thrins were 2.5 and 4 times as toxic to larvae and pupae respectively as allethrin.

3. In oil emulsion-larvicides, applied on water surfaces, pyrethrins also exhibited higher toxicity to larvae than allethrin.

4. The addition of synergists did not materially increase the toxic properties of allethrin to mosquito larvae.

5. Allethrin was nearly as toxic as pyrethrins to mosquito adults emerging from pupae subjected to sublethal dosages of the toxicants.

6. As a substitution in the New Jersey Mosquito Larvicide, the amount of allethrin required to kill 100 per cent mosquito larvae is approximately twice that of pyrethrins.

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MOSQUITO CONTROL TECHNIQUES FOR CONTROL OF *HIPPELATES* SPP (Diptera: Chloropidae)

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During the spring of 1948, tests were conducted in the Coachella Valley of California in order to determine the effectiveness of presently used mosquito control measures in the control of *Hippelates* spp. These gnats, principally *Hippelates pusio* Loew, for many years have been a plague to the residents of the Valley. They have been implicated in the transmission of follicular conjunctivitis which is endemic in the area (Herms, 1939). This disease is particularly prevalent among pre-school and school-age children, although adults are sometimes victims of this malady.

In addition to the public health implication of the problem, the gnats are an economic liability because of their annoying habit of swarming about one's head, particularly the eyes and ears. As a result, much time is lost by agricultural workers, processors of fruits and vegetables, and others accessible to the gnats. In the area, a winter resort section, tourist trade has been discouraged by the swarms of these gnats and real estate values have suffered as a consequence. The predominant agricultural products are dates, grapes, grapefruit, and truck crops.

Although much work has been done over the years in the Valley aimed at the control of *Hippelates pusio* and related species, little success has been realized. In reviewing the existing literature, little information was available which could be used as a guide for this investigation. The principal lacuna was in the realm of biological and ecological information. In order to attempt to remedy this situation, biological studies were begun toward the end of the tests which are discussed below. These studies will be reported at a later date.

Herms (1928) states that a study project on *Hippelates* spp. began in the Coachella Valley in the summer of 1926. His first publication (Herms, 1926) on the subject of *Hippelates* spp. in the Valley stated that their bionomics were unknown and that the residents of the area asserted they had been increasingly disturbed by the gnats for ten or more years.

Burgess (1935) reported on the biology of *Hippelates pusio* and recommended certain control procedures. Some of these recommendations have been followed by the Coachella Valley Mosquito Abatement District through the years subsequent to 1935. To a great extent they have been dependent upon trapping techniques utilizing decaying liver as bait. This putrescent material is so unpleasant as to render the use of traps near habitations undesirable. Such trapping methods serve only to reduce the gnat population by a very limited amount in relatively small areas. Herms and Burgess (1930) reported on the immature stages of *Hippelates pusio* with a description of its life history. Herms (personal communication, 1948) stated that to his knowledge immature stages of *Hippelates* spp. had not been taken from natural habitats in the Valley, but that work on the life cycle had resulted from observations of specimens reared in the laboratory.

Hall (1932) reported on breeding media suitable for the laboratory rearing of *Hippelates pusio* and on the economic and public health problem caused by their presence in the Coachella Valley.

Sabrosky (1941) issued a provisional key to the genus *Hippelates* occurring in the United States. Bigham (1941) reported on his investigation of the *Hippelates* problem in the southeastern states. Tests that he conducted showed that adjustments in agricultural practices could reduce materially the gnat infestation in the areas of Florida which were so plagued. Similar observations were made by Parman and Burgess (1931) in the Coachella Valley.

The residents of the Coachella Valley, through the Board of Trustees of their Mosquito Abatement District, requested assistance from the Bureau of Vector Control in attempting to solve this problem. An attack was launched in order to obtain data as to the effectiveness of existing mosquito control measures when applied against the gnats. This decision was made with the full realization that the experiment might be unsuccessful in view of the limited knowledge of the biology of the species present in the Valley. It was hoped, however, that during the course of the study a method could be demonstrated to the District whereby the gnats could be abated.

