CHELETOGENES ORNATUS (ACARINA: CHEYLETIDAE), A. PREDATOR OF THE CHAFF SCALE ON CITRUS IN ISRAEL (*)

Z. Avidov, D. Blumberg and U. Gerson

The Hebrew University of Jerusalem, Faculty of Agriculture,

Rehovot, Israel

A B S T R A C T

Cheletogenes ornatus (C. & F .) , the most abundant acarine predator of the chaff scale. Parlatoria pergandii Comstock on citrus in Israel, was studied both in the laboratory and the field. Various rearing methods were developed, and the total development of the mite at 28°C took about 3 months. At the most it had 13 progeny. Modest survival occurred under conditions of starvation afid low relative humidities. The acaricide zineb was harmless to C. ornatus whereas chlorobenzilate was highly toxic, ethion being inter- mediate in this respect. Field studies showed the mite's populations to peak in late summer, and 2 annual generations ard postulated. No reproduction took place in winter whether in the field or in the laboratory. The predator's role in the natural control of the chaff scale is discussed and evaluated in the light of the above data.

During a current investigation concerning the natural enemies of the chaff scale, Parlatoria pergandii Comstock (Homoptera:Diaspididae) on citrus in Israel, it was found that several predaceous mites were feeding on this pest. The most abundant of these acarine predators was the cheyletid Cheletogenes ornatus (Canestrini and Fanzago) (Gerson, 1967a).

This mite is known to feed on various small mites and on scale insects in most regions of the world (Baker, 1949). Its association with citrus scale insects was noted in several countries, such as the Western and Eastern United States (McGregor; 1956; Muma 1964), North Africa (Athias-Henriot, 1959), and South Africa (Lawrence, 1954). Notwithstanding the ubiquitness of C. ornatus, very little, except for locality and prey records, is known about it. In former reports from this country, ***some*** preliminary phenological ob- servations were noted (Gerson, 1967a), as well as some additional plant hosts (Gerson, 1967b).

Mites of the family Cheyletidae were formerly considered to be of little importance in controlling insects or mites (Baker and Wharton, 1952). Recently, however, several reports were published which suggest that members of this family may control or limit various pests (Norris, 1958; Pulpan and Verner, 1965; Haramoto, 1966). Thus it was decided, within the context of the above-mentioned project, to study C. ornatus and try to evaluate its role as a biological control agent.

The present paper records these efforts, made up of life history studies in the laboratory and phenological observations in the citrus groves.

Life History Studies

Methods: From the beginning of these studies it became evident that rearing methods would be a critical factor. Notwithstanding our many efforts, it should be noted already at the outset that no completely satisfactory rearing method for C. ornatus was devised. It is, however, pertinent to describe our experiments in detail so that others may benefit from them.

Most of the methods tried were modifications of the commonly-used charcoal and plaster-of-Paris cells. Others employed rooted citrus leaves, aluminium foil or whole squash fruits and lemons infested by scale insects. These methods can conveniently be described in 6 sections. Live mites for these rearings were obtained from chips of citrus bark infested by the chaff scale.

1. The basic rearing cell was modelled on the cells developed by Costa (1966). Plaster-of-Paris and charcoal were thoroughly mixed at a 10:1 ratio and, to eliminate molds, about 1% (by weight) captan was added. The resulting mixture was well wetted and poured into plastic containers, with an 15.5 x 9 cm area and a 3.5 cm depth. The rearing cavity, as well as the water trough, were preformed by plasticine to the desired shape and depth, and pressed on to 2 glass slides. These slides were placed on the bottom of the plastic container, and the plaster-of-Paris and charcoal mixture poured thereon. After drying, the finished, hardened block is easily removed from the plastic container and the slides with the plasticine are also removed. Other, clean, slides are put in place, the water trough filled and the double cell (Figure 1) is ready for use.

Plaster-of-Paris, upon drying, has a roughened surface which apparently is necessary for the free movement of cheyletids (Beer and Dailey, 1956). This material helps also in maintaining the relative humidity within the cells. The charcoal has a fungistatic property, causes the substrate to be more porous and thus facilitates water distribution in the cell. It also provides a dark background convenient for locating the reddish-yellow mites in the cells.

