STUDIES ON AN ISRAEL STRAIN OF *ANAGYRUS PSEUDOCOCCI* (GIRAULT) [*HYM., ENCYRTIDAE*]. II. SOME BIOLOGICAL ASPECTS

BY

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A local strain of *Anagyrus pseudococci* (GIRAULT) (*Hymenoptera: Encyrtidae*) is the dominant parasite of the citrus mealybug, *Planococcus citri* (RISSO), and a minor parasite of the *Pseudococcus citriculus* GREEN on citrus in Israel (ROSEN & RÖSSLER, 1966). Some preliminary data on this parasite were reported by RIVNAY & PERZELAN (1943). The present article summarizes the results of studies on various biological aspects, conducted recently at Rehovot under both laboratory and screenhouse conditions.

The parasite was found to be capable of developing in the citrus mealybug, in *P. citriculus*, and in the long-tailed mealybug, *Pseudococcus adonidum* (L.). Of these, only the citrus mealybug was used as host in the present study.

A. pseudococci was reared continually in a roofed screen-house. Fertilized female parasites were confined with mealybug-infested, sprouted potato tubers in plastic containers, and were transferred daily to new host colonies. The temperature in the screen-house was recorded, and the average temperature during the life-cycle of each individual parasite was calculated. Data on the duration of development, adult longevity, fecundity and sex-ratio of the parasite were derived from these rearings.

The methods employed in laboratory rearings of the parasite will be described separately in the following chapters.

Duration of development

Fertilized, one-day-old female parasites were individually confined for 24 hours in plastic capsules, glued into sprouted potato tubers, artificially infested with the citrus mealybug. The tubers and capsules were subsequently transferred to incubators of various constant

temperatures, where they were kept until the emergence of adult parasites .The results of these rearings are presented in Table 1.

The data on the duration of developement of *A. pseudococci* under varying temperatures, in the screen-house rearings, are summarized in Table 2.

TABLE 1

Duration of development of *Anagyrus pseudococci* under constant temperatures

TEMPERATURE (°C)	MALES Number	MALES Average duration of development (days)	MALES Range	FEMALES Number	FEMALES Average duration of development (days)	FEMALES Range
20	51	29.0	27-31	18	29.7	27-33
24	30	17.8	16-21	31	17.4	17-18
28	138	12.9	11-15	129	13.2	12-15
32	81	10.7	10-12	50	11.1	10-14

TABLE 2

Duration of development of *Anagyrus pseudococci* under varying temperatures

Average TEMPERATURE (°C)	MALES Number	MALES Average duration of development (days)	MALES Range	FEMALES Number	FEMALES Average duration of development (days)	FEMALES Range
14	20	99.2	91-120	10	100.9	85-109
15	9	76.6	71-83	11	83.8	71-118
16	13	51.5	57-65	8	64.7	60-68
18	92	42.0	38-52	36	44.2	38-53
20	11	37.2	35-40	8	36.0	35-40
22	24	30.9	28-33	23	30.7	24-35
24	8	24.0	21-27	20	24.6	24-27
25	31	21.5	19-42	13	22.3	21-24
28	9	16.4	16-17	9	16.7	16-17

As can be seen from Tables 1 and 2, the development of *A. pseudococci* under varying temperatures is prolonged by about one-third in comparison with the development under corresponding constant temperatures.

From the data obtained in the screen-house rearings, the threshold of development (see BODENHEIMER, 1926) of *A. pseudococci* was calculated as 11.4 °C for the females and 12.0 °C for the males; 297 and 285 day-degrees are required for the development of females and males, respectively.

DURATION OF DEVELOPMENTAL STAGES AND EFFECTS ON HOST.

A total of 180 parasitized mealybugs were kept in an incubator at 28 °C, and samples of 8 to 30 were dissected daily in order to determine the duration of development of the various developmental stages. Development of the egg took 1-2 days at the above temperature, that of the larva — 4-5 days, of the prepupa — 1 day, and of the pupa — 4-6 days. The parasitized host was alive during the first 4 days after the parasite's oviposition, and its colour did not change except for a dark area forming around the parasite's egg (see ROSEN & RÖSSLER, 1966). The host's movements ceased on the fifth day; on the sixth or seventh day its integument hardened, and its body assumed a cylindrical shape. From the eighth day on, the host, by then containing a parasite pupa, was completely mummified. Its integument became brown and transparent on the ninth day after the parasite's oviposition. The adult parasite emerged through an irregular exit-hole, gnawed at the posterior end of the mummified host.

