but fortunately they are quite tolerant to methyl bromide. The mortality data from 35 tests with 8,500 lb. of fruit fumigated at a 2 lb. per 1000 cu. ft. dosage at exposures of 1/2 to 3-1/2 hours at 70° F. are shown in figure 3. Fruits were wrapped and packed as for shipment in standard tomato lugs. The fumigation load represented here occupied about 50 to 60 per cent of the free-air space of the chambers. Three tests at the 3-1/2 lb. exposure were conducted in 100 cu. ft. chambers—the rest in 10 cu. ft. chambers. The slope of the present mortality curve would indicate that a dosage of 2 lb. per 1000 cu. ft. at about 3-1/2 hours would be sufficient for the fumigation of tomatoes when they are packed for shipment with citrus tissue in regular tomato lugs.

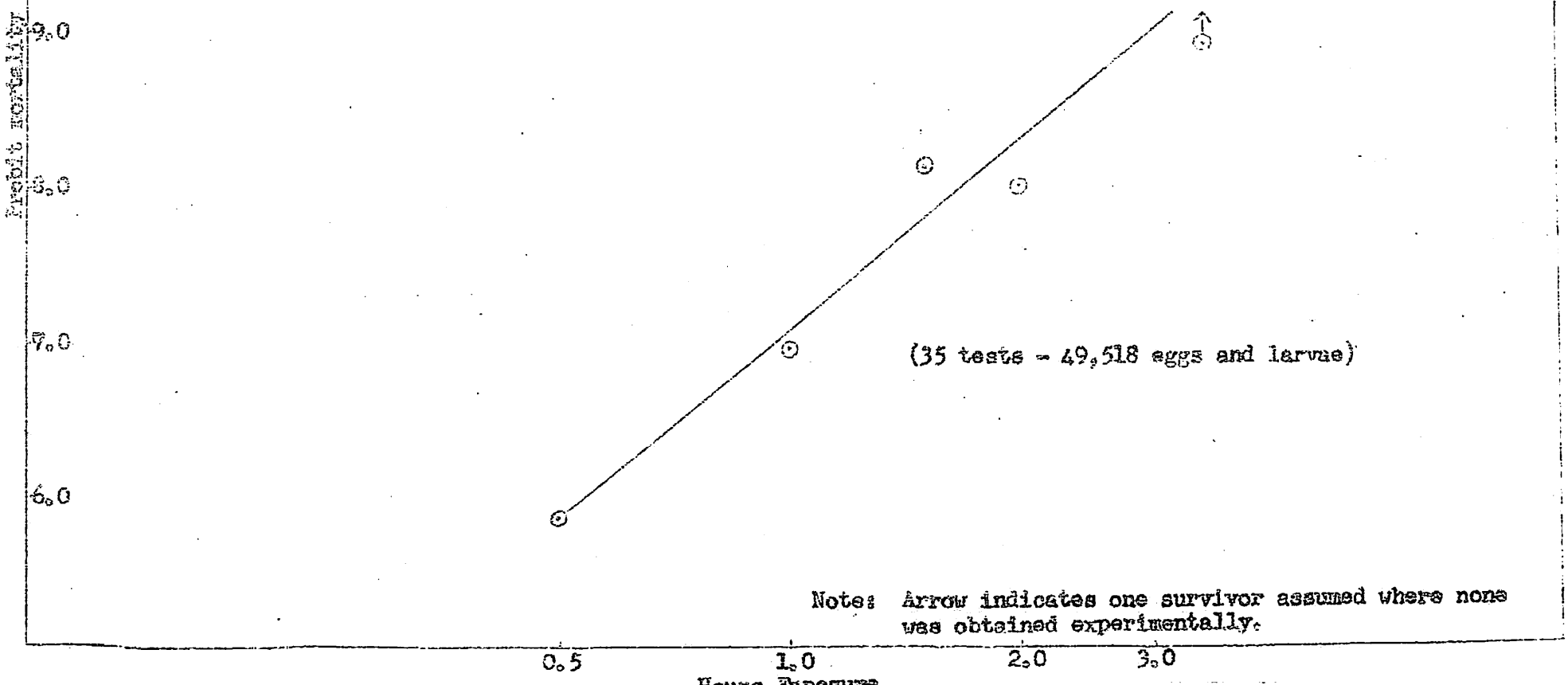
Vapor-Heat Sterilization.—Any further stream-lining of the vapor-heat process will most likely come from the so-called quick-run-up method which was first developed by Stone in Mexico City for Anastrepha ludens. This method calls for determining the thermal death-point of the insect and raising the temperature of the fruit until that temperature is obtained at fruit center under saturated

Figure 1.—Mortality of the oriental fruit fly in papaya fumigated in 10 cu. ft. chambers with ethylene chlorobromide for 2 hours at 70° F. Curve A - naked fruit in field boxes. Curve B - fruits wrapped and packed for shipment in sealed cartons.



(78 tests - 216,798 fruit fly eggs and larvae) - Curve B
(44 " - 175,676 " " " " ") - Curve A

Figure 3.--Mortality of the melon fly and the oriental fruit fly in tomatoes wrapped and packed for shipment and fumigated with methyl bromide at 2 lb. per 1000 cu. ft. at 70° F. (Expt. 156-179).



vapor. This treatment would be particularly valuable for papaya because it combines a fungicidal action which delays the development of storage rot and thereby increases the shelf-life of the fruit. Unfortunately, papayas tolerate this treatment only after careful conditioning for 6 to 8 hours at low humidities and high temperatures, thereby making this process long even under these conditions. Some work was done with this method in 1949 and has just recently been resumed. Altogether 34 tests have been completed and fruit fly mortalities have been determined at fruit temperatures ranging from 111° to 120° F. The earlier tests were done under vapor temperatures of 120° F. and the more recent tests were conducted under vapor temperatures ranging between 113° and 118° F. under conditioning temperatures running in the same range. Previous conditioning was done at 110° F. only but we have found that one shipper in his practice uses a high temperature-low relative humidity procedure and it was thought best to determine how this would effect both mortality as well as fruit tolerance.

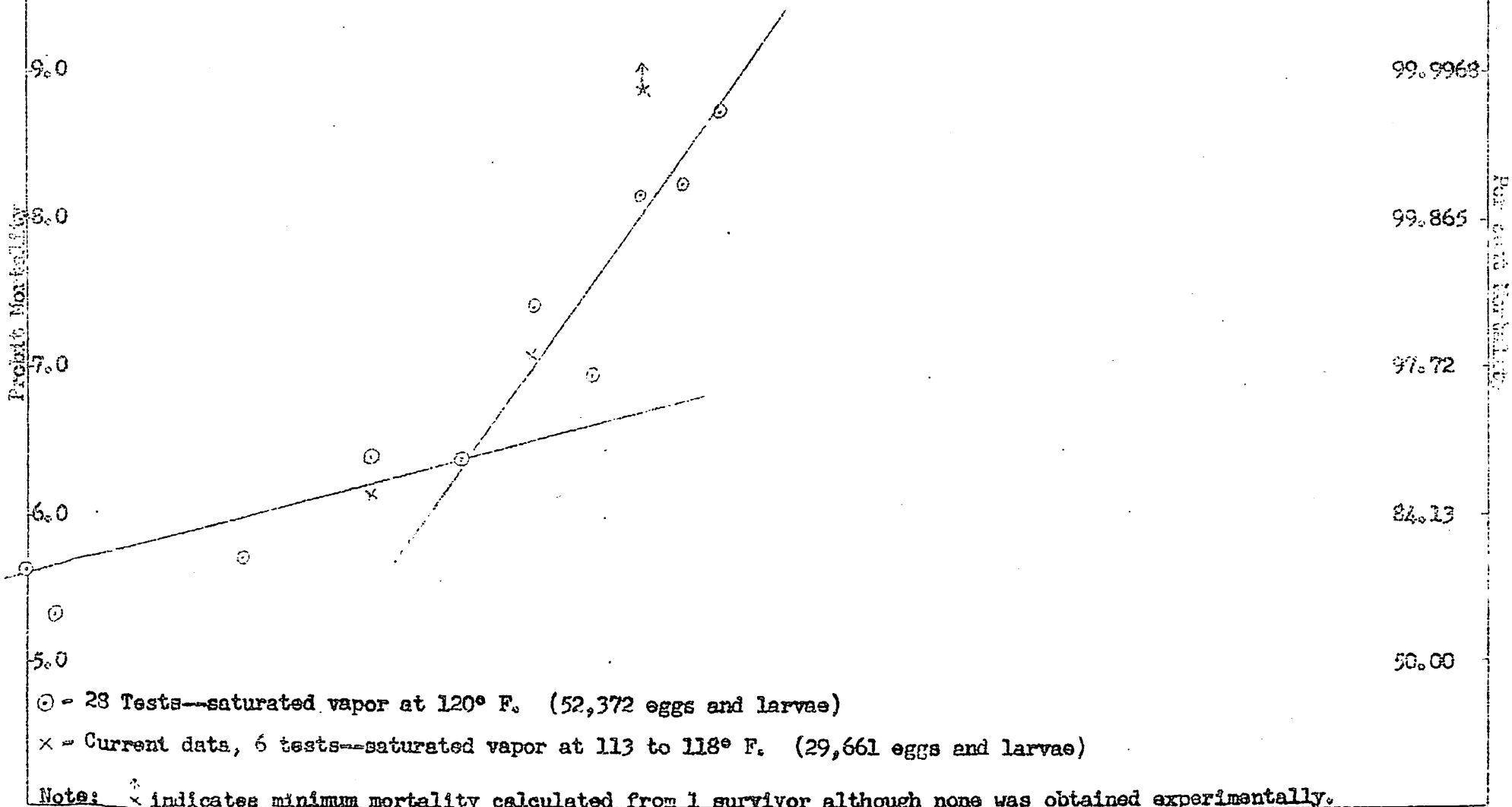
The mortality data for these studies are shown in figure 4. The circles represent the mortalities when 120° F. vapor was used and the "X's" are the results of more recent tests at lower temperatures. In these latter tests survivors were recorded only at 113 and 115° F. Mortalities were complete in two tests at 117° F. and one test at 118° F. The arrow at 117° F. represents an assumed mortality of 1 survivor out of a population of approximately 13,000 fruit flies. The effect of the treatment on fruit appearance and quality was determined by exposing mature-green fruits at the time of treatment. Tolerance determinations were reported by Mr. Akamine of the Hawaii Agricultural Experiment Station. There was no injury at 113° or 115° F., but the results have been very variable at 117° and 118° F., the injury varying between 5-75%. This is based on fruit showing extreme injury such as severely altered taste or external or internal injury. Based on the data we have available at the present time a treatment which raises the temperature of the fruit to approximately 120° F. at the center should be sufficient to destroy fruit fly infestations in papaya.