This cell, as described above, was found to be unsuitable for the rearing of C. ornatus because the mites tended to wander within the cells and were usually trapped and crushed at some point of contact between block and cover slide. The following two methods were modifications of this basic cell.

In this method the glass slides were removed and a small depression, later smeared with various repellents, scratched out around the cells. The materials tried included: Machine grease, machine oil, vaseline, Canada balsam, castor oil and plastic gum, applied alone or in various combinations and ratios. All materials either dried out and thus formed no barrier, or retained their viscosity but did not repel, serving only to trap the mites on them.

3. This modified method utilized similar cells, but these were formed in Petri dishes, 5 cells per dish, or in plaster-of-Paris blocks, as before, but with 10 cells per block (see Figure 2). As it was observed that the mites tend to search for, and remain in, small hiding places (cell corners, empty scale-insect shields and various debris), various such and similar artifacts were placed in the cells. None, however, proved suitable as it was necessary to observe the mites constantly. In the method finally employed numerous small narrow depressions were scratched on the cells' surface. The mites, once reaching such a depression, remained therein, being almost immobile for long periods. They could thus easily be observed and fed, and seldom escaped. To prevent other mites from entering, some vaseline was smeared around the edge of the cells.

Concurrently with the development of this latter method, which was the most suitable one, efforts were also made to rear C. ornatus on the other substrates.

4. Rooted citrus leaves were used as the first substrate. Small leaf areas - about 1 inch in diameter - were ringed by a mixture of Canada balsam and castor oil. A single Cheletogenes female was put within this ring and fed scale-insect crawlers. As the mites remained motionless and the crawlers adhered to the balsam, this method had to be abandoned after a number of trials.

5. Here an effort was made to modify the method developed by Brickhill (1958) for tydeid mites. Cheletogenes was placed on small leaves or aluminium foil disks floating in water in a Petri dish. These experiments had to be discarded since the very high humidity encouraged molds and the mites were totally immobile, apparently because of the unsuitable substrate.

6. Squash fruit or green lemons were artificially infested by the chaff scale, the ivy scale (Aspidiotus hederae (Vallot)) or the Florida red scale (Chrysomphalus aonidum (L.)). As the scales grew, rubber rings were glued with hot paraffin on groups of scales and the top of the rings smeared with vaseline as an adhesive. As soon as crawlers of these scale insects hatched, 10-20 mites were transferred into each ring. Such squash fruits or lemons were then put within plastic cages (see Figures 3-4) and kept in 28°C incubators. The purpose of these experiments was to mass-rear the mite under simulated natural conditions and without individual feeding and manipulation. Apart from the ringed fruits, unringed ones were also tried. The squash and lemons were examined after varying intervals, but extremely few mites were ever recorded. So this method too, had to be discarded.

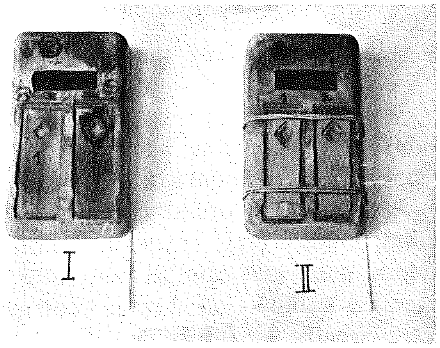

Figure 1: Plaster of Paris cells (method No. 1)

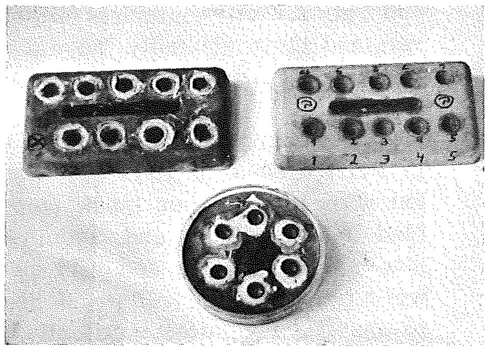

Figure 2: Plaster of Paris cells (method No. 3).

Figure 3: Squash fruits infested by the chaff scale with rubber rings attached (method No. 6).