A. pseudococci develops solitarily. Even when 2 or 3 eggs were occasionally laid into a single host, only one larva completed its development.

Longevity of adults

One-day-old adult parasites were individually confined in 20 ml glass vials that were placed at constant temperatures of 15, 28 and 32 °C. The relative humidity in the incubators was about 60 %. Honey was smeared on the inner walls of the vials as food for the parasites. Thirty females and 30 males were used for each temperature, and their mortality was recorded daily. The results of these rearings, combined for females and males, are presented in Figure 1. A 50 % mortality

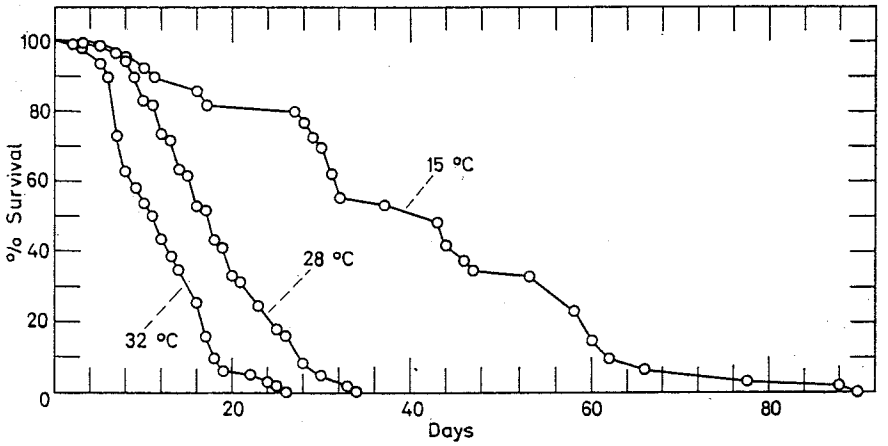

FIG. 1, Survival of *Anagyrus pseudococci* adults under various constant temperatures.

was recorded after 40 days at 15 °C, after 17 days at 28 °C, and after 11 days at 32 °C. Females lived usually somewhat longer than males.

The longevity of 103 ovipositing, fertilized females was recorded in the screen-house rearings under various temperature conditions. The results are summarized in Table 3.

TABLE 3

Longevity of females of *Anagyrus pseudococci* under varying temperatures

Average temperature (°C)	Number	Longevity (days)	
		Average	Maximum
11.1-13.0	18	15.1	32
13.1-15.0	23	14.6	36
15.1-17.0	15	15.2	32
17.1-20.0	12	16.3	31
20.1-22.0	16	14.4	47
22.1-25.0	12	13.7	28
25.1-29.0	7	10.3	18

Comparison of Table 3 and Figure 1 indicates that non-ovipositing females of *A. pseudococci* live much longer than ovipositing females under comparable temperatures.

Further studies of ovipositing, fertilized and unfertilized females at a constant temperature of 26 °C, indicated that fertilized females live longer than unfertilized ones (see Table 4).

EFFECT OF RELATIVE HUMIDITY. The effects of relative humidity on the longevity of the adult parasites were studied according to the method developed by BARTLETT (1962). The inner walls of 20 ml glass vials were smeared with a 50 % sucrose solution, to which a few drops of honey were added as a dispersing agent. The vials were dried for several days in a desiccator, and 10 female or male parasites were then confined in each vial. The vials were covered with silk, and fastened with adhesive tape into similar vials, containing $CaCl_2$ or various concentrations of a KOH solution, intended to create relative humidities of 0, 31, 39 and 61 % in the closed systems thus formed (see PETERSON, 1955). The vials were kept at 28 °C, and mortality of the parasites was recorded daily. At least 20 females and 20 males were used for each relative humidity. The results (see Figures 2-3) indicate that relative humidity has no apparent effect on the longevity of *A. pseudococci* at 28 °C. Females usually lived twice as long as males in this experiment.