That covers my part of the program and if there are no questions, I will call on the other speakers.

I have been asked by Kiichi Chinata to push him up a little bit in the program because he has to go out and collect some samples in the field. Steiner is spraying this morning and these samples have to be collected immediately. So, I will ask Kiichi to take over and give us some information on what he is doing on the residue studies and gas analyses.

Mr. Chinata: The extensive use of EDB as an approved chemical fumigant for commodity treatments required a certain amount of analytical work be done on gas concentrations and other related chemical problems. I would like to concentrate a little more on residues and say just a little about gas concentrations. The procedure employed for the determination of EDB and bromide residues in fruits and vegetables fumigated with EDB is that described by Scheuer, Tanada, and Matsumoto, which combines the methods of Hanson and Schraeder with a few modifications. In this method unchanged EDB is first distilled from the fruit or vegetable sample and determined. The residue left after distillation is then analyzed for inorganic bromide which may be present as a fruit or vegetable constituent or derived as a result of EDB fumigation. These samples were taken soon after fumigation, usually after about a 1-hour period, and 1, 2, 3, and 6 days after fumigation.

Figure 4. Mortality of the oriental fruit fly in papaya treated by vapor heat under quick run-up following conditioning at reduced humidity.



⊙ - 28 Tests--saturated vapor at 120° F. (52,372 eggs and larvae)

× - Current data, 6 tests--saturated vapor at 113 to 118° F. (29,661 eggs and larvae)

Note: * indicates minimum mortality calculated from 1 survivor although none was obtained experimentally.

The various commodities fumigated and checked for residues included pineapple, papaya, string beans, bell pepper, and avocado. All of these were fumigated as they are usually packed for shipment. Therefore, instead of the standard approved 1/2 lb. dosage for 2 hours an EDB dosage of 3/4 lb. per 1000 cu. ft. for 3 hours at 70° F. was used. All of these tests were conducted in the 10 cu. ft. chambers and the load occupied from 10-20 per cent of the available free-air space of the chamber. The per cent sorption of EDB after 3 hours was about 75 per cent for all of the commodities except for pre-packed papayas which contained a little more packing material and therefore absorbed a little more EDB.

Because the loads in the tests were small the residue values are probably slightly higher than would be expected under commercial fumigation conditions.

I would like to mention very briefly the load conditions for the various commodities and the residues found.

(1) Pre-packed pineapple: In 4 tests the load consisted of a crate of 12 pineapples individually wrapped in corrugated cardboard sleeves. Immediately after fumigation about 25 p.p.m. in the hull and 5 p.p.m. in the flesh were found. By the 6th day less than 1 p.p.m. was found. There was no significant increase in bromides due to fumigation. Pineapples have been removed from the restricted commodity list. We will, therefore, not have to concern ourselves with this Hawaiian product any longer.

(2) String beans: In a single test an 18-lb. net load in two paper-lined tomato lugs was treated. At first 25 p.p.m. was sorbed but this was rapidly lost and by the sixth day no EDB was detectable. A slight bromide excess of from 6 to 14 p.p.m. was noted.

(3) Avocados: Avocados are crated as they are packed for shipping. In 3 separate tests several different varieties were treated, using about a dozen fruit each time. In this commodity very high EDB sorption was noted in both the flesh and the skin soon after fumigation. The EDB taken up by the skin was rapidly lost but that in the flesh retained between 35-45 p.p.m. even after 6 days. This relatively high retention may very well be due to the solubility of EDB in the oil or fat of avocado flesh. A check of the ether extractable fat content of 14 mature avocados ranged between 15-30% of the fresh fruit weight. Bromide excess in the flesh was only about 20 p.p.m. over that of untreated fruit.

(4) Bell pepper: In a single test a 13-lb. net load in paper-lined lug was fumigated. EDB taken up during fumigation was about 45 p.p.m. but this was lost quite rapidly. However, here, bromide accumulation was very evident. There was an excess of up to 55 p.p.m. over control values indicating the possibility of EDB breakdown in bell pepper. As far as bromide residues are concerned, this was the first commodity which showed a definite increase due to fumigation.

(5) Pre-packed papaya: In two tests, 3 sealed cartons of 8 papayas each were treated. The fruit was wrapped in citrus tissue and packed in wood excelsior. Only 10 p.p.m. were found in the peels and 4 p.p.m. in the pulp soon after fumigation. Most of this was lost by the third day and by the end of a week no EDB was detected. There was no significant increase in bromides noted in either the skin or flesh.

Charts 5 and 6 summarize the results. You will see that EDB disappeared very rapidly in pre-packed papayas and, of course, in both papaya and pineapples you start out with a very little EDB absorbed. In string beans about 22 p.p.m. was absorbed but this disappeared quite rapidly and the same thing held true with bell pepper. In the case of avocado a large amount of EDB is retained in the flesh even after 6 days. As far as bromide residues are concerned, the results with papaya and pineapple fumigated with EDB show very little bromide residues. However, bell pepper showed up to 55 p.p.m.

Dr. Messenger: Do you assume that the increases in bromide are coming from EDB all of the time?

Mr. Chinata: Yes, because these are all bromide excesses over that of control fruit values.

Dr. Messenger: In a sense those curves to the right should be inverse to those on the left.

Mr. Chinata: Theoretically.

Mr. Balock: That is, if the EDB were being converted to inorganic bromides instead of evaporated.

Mr. Chinata: Now, I should like to take up the EDB-water dip of papayas. Mature green papayas were dipped for 20 minutes in an EDB-hot water solution of 1:6,000 parts by volume at 110-111° F. Mr. Hinman has found that this is the maximum concentration which will not injure papaya. Analysis right after treatment showed EDB residues of about 24 p.p.m. in the skin and 17 p.p.m. in the flesh. Six days later no significant EDB residues were detected. In other words, approximately 4 times as much EDB is initially absorbed in the edible part of papaya after treatment in an EDB-water dip of 1:6,000 parts as is taken up during fumigation of pre-packed papayas, but this amount disappears almost completely after 6 days.

All of these EDB residue values cannot be correctly interpreted, i.e., they may only be spoken of as relatively low or relatively high until tolerance limits are set.

Now, a few words about gas analyses. During the fumigation of commodities the EDB gas concentrations were usually checked at various intervals. These gas analyses were conducted for several reasons. Among them was to determine the gas concentrations in the air which are associated with complete fruit fly mortality. (2) To determine whether there is any relationship between gas concentrations and the type of commodity treated and whether this is a factor in mortality. This conclusion cannot be made as yet but several tests with partial loading of Zucchini squash, papaya, avocado, cucumbers, and bell peppers showed some variation in the beginning but at the end of the usual two-hour fumigation period gas recoveries were just about the same.

Gas recoveries in the various-sized chambers were compared for various commodities. The recoveries in the 10 and 100 cu. ft. chambers were identical at the 2-hour mark at 1 mg./liter or 8.3% recovery. These were with cucumbers, avocados, and pre-packed papayas fumigated at 3/4 lb. dosage for 2 hours. More data are needed on gas recoveries in the 376 cu. ft. chamber.

Mr. Balock: In 1950 our intensive fumigant screening program was inaugurated with the cooperation of Dave Lindgren of the University of California. Since then considerably more work has been done and Frank Hinman will tell you about this phase.

Mr. Hinman: Since 1950 some of these people have had to hear this several times but unfortunately you can't talk about it without going over all of the screening. I will describe the method briefly.

A five-gallon can was used with a friction-top lid with a hole in the center of the lid and the material to be used is measured by a pipette or burette through this hole upon a piece of filter paper set on a platform of hardware cloth about 2" below the hole. In the bottom of the can is a little platform on which are set 50 larvae in cans and 100 eggs counted out on wet filter paper. The fumigant period is two hours at about 75° F. We make the examinations for mortality at 24 and 48 hour intervals.

We have screened a couple hundred halogen compounds and 70 compounds that don't contain halogen. The more we have screened the more we have marveled at the unique properties of EDB. If we were to consider the other bromine- and chlorine-containing compounds as modifications of the ethylene dibromide molecule made by adding or subtracting Cl, Br, or CH_3 groups, we would find that any change reduces the toxicity. The EDB molecule killed 95 per cent of both eggs and larvae at less than 1 mg./liter. The closest we could come to that with any other bromine- or chlorine-containing compound is ethylene chlorobromide--it kills at a little better than 2 mg./liter. The next most toxic compound was 1,2-dibromo-butane and it kills at 9 mg./liter.

Dr. Carter: In the second compound on the chart, did you substitute two chlorines?

Mr. Hinman: No, it's chlorobromide, ethylene chlorobromide.

Then, if we add a methane radical, either at the end or in the middle of the EDB molecule, you have 1,2-dibromo propane and 1,3-dibromo propane, both of which killed 95% of the eggs and larvae at 18 mg. per liter. Substituting chlorines for bromines we have ethylene dichloride which kills 95 per cent of eggs and larvae at 21 mg. per liter. You can see, therefore, that there is quite a drop in toxicity from ethylene dibromide to ethylene chlorobromide and then there is a big jump downward to the other compounds. When you consider the number of particles in a given volume that will cause 95 per cent toxicity of eggs and larvae, the difference is even greater. In ethylene dibromide the number of micromoles per liter affecting this toxicity is a little less than 4; in ethylene chlorobromide the number of micromoles per liter required to give 95 per cent mortalities is 16 (i.e., for 95 per cent mortality you have to have 4 times as many particles in a given volume of space). In 1,2-dibromo-butane 40 micromoles kill 95%; in 1,2-dibromo-propane, 89; 1,3-dibromo-propane, 89; and ethylene dichloride, 212. Therefore, among the saturated bromide and chloride materials EDB stands by itself.

Two of the unsaturated (double-bonded) materials, chlorobromo propene and 1,4-dichloro-2-butane killed at 6 to 8 mg. per liter. Both of these materials damage fruits.

Table 1. Ethylene dibromide and related compounds, in order of the dosage required to give 95 per cent mortality of naked eggs and third-instar larvae of the oriental fruit fly.