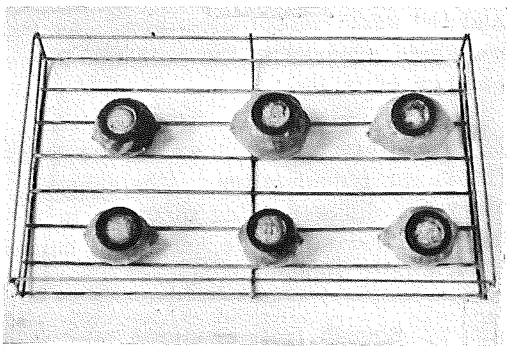

Figure 4: Lemons infested by the chaff scales, with rubber rings attached (method No. 6).

Altogether, more than 1500 individual rearings were carried out, most of the following observations being obtained from method No. 3. All rearings were kept at 28°C.

Development: Duration of the development of all stages of *C. ornatus* is summed up in Table 1. As will be discussed below, the active mite stages were fed one scale-insect crawler a day.

The eggs are orange-yellow, oval, and measure, on the average, 96 x 80 the darker embryo being clearly evident through the chorion 1-2 days prior to hatching. During emergence the egg bursts into 2 dissimilar halves, and the larva, after struggling for some minutes, disengages itself from the shell. It then wanders away, finds some hiding place and lies there in wait for its prey. The larva readily accepts food soon after hatching, but not if the prey is too large. It was subsequently observed that the prey-selection exercised by *C. ornatus* is mostly dependent upon prey size and strength and as a rule only smaller and/or weaker animals are attacked by this predator. Cannibalism was usually negligible.

Some larvae could not free themselves from the egg's shell, and these died within 1-2 days. The majority of the hatched larvae feed for about 2 weeks and then molt.

Table 1: The development of *Cheletogenes ornatus* at 28°C.

Stage	N	Development in days	
		Average	Range
Egg	18	10. 0	6. 0 - 16. 0
Larva	20	14. 0	8. 0 - 25. 0
Chrysalis I	20	2. 5	1. 5 - 3. 0
Protonymph	16	9. 5	4. 0 - 15. 0
Chrysalis II	14	2. 5	2. 0 - 3. 0
Deutonymph	11	23. 0	10. 0 - 35. 0
Crysalis III	10	2. 5	1. 5 - 3. 0
Total		64. 0	

Behaviour of the protonymph and the deutonymph is similar to that of the larva. They are ready to accept prey and to feed on it immediately after molting, differing in this respect from some other cheyletids investigated, which refuse food for several hours after molting (Beer and Dailey, 1956). The 2 nymphal stages are usually immobile, moving only as prey touches them or if disturbed.

Behaviour of the females during the preovipositional period is essentially similar to that of the preimaginal stages. In our rearings the longevity of the females was 43 days on the average, the recorded maximum being 87 days. The males - readily recognized by their pointed opisthosoma - are smaller than the females and appear to be the most active, mobile stage. They were sometimes confined with females, but copulation was never observed in our laboratory rearings.

Oviposition commenced about 25 days (range: 8-40) following the final molt, thus the total development, from egg to egg, takes about 3 months at 28°C.

The eggs, laid at the rate of 1-2 per day, are deposited in corners and hidden places. Gravid females would sometimes lay some eggs at one particular site (up to 9 were found), cover them partially with delicate silk threads and keep guard over them. Oviposition lasts 15-40 days. One female laid 12 eggs in 15 days, and the maximum recorded number was 13, deposited by an apparently unmated female, during 38 days. The small number of eggs, as well as the great variation in duration of development noted (Table 1) appear to be characteristic of laboratory rearings of cheyletid mites (Beer and Dailey, 1956).

Our rearing experiments were continued in the laboratory the year around. During the autumn and winter months, however, it was noted that although always kept at 28°C, no eggs were deposited in the cells. Only by late March were eggs again laid by the females in these rearings.

Feeding: *C. ornatus* does not actively search for its food, but rather sits in ambush and awaits its prey. When a scale-insect crawler, other mites, or even a fine needle, brush against the predator's massive palps, they close in a fast grasping movement. The prey is preferably held by one of its legs or by an antenna, because when thus held it cannot free itself. Crawlers which were caught alongside their bodies sometimes managed to escape. Feeding takes 30-75 minutes, dependent on the prey's size and on the predator's hunger. The latter is almost immobile during feeding, its chelicerae imbedded in the prey, and slight, probably sucking, movements may be seen in the gnathosoma. After the prey is sucked dry the predator disengaged itself and moves to a new position.