With this objective in mind, the decision was made to conduct a series of tests using DDT as the toxicant, with the following methods of application: airplane aerosol and spray; ground aerosol, dust, and spray. In order to evaluate the relative effectiveness of these methods it was necessary to establish trapping techniques and to select the areas to be treated. It was necessary in the selection of areas for treatment to attempt to choose areas large enough to afford satisfactory tests and sufficiently isolated to prevent clouding of results through infiltration of gnats from surrounding territory.

In order to attain these prerequisites, six areas of varying size were chosen. In addition, six check areas were selected which, as nearly as possible, had similar soil conditions, agricultural practices, and crops. These untreated check areas were to be maintained as indices to the natural fluctuations of gnat population.

Throughout these areas bait traps similar

to those used by Burgess, utilizing liver, urea, and water as bait, were placed so that the densities of the gnats could be checked. The locations of the traps were randomized in an attempt to obtain statistically valid samples. The specimens were collected routinely at 24-hour intervals, and the gnats counted and identified in the laboratory.

An agricultural power duster of the orchard type was used to apply DDT dust in the ground pre-emergence tests. The ground spray was applied with both compressed air type and direct gear drive type power sprayers. These were fitted with nozzles delivering a coarse spray which was applied directly to the ground and all vegetation up to approximately 18 inches high. The ground aerosol treatments utilized both a jeep venturi aerosol and a commercial thermal aerosol. The airplane aerosol equipment used was modeled on the type developed by the TVA and mounted on a PT-17 plane. The spray equipment was of the boom type, mounted beneath the wings, with nozzles attached to the boom. Pressure was supplied by a wind-driven, propeller-equipped gear pump mounted on the wing. The spray equipment was mounted on the same plane that carried the aerosol equipment.

RESULTS AND DISCUSSION

Airplane Treatments

The Oasis area was sprayed on the 19th, 20th, 21st of April at the rate of 0.4 lb. of DDT per acre. The Indian Wells area was aerosoled on April 25 and 26, at the rate of 0.1 lb. of DDT per acre, and again on May 10, 11, and 12, with 0.3 lb. of DDT per acre. This latter aerosol treatment was necessary as the discharge rate of the first aerosol treatment was but one-fourth the rate anticipated.

Since it took several days in each case to treat any one of the areas, with only a portion of each plot treated on any one day, a reduction following completion of treatment, rather than a reduction at the time of treatment, would indicate control. No significant control was obtained. Any variation of trap collections between different areas was explained on the basis of natural phenomena. This is made evident on analysis of pre-treatment data. There were numerous instances when the Oasis area had a much larger count than the Indian Wells area and also when the reverse was true.

Ground Application

A tabulation was made of the trap collections of the gnats following the treatment of the Zimmerer area with 0.5 per cent DDT emulsion spray at the rate of one pound of DDT per acre, using ground spray equipment, and compared with those from a nearby untreated area of the same size and same type of vegetation. Apparently there was a small degree of control for a period of at least 27 days. As the season progressed the average number of gnats collected became more nearly equal in each plot, thus indicating a break-down in control.

Brown's area was treated with 10 per cent dust at the rate of one pound of DDT per acre. Brown's area is compared with a similar neighboring area. The results indicate a small degree of control for about a week. However, these data are inconclusive because no trap records were kept for the untreated area until six days after the treated area trap records were started. Later collection records definitely indicated that no control was obtained.

For both sprayed and dusted plots the data show that control operations should have been started later in the year, probably around May 15, when the gnats were more numerous.