Compound	Variation from EDB molecule	Milligrams per liter		Micromoles per liter	
		Eggs	Larvae	Eggs	Larvae
H H BrC—CBr H H Ethylene dibromide	—	0.8	0.6	3.9	3.2
H H BrC—CCl H H Ethylene chlorobromide	1 Cl substituted for 1 Br	2.2	2.3	15	16
H H BrC—C—CH_2—CH_3 H Br Butylene dibromide	Two methyl radicals added	8.7	7.8	40	36
H H BrC—C—CH_3 H Br Propylene dibromide	One methyl radical added	18	1.8	89	8.9
H H H BrC—C—CBr H H H Trimethylene dibromide	One methyl radical added in center	5.5	18	27	89
H H ClC—C—Cl H H Ethylene dichloride	Cl's substituted for Br's	5.9	21	60	212

Some other Cl- and Br-containing compounds kill larvae at dosages as low as 3 to 4 mg. per liter but are much less toxic to eggs. There is a big variation; some materials will kill eggs very readily but not larvae. Others will kill larvae and not eggs.

The iodine-containing compounds behave differently than the bromides and chlorides. The iodides are very toxic and there are 3 of them that kill as well as EDB--1,2-diiodo methane, iodohexane, and iodoheptane. Why these long-chain iodides would kill so well I don't know, but there are many things about them that I don't understand. Quite a number of the iodides reach a maximum kill of larvae, often above 90%, at a very low dosage--a dosage less than needed to saturate the air in the chamber--and at that point they quit killing and you can add much greater amounts of iodide without increasing the kill. Why that it, I don't know.

Another effect of the iodides is to inhibit pupation. Some of the affected larvae will live for days; they won't pupate, but they won't die, and it is difficult to determine the mortality.

The only one of the iodides which has been tested extensively against the immature stages of the fruit fly in infested fruit is methyl iodide. It killed at very low concentrations and yet at 2 lb. per 1000 cu. ft. it didn't kill all of the immature stages in papayas.

There are a couple of chlorofluorides that killed just a little bit better than the corresponding chlorine compounds. We have tested a number of them and would like to test some more.

Straight-chain compounds were more toxic than branched-chain compounds; alkyl side chains were almost always associated with a decrease in toxicity.

Technical chlorobromopropene (principally 1-chloro-3-bromo propene), allyl iodide, and 1,4-dichloro-2-butene were the most toxic unsaturated halogenated compounds tested. All were phytotoxic.

When we come to the non-halogen-containing materials most of those that were effective at low concentrations were unsaturated compounds, very reactive, and damaging to commodities. Any of those that killed below 20 mg. per liter affected commodities adversely with the possible exception of allyl alcohol which was ineffective in killing the immature stages of dorsalis in papayas at 2 lb. per 1000 cu. ft.

Many materials tested were more effective against one developmental stage than against the other. In many instances this difference was pronounced. As an extreme instance, dibromodichloromethane killed 95% of the larvae at less than 6 mg. per liter but was ineffective against eggs at 230 mg. per liter.

Several compounds should be tested further against infestations in fruits. Several compounds toxic to eggs have been tested in combination with compounds toxic to larvae without promising results but other combinations should be tried. There are a few other compounds we still want to try and there are other compounds that will become available but aren't available at present for testing. So we want to keep the program active but we won't be making as many tests as we have in the past.

Mr. Christenson: This screening work with naked eggs and larvae, do you still consider naked eggs and larvae to give you entirely reliable indication of promising materials?

Mr. Hinman: It's quite reliable. There are more compounds that kill larvae fairly well than there are that kill eggs fairly well, and so you do need to test both against both larvae and eggs. We think that any compound that offers promise should kill at a fairly low dosage in the screening.

Mr. Balock: I think we are more or less in the same boat as Mr. Gow is with screening attractants and repellents--the acid test for him is the field test, of course. He uses the olfactometer in the outdoor cage to weed out those materials that show promise and we use our naked eggs and larvae for the same reason.

Mr. Keiser: In laboratory tests DDT is approximately 1/100 as toxic as parathion against adult D. dorsalis or to put it another way, parathion is 100 times as toxic as DDT. Yet there is room for DDT in control work. I was just wondering whether some of these compounds which are not as good as EDB have some advantage from the cost standpoint, or lack of toxicity to the fruit?

Mr. Balock: The point is that in tests with fruits injury occurred in many cases.

Mr. Hinman: Most of those that I mentioned have been tested by the University of California against different commodities--quite a number in fact. Most of them have been found lacking.

Dr. Messenger: Have you recommended any use of chlorobromide? Are there any advantages of it over EDB that would warrant using it?

Mr. Hinman: Its molecule is less heavy, it vaporizes at a lower temperature, and theoretically it should be a better fumigant, so that in spite of it not being quite as toxic as EDB, it should certainly have a place in fumigant treatment. The other thing in favor of ECB is that the California people have found that there were a number of commodities that tolerated ECB a good deal better than EDB. It will find a place in commodity treatments, I am sure.

Mr. Balock: The use of aqueous dips is showing considerable promise as a treatment for fruit fly infestations in commodities and Frank Hinman will tell us of his preliminary tests.

Mr. Hinman: As Ohinata mentioned in his talk, the Plant Physiology Department at the University developed a hot-water treatment for anthracnose rots in papaya. This consists of a 20-minute dip at from 110° to 120° F., and a few months ago the Mexico City laboratory mentioned in a report that they had killed the Mexican fruit fly in mangoes with an EDB-water dip. That, of course, suggested the possibility of combining hot water for anthracnose with EDB added to control the flies at the same time. So we made some tests. When we dipped the immature stages of the flies in hot water at 110° F. or above, it affected them adversely so we made the tests at 102° to 104° F. which didn't affect them. A 20-minute dip at that temperature killed the eggs and larvae at a dilution of 1 part of EDB to 25,000 parts of water by volume.

It was soon found that the EDB disappeared very rapidly from a solution, apparently by evaporation. It disappeared much more rapidly from an open container than from a closed one, and it disappeared more rapidly in a warm room than a cool one, and a little more rapidly in light than in dark.

Periodic samples were taken for EDB analysis from 20 liters of a solution of EDB in water, 1:2,000 by volume, kept at 116-120° F. in an open water bath with 1-1/2 square feet of liquid surface area. The EDB content was found to drop from 500 mg. per liter one-half hour after the solution was made up to 40 mg. per liter 12 hours later. After 12 hours this solution still killed immature stages in infested papayas dipped for 20 minutes and eggs dipped for 20 minutes in a sample cooled to 102-104° F.

Mr. Maehler: At what point from your data would the EDB still be effective:

Mr. Hinman: It would be somewhere just below or just at 50 mg. per liter.

Mr. Balock: What was the original concentration?

Mr. Hinman: 1:2,000 by volume.

Prolonged and vigorous agitation is necessary to get EDB into solution. Some emulsifying materials will break it up so that it can be readily dissolved. Ten materials were tested as co-solvents for EDB and water; none appear promising. Fifty materials were tested as adjuvants with EDB in water and a number were selected for further tests with the immature stages of the fly and with dipped fruits. D. dorsalis eggs were dipped in EDB-water solutions made up with 5 different emulsifiers. These materials increased the kills obtained in EDB-water solutions but no definite differences could be determined between the effects of the different emulsifiers. Tests showed that papayas dipped in EDB in water, 1:2,000 by volume, for 20 minutes at 116-120° F. were sometimes slightly injured. Each of 13 emulsifiers added at the rate of 1 or 2 parts to 20,000 parts of solution intensified EDB injury. Although innocuous by themselves, in combination with EDB all caused injury at 116-120° F. for 20 minutes in a 1:2,000 EDB-water solution by volume. In a 1:4,000 solution by volume, for the same time and at the same temperature, some emulsifiers caused no injury and some caused slight injury. The principal indication of injury was the appearance of darkened areas on the surface of the skin. Taste and flavor were not affected. Riper fruits were more tolerant than greener fruits. On the basis of numerous tests, Atlox G-672 (Atlas Powder Co.) was finally selected as the emulsifier for use in further experimentation.

At present we are dipping papayas in solutions of different strengths, keeping the time and the temperature constant, to obtain dosage-mortality relationships. We have obtained no survivors in EDB-water solutions of 1:30,000 by volume with emulsifier added, or at strengths of 50 mg. per liter of EDB as determined by analysis.

We are also taking periodic samples and dipping papayas at intervals in solutions kept under conditions that would result in rapid loss of effectiveness (temperatures of 118-120° F., low ratio of volume to surface area, continuous stirring and continuous movement of air over the surface of the solution) in order to determine how long a given strength of solution is effective in destroying the immature stages of the flies under the most extreme conditions likely to be met with if a dip were to be used in treating papayas commercially.

With reasonable precautions EDB dips should not constitute a health hazard. Good ventilation is needed to carry the fumes away from the operators and prevent inhalation.

An EDB dip should be a valuable addition to fumigant treatments. The information obtained in developing such a treatment for papayas can be used to test dip treatments with EDB and ethylene chlorobromide or perhaps other fumigants for other insects in other commodities. For instance, recent tests have indicated the possibility of controlling the mango weevil, an insect that has proven extremely hard to kill by fumigation with an ethylene chlorobromide dip. Where we have fumigated for 8 hours with 4 lb. of EDB, we find some of them kicking a little 10 days afterwards. We dipped a few mangoes with a light infestation of mango weevil in EDB at 1:500 dilution by volume--that's almost a saturated solution--and ECB at 1:500, and both of these solutions killed the small population present. With EDB the mangoes were injured. The skin became dark. With ECB they weren't injured, so we may be able to develop a dip for the mango weevil. There is another possibility that some materials may withstand a 20-minute dip where they won't withstand a 2-hour fumigation.

Q. What type of mango?

Mr. Hinman: Haden.

Mr. Barker: Were those 20-minute dips on the mango?

Mr. Hinman: They were 1/2-hour dips, at close to 120° F.

Dr. Newell: What is the solubility of EDB in water?

Mr. Hinman: About 4 gm. per liter at ordinary temperatures.

Q. When you spoke about infestation in the mangoes, was that the weevil?

Mr. Hinman: Yes, the mango weevil.

Mr. Balock: Mr. Ernest Akamine of the H.A.E.S. will now give us a report on his tolerance studies.

Mr. Akamine: If my memory serves me right, the last time I talked to you about the problem of controlling anthracnose rot in papayas and the use of the hot-water dip. Since that time we have gone into the problem in detail and have tried to develop our aqueous dip for the control of anthracnose rot. The research angle of this problem has been finished and the results have been published. By this treatment we have been able to prolong the life of shipment of papayas after fumigation anywhere from a week to two weeks, so from the commercial angle and the shippers' standpoint, this has been of tremendous help to the local papaya shipping. In Hilo this is commercial practice--every papaya shipped out of Hilo is first dipped in hot water at a temperature of 110-120° F. for 20 minutes and then fumigated and then shipped. As far as the Honolulu local shippers are concerned, all of them are extremely interested in the treatment and one of them I think will before long follow this treatment in his plant. After I finish, Dr. Arisumi will tell you about the effect of this treatment.