As noted above (Table 1), the average development of C. ornatus lasts 64 days at 28°C. During this period there are 18 non-feeding days (egg + 3 molt stages) and the female's mean longevity is 43 days. Thus, if the mite is rationed 1 crawler a day, the total consumption of a female throughout its life (at 28°C) is about 90 crawlers.

In the life-history studies, a fine needle was used to offer the prey to the mite. When a second crawler was thus given immediately after the first had been sucked dry, it was also seized and fed upon, but released sooner. If a third prey was offered, it too was grasped but then released. Feeding the mites 2 crawlers a day did not seem to have any effect on their development, hence they were fed only once a day. Furthermore, as no differences were noted whilst feeding the predator on crawlers of the 3 scale-insect species noted above, these were indiscriminately used.

Though initially attacked, crawlers of the soft brown scale, Coccus hesperidum L., or the citrus mealybug (Planococcus citri (Risso)) were not fed upon, apparently because they were too big and strong and managed to escape. When these latter crawlers were wounded or freshly-killed, they readily served as food. C. ornatus was never observed to be feeding on scale-insect or mite eggs.

Beer and Dailey (1956), in their study of Cheyletus eruditus (Schrank) and Cheletophyes knowltoni Beer and Dailey noted that the former injected toxic, paralyzing saliva into its prey and, as the latter weakened, fed on it. C. knowltoni simply overpowered its prey. Our observations show that C. ornatus is similar in this respect to the second species. Prey which escaped after being held even for some minutes was not seen to be particularly harmed, which suggests that no toxic agent has been injected.

The females of C. ornatus can live for relatively long periods without food. Mites which were purposely starved and kept in humidities near saturation point survived, on the average, for 16 days, the range being 1-33 days. This is well in keeping with their sedentary habits and enhances their chances of survival under field conditions.

Survival under various relative humidities. During the rearing experiments it became obvious that the longer the individual mites lived, the more scale-insects were devoured. Hence it became pertinent to examine the effect ot various humidities on the survival of C. ornatus.

The relative humidities used were of 0% (obtained with P_2O_5 crystals), 21%, 50% and 80% (all obtained with appropriate KOH solutions (Peterson, 1955)). The first of these humidities was maintained within a desiccator, the others inside 0. 5 litre jars, closed hermetically with polyethylene bags. The experimental cells were of the No. 3 group, and they were kept for 24 hours prior to the beginning of these trials within the appropriate jars, to achieve equilibrium. As it was not possible to obtain uniformly-aged mites, it became necessary to employ field collected - and thus of unknown age - females, in this and the following series of experiments. These mites were placed within the cells, and the latter suspended by fine gauze above the solutions. The closed jars were kept in 28°C incubators. The cells were taken out once every other day and each mite fed 1 scale-insect crawler. To further examine the effect of those humidities on C. ornatus, eggs, larvae and nymphs were also put in these cells, fed and observed.

