

SULFUR AS AN INSECTICIDE

By GEORGE P. GRAY

(*Withdrawn for publication elsewhere.*)

A large number of photographs illustrating the work of the Mediterranean fruit fly were exhibited by Mr. E. A. Back.

Session adjourned, 12 m.

Afternoon Session, August 10, 1915

The session was called to order at 2.15 p. m. by Mr. H. F. Wilson, president of the Pacific Slope Association of Economic Entomologists.

PRESIDENT WILSON: We will now listen to a paper prepared by Mr. C. P. Clausen which will be read by Mr. S. W. Foster.

A COMPARATIVE STUDY OF A SERIES OF APHID-FEEDING COCCINELLIDÆ¹

By C. P. CLAUSEN, *University of California Citrus Experiment Station, Riverside, California.*¹

Among the beneficial insects of California as well as elsewhere, the Coccinellidæ hold high rank as aphid and scale feeders. In order to determine the relative efficiency of some of the more important forms, a study of eight of the principal aphid-feeding species of this state was made at Sacramento during the season of 1913, and completed at Berkeley and Riverside in 1914. The species under observation were: *Hippodamia convergens* Guer., *Hippodamia ambigua* Lec., *Coccinella californica* Mann., *Coccinella trifasciata* Linn., *Olla oculata* Fabr., *Olla abdominalis* Say., *Cycloneda sanguinea* Linn., and *Adalia bipunctata* Linn.

At the time the investigations were undertaken, an extensive series of tests were made to determine the most satisfactory type of breeding cage for use in the laboratory. By far the most satisfactory results were secured by confining the individuals under observation in plain three-inch vials with cotton stoppers. The stoppers were covered

¹Paper No. 19. Citrus Experiment Station, College of Agriculture, University of California, Riverside, Cal.

with tissue paper to prevent the larvæ from becoming enmeshed in the cottony fibers. Approximately outdoor conditions as regards temperature and humidity were thus secured. Potted plants infested with aphids and covered with chimney glasses were tried for a time, but did not fulfill the requirements, due to the occasional condensation of moisture upon the glass surface and the tendency of the adult beetles to ascend to the top of the glass and to remain there inactive rather than feeding normally upon the infested plant.

The points taken up in the investigation were the following: The length of time intervening between emergence and mating and oviposition, the length of the oviposition period, the rate of oviposition, both as to the number of eggs per day and the total number for the entire period, the life histories, and the feeding habits, both in the larval and adult stages. In every case a sufficient number of individuals were started for each species to make it practically certain that at least ten would complete the test, making allowance for unavoidable mortality. The records given for each species, therefore, represent the average for approximately that number of individuals.

EMERGENCE TO MATING AND OVIPOSITION

No great divergence was found to exist between species as regards the length of time intervening between emergence and mating. The range extended from 1.6 days in the case of *A. bipunctata* to 2.7 days for *C. californica*. No records were secured of *H. convergens* due to the fact that all individuals used in the tests were taken from cold storage in the adult stage. From mating to oviposition the variation was from 8.6 days for *O. abdominalis* to 11.9 days for *C. californica*. The minimum period of time for a single individual was 7.0 days in the case of one female of *O. abdominalis* and one of *C. sanguinea*.

THE PERIOD OF OVIPOSITION

The period of time over which oviposition extends is very largely dependent upon the conditions under which the beetles are kept. Under optimum conditions the deposition of eggs takes place daily during a period extending from approximately two weeks after emergence until death. The maximum average was found to be 48.1 days for *H. ambigua* and the minimum 28.2 days for *A. bipunctata*. The comparatively low average for *H. convergens* may be accounted for by the fact that three of the eleven individuals under observation died within two weeks of the beginning of the experiment. Oviposition by one female of *H. ambigua* extended over a period of fifty-nine days.