The Cercospora sp. rot, which you probably know about by now, is being found in papayas that are especially grown in Hilo, Hawaii. When we got a part of IRAC funds for this project, we were specifically told to work out ways and means of controlling this new disease. We tried known treatments, some of them the hot-water dip, fungicidal dips (using all kinds of fungicides available), radiation and vapor heat. Very unfortunately none of these seem to control Cercospora rot which happens to be a close cousin of the anthracnose family.

Mr. Balock has mentioned something in connection with the problem of vapor-heat treated papayas, i.e., papayas treated by the so-called quick run-up. We found that the aroma was affected by this treatment. He has also mentioned the effect of EDB treatment on pre-packed papayas. To date we haven't been able to find any damaging effect from this treatment. Mr. Hinman has called your attention to the effect of EDB-hot water dip on papayas, and as he pointed out there have been varying degrees of injury all the way from slight scalding to severe scalding.

Bell pepper is another commodity we have been working on. I understand that this commodity has been taken off the list of exportable commodities--am I right, Jack?

Mr. Balock: Yes, that is right so far as EDB is concerned. However, they are still on the approved list for vapor-heat treatment.

Mr. Akamine: That was due to the fact, I think, that standard EDB treatment did not kill the fruit fly infestations. That is kind of hard to reconcile to the fact as Mr. Ohinata pointed out that peppers retain a high bromide residue. As a substitute for this treatment for bell peppers, the Bureau of Entomology has been working on using methyl bromide fumigation. To date we have found that a dosage of 2 lb. for 3-1/2 hours was detrimental to the peppers.

There is no satisfactory treatment for egg plant. EDB is definitely harmful and so are the other fumigants. I don't know whether Mr. Hinman said anything about the use of new chemicals on egg plant--I don't remember. Apparently, some of them are not harmful and others are extremely harmful. The injury done to egg plant by the use of these fumigants is demonstrated by rot at the calyx and so we tried various fungicides and hot water dips to see if we could control that rot but to date we don't have any satisfactory treatment for it. EDB is definitely harmful.

So much emphasis has been put on the treatment of pre-packed commodities. Pre-packed cucumbers treated at a dosage of 3/4 lb. for 2 hours tolerated the treatment.

As Mr. Hinman said, when it comes to mango we still don't have any satisfactory treatment to kill the mango weevil, but as far as tolerance is concerned with EDB treatment up to a dosage of 4 lb. for 8 hours, we weren't able to find any injury.

Passion fruit, when treated with EDB at a dosage of 1/2 and 3/4 lb. for 2 hours tolerated the treatment. Avocado, I understand, is also off the list of exportable commodities. Here again in spite of the high EDB residues in the

edible portions of the fruit some of the flies were not killed with the standard approved EDB treatment. Nevertheless, we discovered that EDB at a dosage of 3/4 lb. for 3 hours did not harm the avocado. On Poha, so far we have only 1 test at a dosage of 1/2 lb. EDB for 2 hours, and one test at 2 lb. MeBr for 2-1/2 hours. The EDB treatment made the fruit last for about 8 days only, whereas the MeBr-treated fruit lasted for 9 days, and the untreated lasted for at least 11 days.

There is one other commodity I would like to tell you about, and that is fox-heads. When these were treated with EDB at the standard dosage of 1/2 lb. for 2 hours, they were definitely injured but when treated with MeBr at a dosage of 3-1/2 lb. for 2 hours, or at a dosage of 2 lb. for 2-1/2 hours, or at a dosage of 2 lb. for 3-1/2 hours, the fox-heads sustained no injury at all.

So much for the miscellaneous commodities.

Now, I wish to spend the rest of my time discussing some ecological phases or aspects on the tolerance of Chinese bananas to EDB. Shortly after Chinese bananas were put on the list of approved exportable commodities (subject to EDB fumigation), we happened to be down to one of the local wholesale markets and we picked up a bunch for our own use, and to our amazement we discovered that that particular bunch did not tolerate the EDB treatment. Therefore, we traced the source of that bunch and we discovered that it came from a farm at Punaluu. The very next day we went out and got a bunch for ourselves and treated it. Again the bunch all turned black upon fumigation. The next thing to do was to find out if location had anything to do with tolerance of Chinese bananas to fumigation. Our next program was to collect Chinese bananas from everywhere Chinese bananas are grown and we proceeded to collect samples from all of the islands. That continued for about a year and with exception of a 2-3 month period during last winter, all of the bunches collected from Mokuleia, Punaluu, from the University Farm in the Mid-Pacific area turned black upon fumigation. All those bunches collected from upper Manoa never turned black, and so the problem became more and more interesting. We tried to compare the cultural patterns of these different places and we discovered that at upper Manoa the standard practice was for the farmers to cover each bunch with sugar sacks or fertilizer sacks. They are doing that to control certain insects and fungus growth on the fingers, which cause the fingers to turn black. That's their primary purpose of covering them in this rainy section. Over at Kaneohe in certain sections, I understand the farmers from time to time take the trouble to cover bunches. So we surmised that those bunches that were treated by the Bureau entomologists probably came from Manoa section or from the Kaneohe section where some farmers do cover the bunches. The next step was to see if we could duplicate the Manoa condition out at Punaluu and Mokuleia where the farmers do not cover their bananas. Therefore, we went out there and covered their bunches and then later treated them. We found that we had duplicated exactly the Manoa conditions---our bunches which had been covered turned out O.K.

From there on the ecological interests are varied. The first sensible thing a physiologist would do would be to determine what condition in the plant tissue was concerned so we ran moisture content analyses on the covered bunches and on the uncovered fingers. We discovered that the covered fingers always ran higher in moisture than the uncovered ones. We thought we had the problem licked then, but to make the job more complete the next sensible thing to do was to determine the true picture of the whole situation. So we took the trouble to analyze the moisture content of the various parts of the banana fruit. We

discovered with bunches not covered, in all cases, the injury was worse at the blossom end, and then as you go down towards the stem end the injury became less evident. Therefore, we divided each finger into 3 sections and ran tests on those different sections for moisture content. We separated the skin from the pulp in each case and ran moisture analyses on that. We discovered that the moisture was much higher at the stem end, 91.1%; less so in the center, 90.1%; and least at the blossom end, 89.3%. So you see there is a definite moisture gradient that is associated with the degree of blackness. The lower the moisture level the greater the injury to the fruit. Tentatively we considered the blossom end to be our index tissue. The pulp behaved in different ways. We discovered upon covering that the pulp doesn't behave so well as the peel, so we tentatively discarded the pulp as being an index. The next problem was to find out which hand should we sample--after all there are many fingers in a small bunch of bananas. Therefore, we took 3 fingers from each hand and then made a compound sample from each hand and ran them. The water content for the blossom end averaged 89.8; center, 90.1; and stem end, 91.1 per cent. So you see it wouldn't matter which hand we would sample. We then tried to determine which finger should we sample. We found the same gradient again in all cases and apparently it doesn't matter which finger you sample or which hand you sample. Another thing we had to determine was what time of the day should we sample. It made little difference although there was some indication that in the afternoon the moisture level may drop slightly so we made it a practice to have the sample brought into the laboratory by noon at least.

When a bunch is covered, as I have already said, the moisture level rises. There was an extreme similarity between the samples but there was no gradient in any case such as was found with the uncovered bunches.

We found that you can induce tolerance in bananas to fumigation by covering only certain parts of a bunch. You don't have to cover the entire bunch--you can cover half of the bunch, or one hand, or one finger, and in each case the moisture level rises where covered. It was also found that the bananas had to be covered for about the last 2 months. If they were covered for a shorter period they didn't tolerate treatment.

Furthermore, we found that if we covered the bunches with some transparent material like cellophane or plastic shower curtain, although the moisture level went up we weren't able to control the tolerance. We, therefore, think that there must be something else associated with the moisture content--probably shade or something else. Also, we found that if we got the moisture content higher than the 90 to 91%, the tolerance was affected adversely.

Therefore, if moisture isn't the critical factor, what is? There are several possible factors. One of them is chlorophyl. When you cover with an opaque material, the bananas are a lighter green than the uncovered ones--that's expected, of course--and that is probably due to the amount of chlorophyl although we haven't had a chance to analyze for it yet. Also, it might be that EDB interferes with the breakdown of the chlorophyl molecules. Asorbic acid as well as acetic has been used by canners to prevent blackening of canned fruits and vegetables, so there might be something there in bananas. We ran tests for asorbic acid and found there was no difference between the covered and the uncovered bunches.

We asked Mr. Ohinata to run some EDB residues for us in bananas which are covered and some which are not. There was no difference in EDB residues.

The farmers who make the practice of covering the bunches always nip the blossom end as soon as they have finished blossoming. They do this to prevent the development of the so-called "cigar" disease. This disease is only prevalent in the rainy areas. At Mokuleia they don't bother to remove the blossom end. We thought that maybe that might have something to do with it. Therefore, we removed some from bunches at Mokuleia but it made no difference.

We also investigated the effect of storage temperatures after fumigation. We discovered that the higher the storage temperature the less the injury, although even at room temperature there was a certain amount of injury. Now, the trouble with room temperature is this--the bananas ripen too rapidly--in 3 or 4 days time they are all fully ripened and in another day or two they are rotten.

(Mr. Akamine then showed some slides to illustrate his points.)

Mr. Keiser: I am wondering if this isn't a highly localized photosyathesis and might be due to the starch content.

Mr. Akamine: We did take into consideration that aspect. However, the starch content in the banana peel is very low.

Mr. Keiser: The blackening might be in relationship to the flesh itself.

Q. Did you say EDB hastens the ripening of banana?

Mr. Akamine: Yes.

Mr. Keiser: Those who use plant hormones might be interested in these findings.

(10-minute intermission)

Mr. Balock: Dr. T. Arisumi, IRAC Project, H.A.E.S., has been conducting some intransit studies with papayas treated with hot water dips to control storage rots and he will give us a report on these studies at this time.

Dr. Arisumi: The following report is a brief summary of 7 test shipments carried on during the winter and spring months of 1953. Laboratory tests conducted by the Department of Plant Physiology, University of Hawaii, have shown that the anthracnose storage decay of papayas can be effectively controlled by dipping papayas in hot water at temperatures between 110°-120° F. for 20 minutes. The tabulated data show that the same results can be obtained under actual shipping and commercial conditions. Papayas used in these tests were shipped from Honolulu to San Francisco via ocean freight. These fruits were examined upon arrival and periodically thereafter.