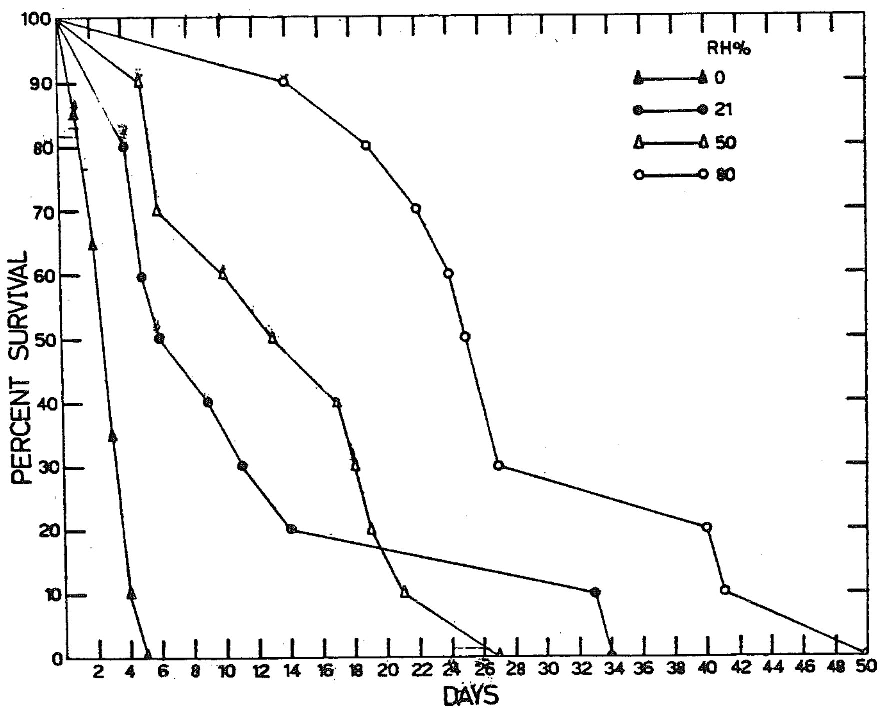

Figure 5: Survival of Cheletogenes ornatus females under various relative humidities at 28°C.

The survival of the mites under the various humidity conditions is shown in Figure 5, and it is evident that the higher the humidity the better the survival. The average of the females kept at 0, 21, 50 and 80% RH was 3, 12.5, 14.5 and 26 days respectively. At 0% RH the eggs shrivelled and died. At 21% RH the eggs hatched, larvae and nymphs molted and females laid eggs, the same occurring, to a higher degree, at 50 and 80% RH.

Though the results obtained from this experiment can be of comparative value only, they are sufficiently clear in showing that raising the humidity prolongs the mites' lives. The results also suggest that C. ornatus is quite tolerant to low humidities, a characteristic of high survival value.

Effect of acaricides on C. ornatus. The acaricides commonly used in Israel to control citrus mites are zineb(1) and chlorobenzilate(1). These were, in fact, applied at one of the study plots whilst the insecticide ethion(1) together with medium-grade petroleum oil was applied at the other (see below). It thus became pertinent to evaluate the effect of these compounds on C. ornatus.

The experimental procedure was slightly modified from the method developed by Swirski et al. (1967). Rooted citrus leaves were dipped for 20 seconds in solutions (having commercially-used concentrations) of these compounds and subsequently dried. There were 7 treatments:

A. Control dipped in water
B. Dipped in 0.12% zineb, used 1 hour later
C. Dipped in 0.12% chlorobenzilate, used 1 hour later
D. Dipped in 0.12% chlorobenzilate, used 24 hours later
E. Dipped in 0.12% chlorobenzilate, used 48 hours later
F. Dipped in 0.12% chlorobenzilate, used 1 week later
G. Dipped in 0.3% ethion + 1.5% medium-grade petroleum oil, used 1 hour later.

At appropriate intervals after dipping, small disks were cut out from the leaves and carefully transferred to Petri dishes padded with wet filter paper. The mites to be used in the experiments were field collected, individually placed on the leaf disks and daily fed a scale-insect crawler. About 30-50 females were employed in each treatment. The disks were kept in the laboratory, at temperatures of 23°C - 27°C and observed daily. The results are presented in Figure 6.

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(1) The chemical definition of these compounds can be found in Billings, (1965).