OVIPOSITION RECORDS

| Species | No. of Specimens | Length of Period, Days | Per cent Days Eggs Deposited | Average for Period | Average eggs Per Day |
|---------------------------------|------------------|------------------------|------------------------------|--------------------|----------------------|
| <i>C. californica</i> Mann..... | 10 | 31.0 | 69.5 | 207 | 8.0 |
| <i>C. trifasciata</i> Linn..... | 10 | 29.2 | 75.0 | 249 | 8.4 |
| <i>H. convergens</i> Guer..... | 11 | 33.3 | 63.8 | 299 | 8.9 |
| <i>H. ambigua</i> Lec..... | 8 | 48.1 | 61.4 | 312 | 7.3 |
| <i>O. abdominalis</i> Say..... | 9 | 34.7 | 70.3 | 234 | 6.3 |
| <i>O. oculata</i> Fabr..... | 9 | 35.4 | 89.3 | 347 | 9.8 |
| <i>A. bipunctata</i> Linn..... | 10 | 28.2 | 69.4 | 190 | 6.7 |
| <i>C. sanguinea</i> Linn..... | 10 | 28.8 | 73.6 | 201 | 7.0 |

RATE OF OVIPOSITION

A very considerable difference was found to exist in the number of eggs deposited by the various species. As would be expected from field observations, *H. convergens* deposited the greatest number of eggs, 609 being secured from a single female, while the average for all individuals was 299, but leaving out of account the three females which died prematurely, the average for the species was 358 eggs. *O. oculata* was a very close second with 347, while *A. bipunctata* was least with a production of 190 eggs. The maximum number of eggs deposited by a single female in one day was 43 in the case of *H. convergens*, while *O. oculata* was last with a maximum of 22 eggs. The latter species, however, ranked first with respect to the daily average for the entire period with 9.8, while *O. abdominalis* was last with 6.3 eggs per day.

FREQUENCY OF OVIPOSITION

The proportion of days upon which eggs were deposited varies greatly, the range being from 61.4 per cent for *H. ambigua* to 89.3 per cent for *O. oculata*. The latter species was found to be markedly uniform in this respect, the range among the nine individuals of the species being from 84.3 to 95.5 per cent, the minimum in this case being higher than the maximum of any other species. It will be noticed, however, that the regularity of oviposition was not in direct proportion to the total production of eggs, inasmuch as *H. ambigua*, the lowest with respect to the frequency of oviposition, ranked second in total production.

LIFE-HISTORY

A greater or less uniformity exists among the various species as regards the length of the different periods or stages of the life cycle. The egg stage ranged in length from 4.2 days for *O. abdominalis* to 6.0

days for *C. trifasciata*. In no case were more than six days required for incubation. Almost invariably the eggs comprising a cluster all hatched within a few hours. The first larval stage varied from 3.3 days for *O. abdominalis* to 5.7 days in the case of *C. californica*. A single larva of *C. californica* required ten days, but apparently was not normal and died shortly after pupation. The second larval stage was found to be uniformly shorter than the first, the variation being from 2.3 days for *O. abdominalis* to 4.7 days for *H. ambigua*. Nine larvæ of *H. ambigua*, three of *C. californica*, and one of *H. convergens* required only two days for this stage, while one specimen each of *H. ambigua* and *O. oculata* required six days. The third stage was of approximately the same length as the second, with the exception of *H. convergens*, in which case the period was much shorter. Two individuals of *O. oculata* required five days. The fourth stage was considerably longer than those preceding it, the range being from 4.7 days in the case of *O. abdominalis* to 7.4 days for *C. trifasciata*. The greatest variation, however, was found in the pupal stage, where 3.5 days were required by *O. abdominalis* and 8.0 for *H. ambigua*. The totals of the successive stages gave a minimum of 21.0 days for *O. abdominalis* and a maximum of 33.2 days for *H. ambigua*.