Dr. Pemberton: Was that after a 20-minute or a 15-minute hot water dip?

Dr. Arisumi: 20 minutes.

Q. Did you say you ran vapor-heat as well as hot water and there was no difference?

Dr. Arisumi: There is no external difference.

Cumulative Percentages of Decayed Papayas

Treatment	Total No. of fruits	Shipping temp.	Per cent Decayed		
			At arrival	3 days after arrival	6 days after arrival
Hot water + EDB	50	50° F.	0	2.0	10.0
Short vapor heat + EDB	50	50° F.	0	8.0	12.0
EDB only	50	50° F.	26.0	52.0	70.0
Hot water + EDB	79	47° F.	0	8.8	15.2
Short vapor heat + EDB	80	47° F.	0	6.2	8.7
EDB only	55	47° F.	14.5	65.4	80.0
Hot water + EDB	140	47° F.	0	0.7	2.1
Commercial vapor heat	140	47° F.	0	4.3	15.7
EDB only	140	47° F.	10.7	37.8	73.6

EDB - approved treatment.

Commercial vapor heat - approved treatment.

Short vapor heat - 3 hr. conditioning followed by 2 hr. saturated temperature 115° F. (For anthracnose control only.)

Hot water treatment - 120-118° F. for 20 minutes.

Mr. Christenson: These were on Oahu papayas?

A. Yes.

Mr. Barker: Did you compare vapor-heat treatment with the hot-water dip 12 days after?

Dr. Arisumi: Yes.

Q. What were your observations?

Dr. Arisumi: After six days in San Francisco the hot-water papayas showed 2.1% injury, the vapor heat, 15.7, and the controls, 73.6.

Q. Then your hot-water treatment is more superior to vapor heat?

A. That is a conclusion we would like to draw, but the injury may have been due to bruising or injury to fruit before treatment.

Mr. Christenson: Do you plan additional tests--intransit ones?

Dr. Arisumi: No. These were carried on with winter vegetables, also. Unless we carry them out with other varieties of vegetables.

Mr. Balock: Your results here show that papayas need a hot-water treatment, or otherwise the arrival condition will be poor.

Q. Do the fruits ripen before arrival?

Dr. Arisumi: No. The common practice is to pick and hold the papayas 2-3 days before shipping.

Q. That would mean that you would have none of the fruits without rot?

Mr. Akamine: Heretofore shippers have reported erratic results. Those people assumed if they found one rotten fruit, the whole crate was considered rotten. We consider these data more accurate than the previous data. In answer about continuing the test shipping--we asked IRAC for additional funds but were refused.

Mr. Balock: Ken Maehler, who is a former member of our staff, needs no introduction, I am sure. He will tell you about the relationship of research to practical quarantine problems.

Mr. Maehler: In the remaining minutes of this policy meeting I would like to discuss briefly some of the relationships between Research and Plant Quarantine. To give you an example of what I mean--this is an agricultural aerosol bomb--it works like this--you turn the valve on and turn it off. A simple operation. But is it really so simple? Actually before they worked out the aerosol principle, they had to develop a formula for the insecticide. Now, you wouldn't let Loren Steiner give you this demonstration with a knapsack sprayer with wettable DDT because there would be more here than wrinkled noses. Research finally developed a formula, G-651, which incorporated a number of desirable features. It had good mortality; wasn't toxic to human beings; wouldn't stain upholstery; or craze plastic or tarnish instruments. This G-651 contains 2% DDT, 6% pyrethrins, 8% velsicol, and 84% Freon. Having arrived at a formula it was necessary to figure out a dosage, so over a period of time they ran a series of exhaustive tests in the Peet-Grady chamber and on aircraft, and they determined that for the Public Health dosage we could use 7-1/2 grams of this formula, and for the Agricultural spray we could use 30 grams per 1000 cubic feet. Having arrived at that point, it was necessary to get some kind of dispenser for the formula, so they devised the Yeoman nozzle. It has two apertures, which have an orifice of 0.017 and a rate of flow with G-651 of 3.3 grams per second. Having gone thus far, then it was necessary to find out the volumes of all of the aircrafts--the C-54, the C-97, the B-47, the C-124's, and all of the rest of the aircraft. So we wrote all of the major aircraft manufacturers in the U. S., as well as the Civil Aeronautics organization in Washington, and they finally gave us the volumes of these aircraft. So we knew the volumes; we had the formula; we knew the dosage. It was then a simple matter to explain to our inspectors somewhat as follows: "Now, this is a C-54 aircraft; its volume is 3,500 cubic feet; turn the nozzle on and then turn it off in 32 seconds." So, turning on this valve is a simple operation, but actually a tremendous amount of research is back of it. As fringe benefits, they now use this aerosol principle for propelling a number of things--they whip cream, propel shaving cream, I even saw one for a wave set (I'm not particularly interested in that); they put paint on cars, and a number of other things. There is a multimillion dollar industry in aerosols alone. That will give you an example where Research fits into our program--we aerosol planes every day.

That is just one treatment. We have many treatments--treatments for propagative material, for cotton, for burlap, for soil, for seeds. All of these treatments are based on research. In addition, plant quarantines themselves are based on entomological observations on insect distribution, and on the fact that insects have certain hosts and, while our quarantines are not perfect, one of the reasons is that the research people can't give us all of the answers that we need. That, briefly, ties in Research with Plant Quarantine.

A phrase that has become accepted lately is "calculated risks." Actually, the enforcement of plant quarantines has for years been promised on calculated risks. If you will turn to the first page of this little brochure that they have passed around, "Work Load Statistics for Fiscal Year 1953," you will see the figures of 17,000 planes and 1,071,338 passengers' baggage, 414,873 boxes of cut flowers; the thought must occur to all of you--how can they possibly look through all of that material and not miss something? We are the first to admit that we do miss some contraband. How much we miss we don't know. It's like the question the lady asked a guide in Carlsbad Caverns as they walked along, "How much of this cavern is still unexplored?" Obviously, the guide couldn't provide that information. You will see at the bottom of the page that we did intercept over 16,000 lots of

WORK LOAD STATISTICS

Port of Honolulu, T. H.

Fiscal Year 1953

Total Planes	17,863
Foreign	7,963
Domestic Dept.	9,060
Total Passengers' Baggage	1,071,338
Foreign	485,363
Domestic Dept.	585,975
Cargo - Domestic Departures	39,950
Mail Inspection	732,969
Miscellaneous Vegetables (Pounds)	283,338
Cut Flowers (Boxes)	414,873
Treated Fruit (Containers)	122,280
Interceptions of Plant Material	16,461

plant material on foreign aircraft and domestic aircraft. Fortunately for Plant Quarantine, the natural phenomena known as environmental resistance tend to prevent new insects from establishing themselves in new places. The insect's biotic potential tends to increase its numbers; the environmental resistance tends to reduce them, and probably environmental resistance is Plant Quarantine's chief aid because when we do miss some infested plant material, unless many different factors are synchronized, the probability is the insect won't become established. We know that tens of thousands of insects are carried by aircraft annually, and yet the records for Hawaii indicate that only about 150 have become established during the post-war years, including the beneficial ones. Therefore, the chance of an insect's becoming established is greatly reduced by environmental resistance which includes meteorological and biological factors which tend to destroy the insect.

One of the things that we are particularly interested in is commodity treatments, and I think our two organizations tie in pretty well together. I would like to show you some of the progress that Research people have made. You will notice on the next page that in October of 1949 they had vapor heat approved for the treatment of bell pepper, papaya, tomato and Zucchini squash; shortly after that, pineapple was also added to the commodity treatment by vapor heat (1951). Then on April 20, 1951, there was a series of commodities including avocado, bell pepper, bitter melon, Cavendish banana, cucumber, string bean, pineapple, and Zucchini squash, approved for EDB. In June, 1953, based on research again, pineapple was removed from treatment requirements, and they were allowed to be shipped subject to inspection only. Then on August 3, 1953, it became necessary to remove avocado and bell pepper from the EDB fumigation, because current tests indicated that the present dosage was inadequate to control the fruit fly larvae.

At the bottom of the page is a summation. On the left-hand side are those commodities that are certifiable and may go to the mainland, and on the right-hand side are a few of the commercial commodities that are prohibited at present for which it would be desirable to have treatments. These include avocado, other varieties of banana, chili pepper, egg plant, litchi, mango, and certain other fruits for which a market might be developed on the mainland. So the ones to the left are the only fruits and vegetables that may be shipped, plus certain leafy vegetables and root crops which are shipped subject to inspection only.

If you will turn to page 117--this is really an eternal triangle--Plant Quarantine, Commodity Treatments, and the Commercial Shipper. Briefly outlined are the commercial shippers' interests and what they would like Research to work on. Mr. Holzman, of the Aloha Papaya Co., would like quick run-up for vapor heat and an approved treatment for egg plant and chili pepper. Slim Asakura (Rancho Products) would like fumigation for packed fruits and approved treatment for tomato, bell pepper, and apple banana. He doesn't particularly like the vapor-heat treatment for tomatoes because he had some tomatoes cooked up pretty badly at one time. At Sea View Farms, (Twitty) they would like a fumigation for packed fruit and approved treatment for avocado and mango. Mr. Kazanteno (Tropical Fruit) would like a fumigation for packed fruits and approved treatment for egg plant. Over at Hilo, (Kokosui) they would like a fumigation for packed fruit. These are their problems. 1/

1/ Editor's Note: Most of these problems have been under investigation for some time and there are enough data available already to indicate that recommendations may be possible in the not too distant future. Accounts of the most recent progress in the packaged fruit studies are contained in previous reports presented by Messrs. Balock and Ohinata.

DATES OF APPROVED TREATMENTS FOR COMMODITIES

FOR SHIPMENT TO THE MAINLAND

October 19, 1949 BEPQ-481

Approved: Vapor-heat 8-3/4 hour, 110° F., 100% RH

Bell pepper
Papaya
Tomato
Zucchini Squash

December 10, 1951 BEPQ-481 Rev.

Approved: Vapor-heat

Pineapple

April 20, 1951 BEPQ-529

Approved: EDB 1/2 lb., 2 hr. 70° F.