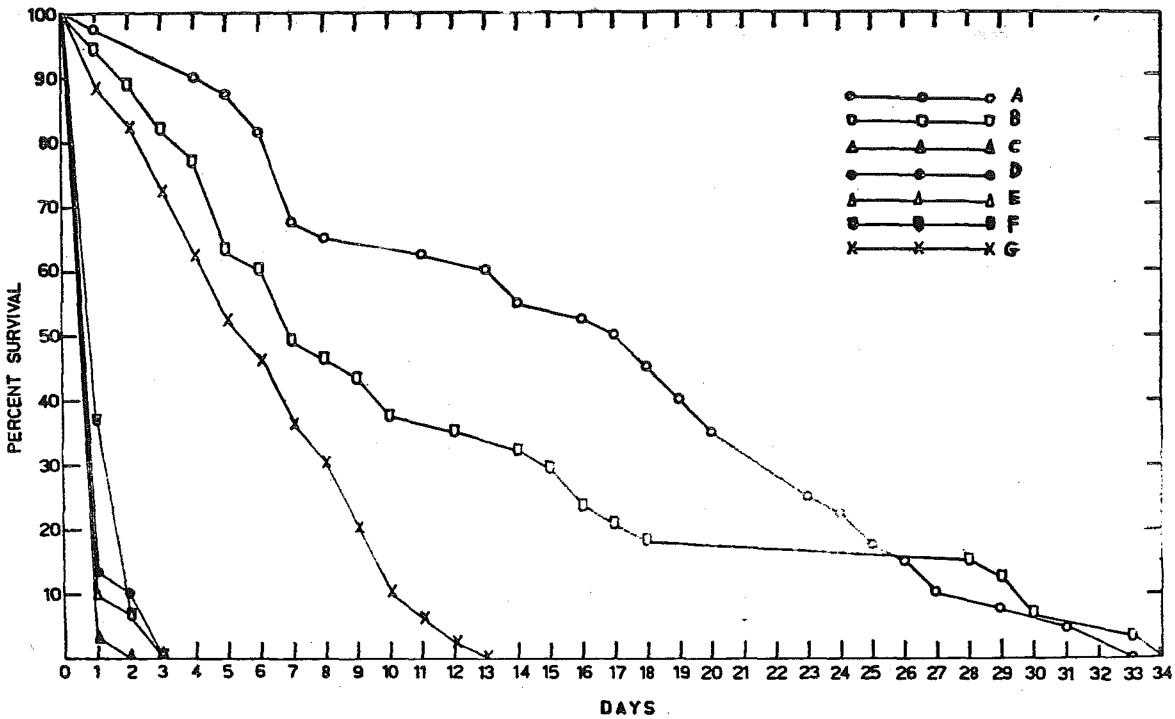

Figure 6: Survival of Cheletogenes ornatus females following exposure to various pesticides.

It is evident that zineb had very little, if any, effect on the survival of the mites. Chlorobenzilate, on the other hand, was quite toxic and ethion was intermediate. The differences in time between dipping and exposing the mites to the disks slightly prolonged their lives. In experiment C, 97% of the mites were dead after 24 hours, as compared to 63% in experiment F, but 3 days after exposure all mites in the chlorobenzilate series (C-F) perished. These results suggest that under field conditions, the latter compound might be much more detrimental to C. ornatus populations than zineb. Swirski et al. (1967) found that both zineb and chlorobenzilate, at the same concentrations, had a low toxicity against various predaceous phytoseiid mites, whilst ethion was rated as highly toxic to another mite of that family (Bartlett, 1964).

Field Studies

Methods: Observations have shown C. ornatus to occur mainly on the bark of the trunk and main branches of citrus trees, though occasionally also on the leaves and fruits. The preponderance of the mites on the former plant parts is easily understandable, as these harbour large, live, chaff scale populations the year around (Gerson 1967c). It was, however, decided to sample both the bark and the leaves, so as to gain an understanding of the mite's population trends thereon. For this purpose, several sampling methods were tried and used.

The leaves were collected from at least 10 trees per grove, and from these trees 25 branches were taken, each having 4 or more leaves. Another sample of 200 leaves from about 50 branches was also collected. All leaves and branches were carefully picked into plastic bags and brought to the laboratory. Sampling of the leaves (all at least 1 year old, as younger ones have but few scale insects and their predators on them) was carried out by:

(a) Examining a fixed, 1 sq cm area at the base of the upper and lower side, respectively, of 100 leaves under a stereoscopic microscope.

(b) Processing the 25 branches through Berlese funnels, of the type developed by Dietrick et al. (1959).

The trunk and main branches were sampled but cutting off small chips of bark, having an area of 16 sq cm (8 cm x 2 cm) from 10 trees, 5 chips per tree. These were examined in the laboratory by:

(a) Counting the number of all stages of C. ornatus, alive and dead, seen whilst counting 400 live chaff scale females. This was the method used by Gerson (1967a).

(b) Immersing 20 chips of bark in jars containing 70% alcohol, for a total of 72 hours. At the end of each 24-hour period the alcohol was passed through a Buchner funnel padded with white filter paper, the reddish mites counted thereon and recorded according to stage.