At Duncan's area there was a sharp decline in the number of gnats collected for three days after the treatment, which was a ground aerosol application of 5 per cent DDT in diesel oil. This drop was followed by a sharp rise in the number of gnats collected. On analysis, however, it appeared that the decline and subsequent rise corresponded closely with the rise and decline of the temperature (Figure 1) and the average counts of all traps. This drop

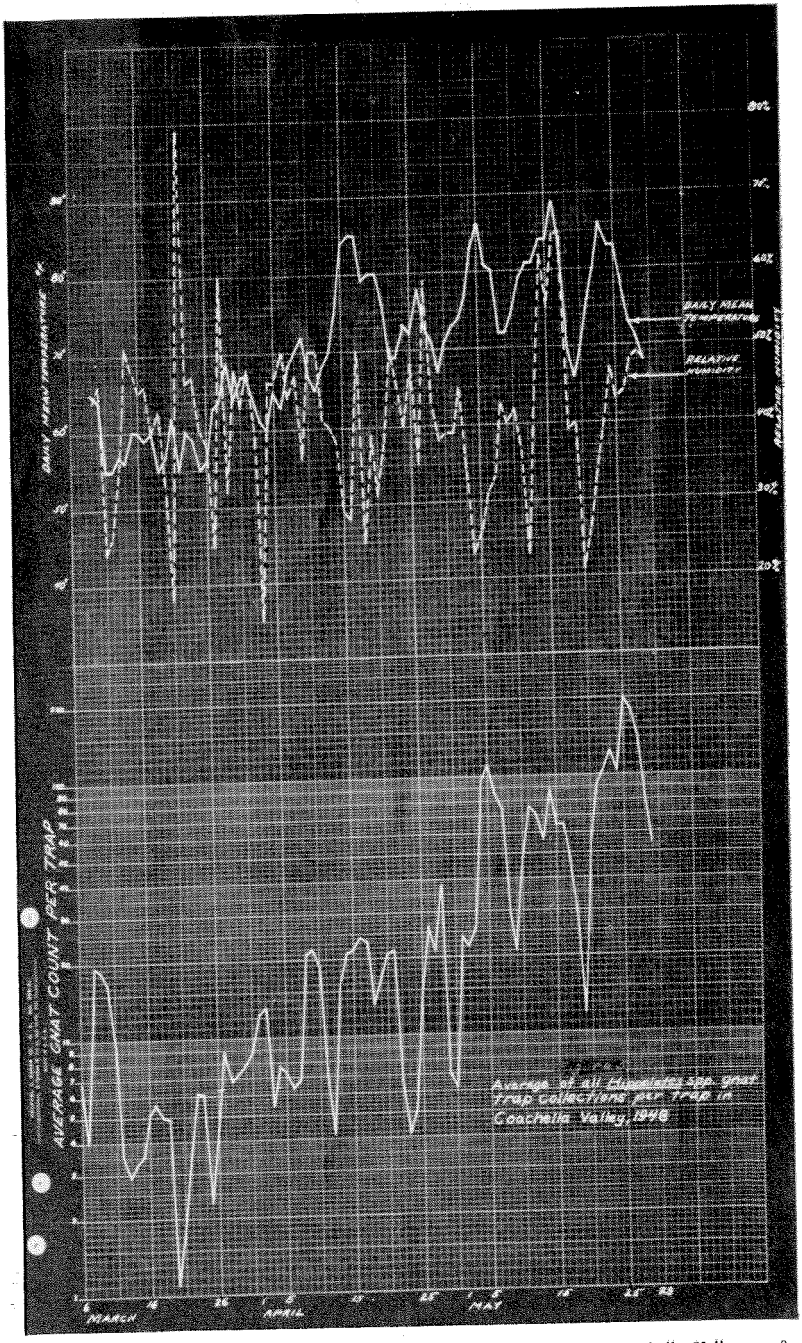

FIGURE 1. Average of all *Hippelates* spp gnat-trap collections per trap in Coachella Valley, 1948.

also appears to be one of a series of natural fluctuations.

Pre-treatment Emergence Traps

From 20 pre-treatment emergence traps set out in both treated and untreated plots, a total of 11 gnats was recovered in three traps. Only one trap in each of two untreated plots and one in a dust treated plot captured gnats. Condensed moisture was observed on the interior surfaces of traps, and it is possible that this water-of-condensation may have trapped emerging gnats or the high humidity may have prevented their emergence.