Comparison of the data summarized in Figures 1, 2 and 3 indicates that the longevity of *A. pseudococci*, when fed on honey, is considerably prolonged as compared to sucrose-fed adults under comparable temperature and relative humidity combinations.

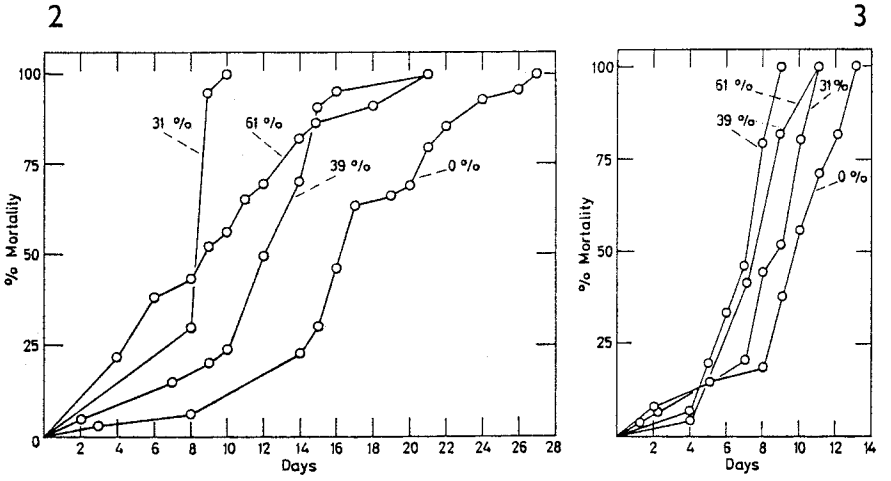

FIG. 2-3, Mortality of *Anagyrus pseudococci* under various relative humidities at 28 °C. — 2, females; 3, males.

Fecundity and Sex-Ratio

A. pseudococci is an arrhenotokous species, unfertilized eggs developing into males only. The fecundity of 10 fertilized and 10 unfertilized females was compared at 26 °C. The female parasites were individually transferred at daily intervals to potato tubers infested with the citrus mealybug. Data on daily oviposition, based on the emergence of adult progeny, are presented in Figure 4. Additional data are summarized in Table 4.

Fecundity of fertilized females was found to be considerably higher than that of unfertilized ones.

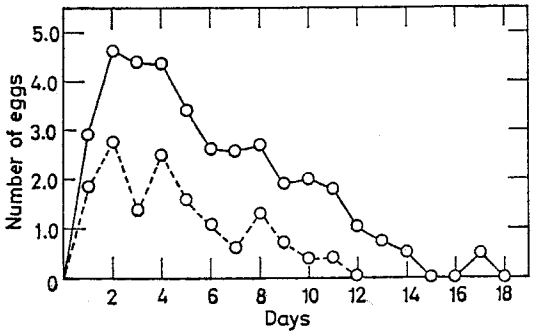

FIG. 4, Daily oviposition of 10 fertilized (———) and 10 unfertilized (- - -) females of *Anagyrus pseudococci* at 26 °C (based on emergence of adult progeny).

TABLE 4

Longevity and fecundity of fertilized and unfertilized females of *Anagyrus pseudococci* at 26 °C

	FERTILIZED females	UNFERTILIZED females
Average longevity (days)	13.5	10.4
Maximal longevity (days)	19	14
Average oviposition days	8.8	5.3
Maximum oviposition days	14	8
Average number of offspring	33.0	14.5
Maximal number of offspring	65	25
Average number of eggs per oviposition day	3.5	2.7

The fecundity of 103 fertilized females was recorded in the screen-house rearings. The results, summarized in Table 5, indicate that the fecundity and the number of oviposition days of *A. pseudococci* increase with the rise of temperature. The corresponding increase in the number of progeny per oviposition day, although less pronounced, was still found to be significant at the 0.05 level.