DURATION OF DIFFERENT STAGE IN DAYS

| Species | No. of Specimens | Egg Stage | Larval Stages. | | | | Pupal Stage | Total |
|---------------------------------|------------------|-----------|----------------|--------|-------|--------|-------------|-------|
| | | | First | Second | Third | Fourth | | |
| <i>C. californica</i> Mann..... | 13 | 5.4 | 5.7 | 3.3 | 3.4 | 6.8 | 4.5 | 29.1 |
| <i>C. trifasciata</i> Linn..... | 12 | 6.0 | 5.3 | 4.2 | 3.3 | 7.4 | 3.7 | 31.8 |
| <i>H. convergens</i> Guer..... | 8 | 5.0 | 3.9 | 3.6 | 2.3 | 6.5 | 7.5 | 28.8 |
| <i>H. ambigua</i> Lec..... | 10 | 5.5 | 3.8 | 4.7 | 3.6 | 7.3 | 8.0 | 33.2 |
| <i>O. abdominalis</i> Say..... | 14 | 4.2 | 3.3 | 2.3 | 2.8 | 4.7 | 3.5 | 21.0 |
| <i>O. oculata</i> Fabr..... | 11 | 5.0 | 4.6 | 4.5 | 4.2 | 7.0 | 5.1 | 30.2 |
| <i>A. bipunctata</i> Linn..... | 7 | 5.0 | 4.6 | 2.9 | 3.0 | 5.6 | 6.0 | 26.7 |
| <i>C. sanguinea</i> Linn..... | 10 | 5.3 | 4.5 | 3.7 | 3.2 | 4.9 | 4.2 | 25.3 |

FEEDING RECORDS

The average number of aphids eaten by a larva during the entire period ranged from 216 for *C. sanguinea* to 475 in the case of *C. californica*. One individual of the former species came to maturity after consuming 147 aphids, while one larva of *C. californica* required 580, this being the maximum for a single individual.

Daily feeding records of the adult beetles covering a fifteen-day period were secured with the exception of *H. convergens*, the records of which extend over only eight days. The maximum period average

was 624 aphids for *O. oculata*, and 234 as a minimum for *C. sanguinea*. One adult of the former species devoured 672 aphids during this period. On a daily basis the variation extended from 56.1 aphids per individual for *H. convergens* to 15.6 for *C. sanguinea*. *C. californica* was conspicuously low in this respect when the size of the beetle is considered, the average being only 34.0 aphids per day.

FEEDING RECORDS

| Species | Larvæ | | | | Adults | | |
|---------------------------------|------------------|-----------------|--------------|-------|------------------|------------------|----------------------|
| | No. of Specimens | Length of Stage | Aphids Eaten | | No. of Specimens | Length of Period | Aphids Eaten per Day |
| | | | Period | Daily | | | |
| <i>C. californica</i> Mann..... | 13 | 23.7 da. | 475 | 24.9 | 10 | 15 da. | 34.0 |
| <i>C. trifasciata</i> Linn..... | 13 | 25.8 | 294 | 15.8 | 10 | 15 | 28.9 |
| <i>H. convergens</i> Guer..... | 12 | 23.8 | 349 | 20.7 | 6 | 8 | 56.1 |
| <i>H. ambigua</i> Lec..... | 8 | 27.7 | 312 | 11.4 | 10 | 15 | 26.5 |
| <i>O. abdominalis</i> Say..... | 14 | 16.7 | 240 | 19.8 | 9 | 15 | 30.4 |
| <i>O. oculata</i> Fabr..... | 10 | 25.2 | 326 | 17.2 | 10 | 15 | 41.6 |
| <i>A. bipunctata</i> Linn..... | 10 | 21.7 | 252 | 14.1 | 10 | 15 | 16.7 |
| <i>C. sanguinea</i> Linn..... | 10 | 20.0 | 216 | 14.5 | 10 | 15 | 15.6 |

On the basis of the results secured in the studies previously outlined, the following conclusions may be drawn:

1. Temperature and humidity are very strong controlling factors in the development and behavior of the different species.
2. The number of eggs deposited under normal field conditions varies from 200 to 500 and occasionally more, extending over a period of four to eight weeks in case the female lives the full adult life.
3. The period intervening between emergence and mating is one to three days, and from mating to oviposition eight to eleven days. A period of ten to fifteen days thus intervenes between emergence and the beginning of oviposition.
4. Oviposition normally takes place daily, with occasional exceptions.
5. The number of aphids eaten by the larvæ of the different species varies approximately with the size of the individuals, the number varying from 216 to 475 for the entire larval period.
6. The above to a somewhat lesser extent is true of the adults also.

PRESIDENT WILSON: The next paper is by Mr. J. F. Illingworth and will be read by Mr. O. H. Swezey.