Avocado
Bell pepper
Bitter melon
Cavendish banana
Cucumber
String bean
Pineapple
Zucchini squash

June 27, 1953

Removed treatment requirement for:

Pineapple

August 3, 1953

The following commodities no longer approved for EDB fumigation:

Avocado
Bell pepper

SUMMATION

Certifiable Have Approved Treatment	EDB	VH
Bell pepper		*
Bitter melon	*	
Cavendish banana	*	
Cucumber	*	
Papaya	*	*
String bean	*	
Tomato		*
Zucchini squash	*	*

Prohibited
No Approved Treatment

Avocado
Banana (other var.)
Chili pepper
Egg plant
Litchi
Mango
And all other pulpy fruit which have no approved treatment.

COMMODITY TREATMENT PROBLEMS

The commercial fruit shippers indicate the following to be of greatest interest to them insofar as research developments are concerned.

I Aloha Papaya - J. Holzman

1. Quick Run Up for Vapor-heat

2. Approved treatment for:
   Egg plant
   Chili pepper

II Rancho Products - S. Asakura

1. Fumigation for packed fruit.

2. Approved treatment for:
   Tomato
   Bell pepper
   Apple banana

III Sea View Farms - C. Twitty

1. Fumigation for packed fruit.

2. Approved treatment for:
   Avocado
   Mango

IV Tropical Fruit - S. Kazanteno

1. Fumigation for packed fruit.

2. Approved treatment for:

   Egg plant

V Kokosui - Hilo

1. Fumigation for packed fruit.

On page 119 you will see some plant quarantine problems and research developments we would like. At the top of the page is shown the man hours that are utilized in the supervision of commodity treatments and to carry on the post-treatment safe-guards. You will notice that for a period of 12 months this amounts to about 5,000 manhours. Below is indicated that in the last six months they have shipped about 259 tons of papaya and a little over 700 tons of pineapple. At the bottom is shown how our time is actually utilized--i.e., about 75% supervising the packing of these commodities, 20% in starting and stopping the treatments, and about 5% convoying the commodities and seeing they are properly stowed aboard the ship.

So, if a satisfactory fumigation for packed commodities could be approved, it would help us save some time in supervising and packing operations at the various treatment plants in Hawaii.

I was particularly interested yesterday in some of the histograms and charts and the thought occurred to me that probably never had so much work been explained in so few words. I worked for this project for two years and know how much guava picking and sifting and counting puparia, etc., goes into a simple histogram, and I thought you might be interested in knowing that the manhours involved in work on this first sheet required about 80,000 manhours, and as I pointed out, undoubtedly we miss certain things.

To give you some idea of the research problem involved in determining an adequate fumigation dosage for packed fruit, I would like to show you some of the different types of packing containers. A box like this is all cardboard and sealed up. This box is open but has packing material. This box has packing and partitions. Some of these gift boxes have paper in them at the bottom--and so there are a lot of different types of pack. Note this box. This is a box that Tropical Fruit uses to ship papayas--there is a layer of excelsior in the bottom, a layer of fruit on the top. This is the way the fruit is being treated at present--in a field box. This is the way they would prefer treating in a packaged container.

I don't mind competing with other speakers, but I don't want to compete with the lunch hour, and if there are any other questions I shall be glad to answer them. If there are no other questions, I will turn the meeting back to Mr. Christenson.

Mr. Christenson: Thanks a lot, Ken. We have had a very fine session this morning and I want to thank everyone who has participated in the meetings.2/

Meeting adjourned.

2/ Maehler's reference to Mr. Balock's data and the ensuing discussion has been deleted by him since Research felt that he had misinterpreted that data.

COMMODITY TREATMENT SUPERVISION

MAN HOURS REQUIRED

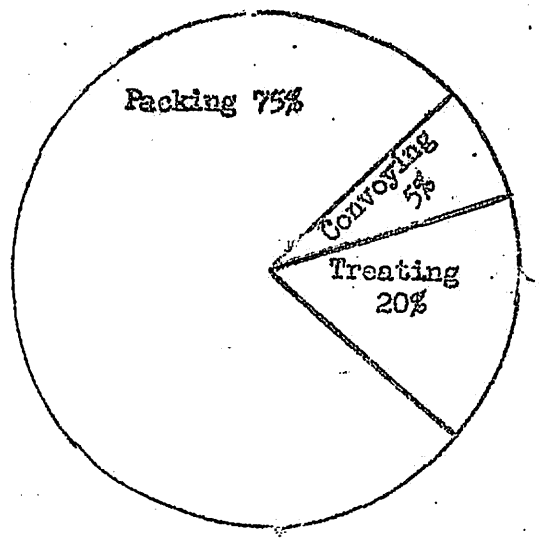
Oct.	331	Feb.	504	June	443
Nov.	392	Mar.	564	July	345
Dec.	438	Apr.	536	Aug.	166
Jan.	400	May	716	Sept.	128

Total for twelve months - 4,962

COMMODITIES SHIPPED IN PAST SIX MONTHS

	Cartons	Pounds	or	Tons
Papaya	51,887	518,870		259
Pineapple	57,531	1,438,275		719

PERCENTAGE OF TIME REQUIRED FOR SUPERVISION OF TREATING, PACKING, CONVOYING.



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POLICY COMMITTEE MEETING

(Closed Session - October 2, 1953 - 2:00 P.M.)

Present: Dr. B. A. Porter, Investigations of Fruit Insects
Mr. C. P. Clausen, University of California Experiment Station
Dr. P. S. Messenger, " " " " "
Dr. C. E. Pemberton, Hawaiian Sugar Planters' Association
Mr. Alan Thistle, Territorial Board of Agriculture and Forestry
Dr. Henry A. Bess, University of Hawaii Agricultural Experiment Station
Mr. K. L. Mashler, Division of Plant Quarantines
Dr. Walter Carter, Pineapple Research Institute
Mr. L. D. Christenson, Investigations of Fruit Flies in Hawaii
Mr. L. F. Steiner, " " " " " "
Mr. J. W. Balock " " " " " "
Mr. N. E. Flitters " " " " " "
Mr. L. A. Planck " " " " " "

Mr. L. D. Christenson - Presiding.

Mr. Christenson: I feel that once more we should call attention to the fine cooperative spirit which has been a feature of the Oriental Fruit Fly Investigations. Quite often we don't say these things but from our Bureau standpoint our strategic location on the University of Hawaii campus and in Honolulu--affording us many opportunities to gain assistance from the Hawaii Agricultural Experiment Station, the University of Hawaii, the Pineapple Research Institute, the Territorial Board of Agriculture and Forestry, and the Hawaiian Sugar Planters' Association--and the continued active participation of the University of California in certain phases of the investigations have been very important to us. A great deal of our progress in the lines of work assigned to the Bureau has been dependent upon these features.

Recently I received a letter from Mr. Jacobsen of the State Department of Agriculture of California, which was written in reply to my invitation to attend this meeting. He regrets that it was not possible for the California Department of Agriculture to be represented and lists a number of items which he would like brought up at this meeting. I think it is fitting that his letter be read at this time.

"This is in reply to your letter of September 11, enclosing copies of a tentative program for the meeting of the Oriental Fruit Fly Policy Committee to be held October 1 and 2 in Honolulu.

"While we are deeply interested in the fruit fly problem and in keeping up-to-date with the various research developments, it will not be possible for us to have a representative of this Department at the Policy Committee Meeting. There are, however, several items in which we are particularly interested and which we hope will come up for discussion. They are as follows:

"(1) We hope that there is no intent to discontinue or seriously curtail further studies of these three species of fruit flies, particularly the Mediterranean fruit fly and the melon fly until adequate information has been obtained.

"(2) While attention has been given to the use of ethylene chlorobromide as a fumigant, the question has arisen here several times as to whether it might merit more attention than it has received, in view of its demonstrated effectiveness and the fact that it is easier to handle from the operations standpoint than ethylene dibromide or methyl bromide.

"(3) The matter of progress made in reducing the exposure period for commodity treatments might be discussed. We know that some work has been done along this line and believe it to be important from the commercial standpoint where volume movements might be involved.

"(4) We do not know how much thought has been given to determining the extent to which any of the parasite species introduced into Hawaii might be adaptable to mainland conditions should the need arise. Perhaps this could be determined in the climate chambers to a limited degree. More detailed study along this line might be of considerable value to us at some later date.

"(5) We hope that the quarterly reports will be continued in their present form until the projects covered have been completed or dropped. Otherwise there would be a serious break in the valuable detailed information that has been furnished to date.

"We appreciate your kindness in furnishing us copies of the program and regret that we will not have a departmental representative present. We hope, however, that copies of the proceedings of the meeting can be made available to us."

Very sincerely yours,

(s) W. C. Jacobsen
Deputy Director

We are planning to continue work on all of these items during the next fiscal year and we hope that the progress will be entirely satisfactory.

I don't see any point in going over the charts of population trends again--they do show a definite recent upward trend in populations. Infestation trends are also up somewhat. Records of fly abundance and infestations during the past two years, I think, are ample justification for the conclusion the University of Hawaii has made recently that unless some unexpected factors are introduced no very great changes in the present basic population levels can be expected. Nonetheless, we hope the parasites and other mortality factors will suppress the populations even more than they have. If they don't, we will have a continuing commodity treatments problem of serious proportions and it seems unlikely that certain kinds of fruits, of high quality and with good shelf-life, could ever be produced in Hawaii without resorting to a spray program.

There has been considerable nation-wide and international interest in our fruit fly problems and the results of our research work. This is not only in biological control work (parasites have been shipped to a good many parts of the world), but in the fields of commodity treatments and chemical control there is likewise a great deal of interest. Israel has been quite anxious about her Mediterranean fruit fly infestations in citrus and has shown a great deal of interest in the possible use of EDB to permit expansion of their export trade.

EDB shows signs of solving an internal fruit fly quarantine problem of considerable consequence in Australia. There are also indications that EDB might ultimately be adapted to the Mexican fruit fly problem in Texas. EDB has already been approved as a treatment to permit shipment of mangoes into the mainland from the West Indies. Information on insecticides and the bait sprays has been transmitted to Israel, Mediterranean areas, South America, Mexico, Australia and some of the Pacific Islands. Throughout the world fruit flies are of great agricultural importance and we are pleased that the research in Hawaii is providing leads that may be useful everywhere.

Now, as for our own Bureau program--from the financial aspect, in the fiscal year ending June 30, 1953, the total expenditures were $233,706.70 which were expended as follows:

Commodity Treatments	$59,296.73
Chemical Control	84,551.25
Biology-Ecology	83,762.92
Physiology	6,095.80

For 1954 we don't have the complete figures as yet but the indications are there will be only a slight reduction in the total available to us.

As far as the picture from the future budgetary standpoint is concerned we just received an indication that the policy of the present administration will be to cut down on Governmental expenditures. Whether this will affect our research beyond the curtailments that should be made when certain phases of the studies have been completed is a speculative matter. By and large the new administration seems to be very favorable to Research.