TABLE 5

Fecundity of fertilized females of *Anagyrus pseudococci* under varying temperatures

Average TEMPERATURE (°C)	Number	Average number of OFFSPRING PER FEMALE	Average OVIPOSITION DAYS per female	Average number of OFFSPRING PER OVIPOSITION DAY
11.1-13.0	18	0.4	0.3	1.3
13.1-15.0	23	2.4	1.7	1.3
15.1-17.0	15	4.2	3.0	1.4
17.1-20.0	12	8.6	5.7	1.5
20.1-22.0	16	6.8	4.3	1.6
22.1-25.0	12	10.4	4.8	2.1
25.1-29.0	7	25.0	8.6	2.7

EFFECT OF HOST SIZE. Uniform colonies of the citrus mealybug were started by placing 80 sprouted potato tubers with mealybug egg masses for 24 hours at 28 °C. At weekly intervals, 20 one-day-old, fertilized female parasites were confined with 20 host colonies for 4 hours at 26 °C. The emerging parasite progeny were subsequently recorded (see Table 6).

The number of parasite offspring, and the ratio of female progeny, increased considerably with the increase of host age and size. Similar effects of host size on the sexratio of parasitic *Hymenoptera* have been noted in several instances (CLAUSEN, 1939). The duration of development of *A. pseudococci* did not change with the age of the host.

TABLE 6

Effect of host size on the fecundity and sex ratio of *Anagyrus pseudococci*

AGE OF HOSTS (weeks)	HOST INSTAR	Average NUMBER of OFFSPRING PER FEMALE	RATIO OF FEMALES in parasite progeny
—		—	—
1	First and second larvae	—	—
2	Third larva	2.5	16.0
3	Young female	3.7	57.0
4	Female with ovisac	5.9	76.0

SEX-RATIO IN SCREEN-HOUSE CULTURES. Data on the fecundity and sex-ratio among the progeny in the screen-house rearings were summarized for groups of 10 fertilized female parasites, ovipositing in mealybug colonies under various average temperatures. The results, presented in Table 7, indicate an increase in parasite fecundity, as well as in the ratio of female progeny, with the rise of average temperature.

TABLE 7

Sex ratio among the progeny of *Anagyrus pseudococci* under varying temperatures

Average TEMPERATURE (°C)	Total number of OFFSPRING	RATIO OF FEMALES in parasite progeny
—	—	—
12.5	5	—
15.5	82	18.3
17.5	76	27.6
22.0	197	48.7
27.5	224	62.5

Observations on adult behaviour

Both females and males *A. pseudococci* are positively phototactic and negatively geotactic.

MATING. The male approaches the female from the side or front, and, if not rejected, immediately ascends on her thorax, assuming a courtship position with his head just above the female's head. After several seconds, the male moves to the copulation position on the caudal and of the female's back. Copulation itself, during which the male's abdomen is being bent downwards and forwards, lasts several seconds. The male then resumes the courtship position on the anterior end of the female's thorax, rhythmically moving its abdomen up and down. The female starts moving after about 2 minutes, with the male riding on her back for about 2 additional minutes.

OVIPOSITION. The oviposition of *A. pseudococci* in the citrus mealybug is very rapid, and is usually completed during 15-40 seconds. After approaching the host, the female parasite examines it with its antennae for several seconds. It then turns its caudal end towards the mealybug, everting the ovipositor and thrusting it between the wax filaments on the lateral margin of the host's body. The wings and hind legs are held upright during this process. The attacked mealybug reacts initially with wriggling and raising the posterior end of its body. As the oviposition proceeds, even this resistance ceases.

RÉSUMÉ

Quelques aspects biologiques d'une race locale de *Anagyrus pseudococci* (GIRAULT), un parasite des Pseudococcines, ont été étudiés sous des conditions du laboratoire et de la serre. Ces parasites ont été élevés sur leur hôte, *Planococcus citri* (RISSO).

La durée du développement, la longévité des adultes et la fécondité ont été étudiées sous des combinaisons différentes de température et d'humidité relative. La longévité des parasites adultes n'a pas été effectuée par des fluctuations d'humidité relative à une température de 28 °C. La fécondité et le taux de femelles dans la descendance augmentent avec l'âge de l'hôte ainsi qu'en fonction de l'élévation de la température.

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