Meteorological and Natural Factors

Among the factors that may have influenced gnat collections were humidity, temperature, season of year, type of vegetation, and cultural practices. Consideration was given to these factors as possible explanations for the results obtained in this study.

The mean daily temperature and relative humidity, as recorded at the U. S. Government Date Garden at Indio, were plotted graphically with average gnat catches for all traps used in this study (Figure 1). The reliability of the gnat counts for the first sixteen days is subject to question as some degree of control was obtained in the ground spray and dusting studies. However, the remainder of the gnat trap counts appears to be reliable as no subsequent control was indicated in these plots. In like manner no control was indicated at any time in the airplane and ground aerosol plots. Study of Figure 1 indicates a clear-cut relationship between temperature and gnat collections, since collections vary directly with mean daily temperature. There does not appear to be a similar correlation with humidity. An over-all seasonal trend following the temperature is seen clearly. As the season advanced the average daily collections increased. This parallels the trend towards higher daily mean temperatures. Again there is no detectable correlation with humidity.

Collections of gnats in citrus groves, date gardens, and grape vineyards closely paralleled each other, increasing and decreasing together. Without considering any seasonal variation, the average number of gnats collected per trap per day for the entire period of the study was determined for each of the three types of habitat. The gnat collections in date palm gardens were largest with an average of 40.6 gnats per trap per day; citrus groves were second with an average of 31.7 gnats per trap per day; grape vineyards yielded the smallest number with an average of 24.1 gnats per trap per day. Early in the season the vineyard collections may have been smaller due to the lack of vegetative growth. Later on when there was a large amount of foliage the collections were more nearly equal to those of the date palm gardens and citrus groves.

Desert Traps

There was considerable speculation as to whether the gnats were limited to cultivated areas in the Coachella Valley. If they were, it was felt that a control program limited to those areas might eventually effect the elimination of these gnats from this valley. On the other hand, if they were found in uncultivated desert areas it would be assumed that a continuous control program would be necessary as cultivated areas would be subject to reinfestation.

With this in mind, three bait traps were operated in an isolated uncultivated desert area. The nearest cultivated areas were the Dos Palmos Ranch, which was three miles away, and the Zimmerer area which was about four miles away. The traps were operated for nine days. Within that time a total of 16 gnats were captured, one trap capturing 10, another—5, and the third—1. The maximum number collected in any one day from a single trap was five. It is possible that the gnats are indigenous to this desert area, and if so, a control program would have to consider the possibility of reinfestation from such sources.

SUMMARY AND CONCLUSIONS

1. Mosquito control techniques were used in attempts to control *Hippelates* spp. in the Coachella Valley in the spring of 1948. These methods were generally unsuccessful.

2. Two airplane applications of DDT in oil in the form of a thermal aerosol and one application in the form of a water emulsion spray failed to control these gnats. The first aerosol applications were at the rate of 0.1 lb. of DDT per acre and the second one at 0.3 lb. of DDT per acre, while the spray was applied at the rate of 0.4 lb. per acre.

3. Results of ground application of DDT at the rate of one pound per acre, as a spray and as a dust, indicated a small degree of control for at least 27 days and seven days respectively. Ground aerosols applied with a Tifa aerosol generator failed to control the gnats.

4. The pre-treatment emergence traps collected too few gnats to afford any control data. Improved traps are probably necessary before satisfactory collection data can be obtained.

5. Trap collections of gnats varied directly with the daily mean temperature. There was no evident correlation with humidity. As the season advanced the average trap collections increased. This paralleled the seasonal trend toward the higher daily mean temperature.

6. For the whole season more gnats were collected in the date palm gardens than in citrus groves or vineyards. Vineyards produced the fewest gnats early in the season, but later on, the density was nearly equal to that found in the date gardens and citrus groves.

7. Gnats were collected in uncultivated, isolated desert areas in small numbers, suggesting that they are present throughout the valley, and that the desert areas may be a source of reinfestation of cultivated areas.

Acknowledgments

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