Dr. Pemberton: Are those figures for 1952 or 1953?

Mr. Christenson: They were for the fiscal year which ended June 30, 1953. We are now in the 1954 fiscal year.

With regards to the Bureau's activities, for the present in Biology and Ecology there are no plans for further curtailment. However by the end of 1954 we will probably have come to a practical end point in the bioclimatic studies. This work undoubtedly will be curtailed and it may be discontinued altogether at that time. We feel that a certain amount of work on the biology and ecology of our fruit flies should go on as long as the flies remain a problem. We plan at least for this fiscal year to continue on the same basis we are operating on now. In the bioclimatic cabinets there are a few more sites we need to simulate. There are also certain special cabinet studies that should be made to determine exactly what happens when you go down to marginal and submarginal conditions, and to find out what the actual lethal points are for short-term exposures of the flies at both hot and cold extremes. As far as the results of the cabinet studies are concerned, Mr. Flitters of the Bureau and Dr. Messenger of the University of California have a major job of compiling and evaluating the information that has been gathered. What we get out of the cabinet studies will depend on how hard we work on the harvest.

We feel that there should be much more work on the biology and habits of the introduced parasites. We hope the good work Dr. Bess's people are doing will be continued. The parasite evaluation work of the University of Hawaii is very important. We hope that it will be continued. We plan to continue to study some of these parasites in the bioclimatic cabinets as long as we are running them.

The re-evaluation of doubtful fruit fly hosts is a very important phase of our work that must go on for some time. We don't visualize that there are many more smooth Cayennes in the lot that we can send over to the Mainland without treatment, but there may be a few. We have a problem with egg plant and another with avocado—there may be varietal differences in infestation that might be recognized in the quarantine consideration of these hosts. There are also things of interest to tourists that should be cleared if they are not hosts. We should continue to study indices of infestation and their utilization in considering quarantine problems.

The Biology-Ecology project is in a very fine position to do a great deal to further our export trade through the solution of some of these interesting host problems.

There is a lot of work to do on insecticides yet, and we will need to evaluate insecticides against the three fruit flies and determine their limitations for some time to come if we are to have the best possible information available for Mainland use in the event of a fruit fly emergency. The bait sprays are very promising. We should evaluate further materials less toxic to warm-blooded animals such as malathion. In our work on the fruit flies we will also continue to do everything we can to develop information of possible practical application to our Hawaiian agriculture.

In the Chemical Control investigations we have been considering one project in particular that I should like to have some comment on. This has to do with the feasibility of testing the male annihilation method—utilizing poisoned methyl eugenol lures—on the island of Rota. We don't have a very good island for conclusive tests among our Hawaiian Islands. Lanai, the most suitable, is subject to cross-channel movement of flies and is 3 to 4 times as big as Rota. Mr. Steiner went to Rota, Saipan, and Guam to investigate the possibility of using one of these islands for a large-scale test. He found that Guam is too large and otherwise not entirely suitable. Rota is quite ideal except that they import vegetables from Guam and it might not be possible to maintain complete isolation. The nearest land mass is about 45 miles away and the prevailing winds would not be likely to bring flies from outside sources.

In cooperation with Mr. Peterson, Entomologist in the Territory of Guam, we are getting some information on oriental fruit fly populations over there. There are quite a few flies but the numbers in the catches apparently fluctuate quite a bit. We get more per trap day on Rota than anywhere else. The sort of test we are considering would be interesting and ultimately, it might be of great practical importance. California particularly might be very much interested to see how far we could go in control with the cheap poison-lure method. If the fly can be eradicated with this method or contained until adverse winter conditions come it might be a very useful procedure in the event of an oriental fruit fly infestation in California. The Rota experiment would cost about $25,000 during a year to 18 months' period. A special report prepared by Mr. Steiner outlines the Rota experiment we have under consideration. We will include this report in these proceedings.

Q. How did the Hawaii results work out?

Mr. Steiner: We got excellent control above the 300' elevation. This information wasn't presented yesterday but will be included in these proceedings. The guava infestations early in 1953 were generally greater on Hawaii than in the comparable period of 1952. In the control areas this increase amounted to 160 per cent compared to only 60 per cent in the methyl eugenol area.

Q. How long would this Rota experiment last?

Mr. Steiner: At least a year, but it should run long enough to overlap several months of the second year.

Q. How close should the traps be set for coverage?

Mr. Steiner: About 1/10 of a mile across the prevailing wind with 40 to 50 per square mile.

Q. Do your flies go to the top of ranges?

Mr. Steiner: Yes. We got them at 7600' on Mauna Loa in January and March.

Q. Could you do effective work on the dry side of this island?

Mr. Steiner: We are convinced that fertile females could move from any part of this island into any treated area no matter how well isolated.

Mr. Christenson: One place which might do is Kaulalau Valley on Kauai. It is isolated with non-host valleys around. There are no hosts adjacent. We don't get any flies at Kokee.

Dr. Carter: The opportunity is so great I hope the project can be supported. The performance in two large tests has been so good that I have a feeling that if this method alone were used in Southern California you could prevent any development of the flies to serious economic proportions.

Q. What is the objection to Lanai?

A. It is too big.

Mr. Maehler: At Rota, there is plenty of traffic back and forth.

Mr. Steiner: Most of it is out of Rota, not into. If we had good trap coverage we could pick up the males before the females could become fertilized. The other advantage is that we would have Saipan and Guam for check areas to follow along and determine population curves. This information would have additional value from the standpoint of population trends in areas almost completely devoid of guavas.

Q. Is that included in the cost estimation?

A. I think the $25,000 would take care of Rota as well as periodic surveys of Guam and Saipan.

Q. How much personnel would be involved?

A. One entomologist plus one assistant. Most of the work involved is locating and servicing the traps in addition to fruit sampling. The traps should all be serviced monthly. We should place the traps so that there are about 40 per square mile, or that they are 1/10 mile apart across wind and 1/4 mile apart downwind. The biggest job would be getting them spaced and finding them again. One initial big expense would be the cutting or marking of trails. It will take two men working together--for safety reasons--there is no good radio contact with Guam, no regular transportation, and only 1 doctor.

Q. Wouldn't you have to make fruit collections?

A. Not too many, other than breadfruit, mangoes during season, and wild papayas.

Q. What are the flies breeding up in?

A. The people say breadfruit, but I couldn't find an infested one. We think papaya is an important host. Within two weeks, Mr. Peterson caught 35,000 to 40,000 flies in some 40 traps we had distributed on Guam. Peterson continued to get larger catches after the rainy season started, probably because of better fly emergence under moist than the previously extremely dry hot conditions.

Q. That would be contrary to Nawell's theory. In your experimental areas on Hawaii did you get a marked reduction in fertility of eggs?

A. We presumed that happened at first, although we were unable to check it.

Q. What happened to reduce the overall population?

A. With the reduced hatch that followed male elimination, the population declined within a generation or two so that stung fruit was rarely seen.

Q. Have you taken females and brought them into the laboratory to determine their fertility?

A. Not from the Hawaii experiment, but we did set up a similar experiment in the olfactometer. There was only about 1% fertility in the female population.

Q. By actual sampling, your deductions are more accurate?

A. Perhaps, but it would take extensive sampling (large and frequent collections of female flies or eggs) and we don't have the facilities. We have considered it, however.

Mr. Christenson: As far as the method itself is concerned, there is a good deal more we need to know. From a practical standpoint we are far enough along to go ahead. We think the Rota experiment would provide us with a definitive conclusion if it were conducted with the necessary thoroughness.

Q. How much of a pre-treatment survey would you require?

A. I think we ought to go in for a couple of months with a limited number of traps to obtain population estimates. Then we should intensively treat with poison bait stations until no more males are caught in the methyl eugenol traps.

Q. Populations on Lanai are at about the same level after 3 months of chemical control. It is more like an incipient infestation on the mainland.

Mr. Christenson: Eradication gets down finally to elimination of an extremely light population. One thing that worries me--a remote possibility--is that on Rota with the sparse population and the sparse host density maybe you will be giving this method a little extra help that it might not get elsewhere and that the results might not give us an accurate measure of how good it might work in another area.

Mr. Steiner: The safety of the personnel working the island is a real problem.

Mr. Christenson: There are many people that would eat up an assignment like that and do a good job. I think the proposed test is sufficiently important to warrant further careful consideration.

Q. What is the prevailing wind? Is it from the other islands?

Mr. Steiner: It is across the chain. Typhoons might mix up the fly population. I don't know what it is like in the wet season--I was there in the dry season. There is a lot of vegetation including sword grass and dense koa haole undergrowth.

Q. How soon after emergence do males respond to methyl eugenol?

Mr. Steiner: Not much the first day but thereafter they react strongly and respond long before they reach sexual maturity. Under olfactometer conditions the females show some response also but few are caught in the field.

Dr. Carter: If you use a spray you use it once. If this attractant is there it is there a whole year.

Mr. Christenson: I think this is something we will have to study a little bit. If we do undertake the project it could only be done at the expense of other chemical control work and we would have to make some adjustments in the local program.

Also in chemical control work a little more attention should be given to the effectiveness of some of the newer insecticides in large-scale applications--perhaps in tests involving airplanes.

In the Bureau's commodity treatments program we will continue to work on the fumigation of packaged commodities with EDB. Also to determine dosages required for the treatment of avocado and bell pepper. We will also study load relationship and minimum effective concentrations. The shortening of exposure periods and the dosage-temperature relationships need more study. We shall also continue to investigate the promising aqueous dip method, ethylene chlorobromide, and the quick-run-up vapor heat method. There is a certain amount of fundamental research that will still have to be carried on to supplement the great amount of service research we are now engaged in. The quick run-up for vapor heat treatment is going along pretty well now. Mr. Holzman would like to have this method and we would like to give it to him. Whether this can be done will ultimately depend on the tolerance of commodities to this treatment.

We shall also continue trying to find a treatment for mangoes to eliminate the mango weevil. Mangoes could be shipped to the mainland if it weren't for this pest. There is considerable trade in mangoes developing at present. They are being shipped in from Mexico and Puerto Rico. There are some mangoes in Florida, but production is not heavy.

Q. The quarantine against the mango seed weevil is for the Florida people, isn't it?

Mr. Christenson: Apparently so. Mangoes do not seem to do well in California.

We will now take up the work being done by our various cooperating agencies. What does the Hawaii Agricultural Experiment Station plan for the next fiscal year, Dr. Bess?

Dr. Bess: I discussed the major aspects of our work at yesterday's session. However, I failed to mention that Mr. Tomashiro is working on the susceptibility of parasitized larvae to insecticides for his master's. He has found quite a difference in the susceptibility of parasitized larvae, or shall we say the parasite and its host. As far as Ceratitis capitata is concerned we are not intending to do any expanded work on it. We are continuing to get records from coffee, and some from peaches, and guava at the higher elevations. We won't spend more than $1,000 on this work during the year. Probably we should do some more chemical work. We have gotten good control with simplified methods. We will probably spend between $500 and $700 a year on capitata research. In regards to Dacus cucurbitae, Nishida is working on the ecology, and we plan to expand the chemical control work the first of the year. We will try to prevent build-up as the crop develops. We will start the control with the planting of cucurbits and tomatoes in the spring. The amount of work and expenditure will depend upon the populations present, build-up, and whether we use a mist blower or contract for aerial spraying. We will be asking you Bureau people a lot of questions and we aren't sure what materials will be used. Aphids may be a very important factor. It may be more economical for us to resort to airplane spraying.

Q. Wouldn't you find that difficult in Waimanalo where you have diversified plantings?

Dr. Bess: We are convinced there are acres where there are no flies at all. If we could use a plane the spraying might be cheaper. We have one man assigned full time to this work. We will need some help from our labor crew at Waimanalo and also possibly technical assistance.

Mr. Christenson: We feel that the area approach to the melon fly problem would be a fine one. We might get together with some cooperative studies.

Dr. Bess: We feel that the results obtained from spraying have been worthwhile, and that it may be possible to test DDT against another material, also to try more than one method of application. As far as further ecological work is concerned we do not plan to do much but hope to find time to study the movement of fly populations.

Our Dacus dorsalis program is going to be curtailed to some extent. Newell and Haramoto have been devoting half of their time to this subject during the past year. There have been and will be several papers on it. They thought that on the basis it is now set up it could be reduced to 1/4 of their time, or 1/2 man-time. They have found that less samples are probably adequate. It will not be reduced to the point where it would affect the continuity of records. Newell is having some difficulty in transposing the figures he is getting now into a common denominator with those he got before. We did think in terms of keeping this project going for a number of years. Dr. Newell feels that it is one of the better ones to work with as far as populations are concerned.

Mr. Christenson: The fact that we have two other fruit flies here plus a number of introduced parasites makes it all the more interesting.

Dr. Bess: One of the points we would like to stress are space sprays, residual sprays and a combination of them. I wish Mr. Steiner would devise a method so we could measure the mortality attributable to space action and that to residual action. We had hoped Dr. Ebeling could do this. We want to know how much in the way of benefits we actually get from residual action.

Mr. Steiner: We sprayed bananas 3 to 4 times with aldrin and DDT fogs. There was a good if not almost complete kill from the space spray effect with no residual action. There was no reduction in infestation, even in the larger 65-acre plot, because of fly movement across the area. Space sprays without residual action would likely be of value only against isolated populations. The flies presumably came down off the mountain. These experiments were at Mokuleia.

Mr. Christenson: By space sprays do you mean something different from the space or fumigant action of parathion?

Dr. Bess: Dr. Carter at one time had an experiment set up where a gulch was sprayed with DDT by plane. He got complete elimination of the flies in that gulch but at the time the next spray was applied (about 1 month) the population was higher than at the previous spraying. The dosage was high (possibly 10 lb. of DDT per acre), and there was considerable residue. A low fly population may sting a lot of fruits.

Mr. Maehler: I don't see how growers would have a practical use for space sprays.

Dr. Bess: We are interested in it from a fundamental standpoint. It would also help us in the development of spray programs for considerably more material is needed to be effective as a residual spray.

Mr. Christenson: Can you give us an estimate of the total amount you people might spend during the present fiscal year?

Dr. Bess: It will be in the neighborhood of $16,000. This represents a reduction of about $8,000 over last year. There will probably be some further shifts made after July 1, 1954.

Mr. Steiner: The Hawaii Agricultural Experiment Station has provided us with an excellent experimental site, in their guava plantings. I am wondering if there would be any interest in plantings of thin-skinned avocados and maybe citrus? If we can find an effective fly control for use on citrus, a citrus industry might well be built up.

Dr. Bess: At the present time there might well be some land available at Waimanalo and it will take some time for the Station to get the entire acreage under management. As things stand now, we can't afford to buy the water and do much work on the farm ourselves. Possibly some cooperative deal could be worked out between the Bureau and the University.

Mr. Steiner: We need to develop more information on citrus sprays for mainland use.

Dr. Bess: Fruit fly damage to passion fruit is also a problem. It has been reported that about 25% of the fruits are lost because of flies.

Q. Isn't it pollinated?

A. Yes. Carpenter bees are considered to be the principal pollinators.

Mr. Christenson: Dr. Pemberton, can you tell us what the H.S.P.A. plans to do this coming year? We certainly appreciate all of the very fine help given us in letting us use your Molokai set up.

Dr. Pemberton: I am sure that the Molokai plantings will be available to you at any time you want. Theoretically we are not allowed to sell the fruit so the staff buys it for the cost of shipping. I think the population studies of the fruit flies should be continued. Too little done would be bad because of constant questioning from other agencies and people. There is one question I should like to ask. When you refer to funds for the fiscal year 1953-1954, is that practically all U.S.D.A.?

Mr. Christenson: Yes.

Dr. Pemberton: What action has been taken for plans for publishing the biological control work?

Mr. Christenson: It is going ahead. We set a deadline of March 1, 1954, and some of the manuscripts have already been turned in. As far as I know the Bureau has given us the go-ahead sign.

Dr. Porter: It may not get immediate publication but it will be put high on the list.

Mr. Christenson: By March 1st we hope to have a manuscript ready for review and suggestions. We haven't heard from Dr. Clancy as to how he is coming with his section.

Dr. Porter: Dr. Clancy can do very little until after the first of December. He should have time to work on it this winter, however.

Mr. Christenson: We shall now hear from Mr. Thistle of the Territorial Board.

Mr. Thistle: We are doing very little at present. There are about 4 parasites still in production. The reason for this is to keep our staff busy until the next project is filled in. The other thing is our fumigation plants. There is one on each of the major islands and one under construction in Hilo. There are 14 inspectors who assist the Quarantine people. There is no exporting from Maui just now. The most the expenditures would amount to would be about $1,000 to $1,500. This will drop off in the very near future. We are rearing parasites for export. Every month or so we have a request from a foreign area for shipments.

Mr. Christenson: Mr. Clausen, do you have the University of California figures available?

Mr. Clausen: The number of line projects the University is interested in has tapered off substantially and is down to 2 lines--the bioclimatic cabinet studies and Dr. Sinclair's commodity treatment work at Riverside. We are spending about $36,000 a year on these projects. As far as the bioclimatic cabinet work is concerned we are rather up in the air. Within the Department it was felt we should close out this work at the end of this fiscal year. The difficulty is the Department of Agriculture is pressing for some added work--additional stations to be run through and to do that would require another year's work. Another question is, if we do close out at the end of this year where will the cabinets go? This is a point of argument. Before leaving for these meetings I asked Dr. Sharp for some information on the point. He answered all of my other questions but ignored this one. On that basis we have set up a budget for 1954-1955 for continuation of the work here. Obviously it was the only thing we could do. The budget is the same as before but Dr. Sharp has indicated that he expected it to taper off after 1954-1955.

Mr. Christenson: Do you know anything about the work of Dr. Claypool and Dr. Pratt?

Mr. Clausen: That has been discontinued completely.

Mr. Christenson: There is a field of work that would be of some interest to us and which should be done--that is study of gas concentrations in refrigerator cars. Ultimately we may have to know a good deal about conditions in these cars and there is no way we can study this matter over here.

Mr. Clausen: Hasn't there already been a good deal of that been done elsewhere in the Bureau?

Mr. Christenson: There may have been, but the type of commodity and the load would be the critical things. Dr. Carter, do you have anything to report for Pineapple Research Institute?

Dr. Carter: We have one or two manuscripts that will be available. There is no active financial aid anticipated.

Mr. Christenson: We continue to get a great deal of help from your organization. This was especially important in the recent pineapple studies. Dr. Porter, do you have any remarks you would like to make at this time?

Dr. Porter: The amount of support this work will have in the following fiscal year depends largely on the recommendations you make following this meeting. There has been the expectation in Washington that the bioclimatic cabinet work would be discontinued toward the end of this fiscal year. If California continues to operate theirs, we should continue also. There are some angles which should be followed up. When statements were made that we should discontinue the cabinet studies at the end of this fiscal year, I changed it to "calendar" year 1954. The general fund situation looks pretty good inspite of general expenditures. The funds are slightly more than last year. The President, Secretary, Advisory Committees (some 20) are all in favor of Research and in practically every case have greater money for research. The Bureau will get its amount for Insect Investigations. In the President's directive to pull in horns during this fiscal year, I don't know just what is implied. Probably his idea is to work down to a lower level so that it won't be too hard to take a decrease next year. As you all know sometimes Congress doesn't act until we are well into the fiscal year.

Mr. Christenson: We have had a perenial subject--how to cut down the reporting system to a more concise one. We are now preparing a short quarterly report for the Washington office and sending this to you. This gets out within a few weeks after the close of the quarter. We have suggested that we might eliminate our detailed quarterly reports and submit only the summary report and special reports whenever lines of work were completed. There were a few reservations about this and some said they would like to have detailed reports.

Mr. Clausen: I think the present system of the concise quarterly followed by the more detailed one later is all right. It seems to me that a good deal of cutting down has already taken place. You could eliminate the detailed tables but the detailed data are the things the cooperators are interested in. They are concerned with the conclusions arrived at rather than analysis of data.

Mr. Christenson: You would still prefer the detailed type of report?

Mr. Clausen: If you eliminated the tables you could hardly call it a detailed report.

Dr. Bess: I like to get the impressions of the investigators. I am not so sure about cutting out some of the detailed tables. More graphs might be good.

Dr. Carter: The fundamental issue is whether publication is far enough in advance and if not I think detailed reports have quite a place.

Mr. Christenson: In our own work we are not able to keep up to date in publication at all.

Dr. Carter: One of the strengths of this project is the detailed reporting.

Mr. Christenson: One point-of-view is the usefulness of the reports as a record for workers. Another angle is the cooperators who are concerned only with the conclusions reached from time to time.

Q. Haven't they indicated that they like the detailed reports?

Dr. Porter: One advantage in detailed reports that are distributed to cooperators is that if you have a fire you can assemble the reports again.

Mr. Christenson: If there is no further business, the meeting is adjourned.