Both leaf and bark samples, as well as occasional fruits, were collected at monthly intervals in 2 citrus groves. These were located at Kefar Warburg and Mash'mia Shalom (designated herein, respectively, as grove A and grove B) in the southern coastal plain of Israel. Both groves were over 30 years old, an age at which they are heavily infested (especially on the bark) by the chaff scale (Gerson, 1967c). Pest control treatments applied at grove A were an acaricidal August spray with zineb (0.12%; WP), a similar early September treatment with chlorobenzilate (0.12%; EC) and the autumnal, annual malathion + bait applications against the Mediterranean fruit fly. At grove B, except for the latter sprays, an application of ethion (0.3% WP) + 1.5% medium grade petroleum oil was given in late September. During December several plots in grove B were used by the grower to test various organo-phosphorous insecticides against scale insects. Though obviously detrimental to C. ornatus, it was nevertheless decided to proceed with the samplings so as to observe the effect of these pesticides on the predator.

Results: The numbers of mites obtained from the leaves by the 2 sampling methods were very small and showed no seasonal variations. They were, in fact, so small that no comparison was possible between the two methods, and the examination of the leaves was terminated at the close of 13 months' consecutive samplings.

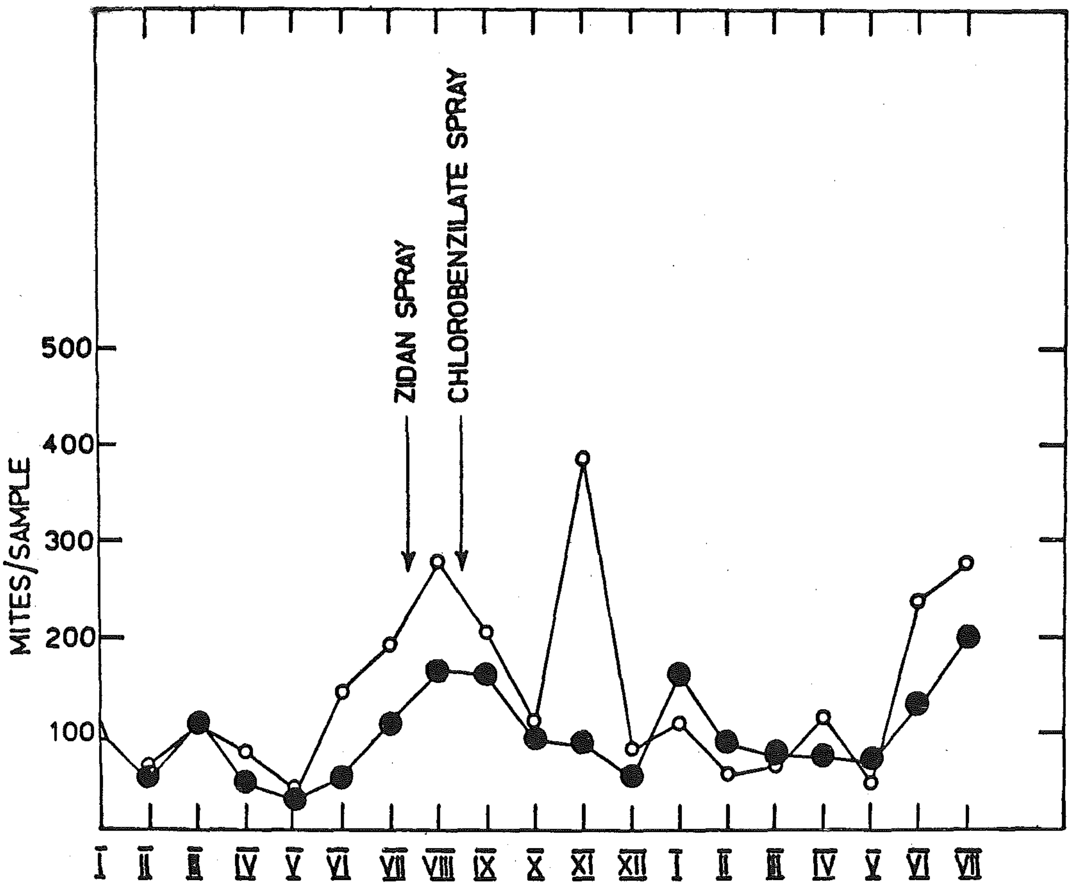

Figure 7: Population trends of <u>Cheletogenes</u> <u>ornatus</u> on citrus trees at grove A. According to numbers obtained in the alcohol extraction method (0_____0); and obtained in the direct counting method (●_____●); (Zidan is a local Zineb Formulation.)

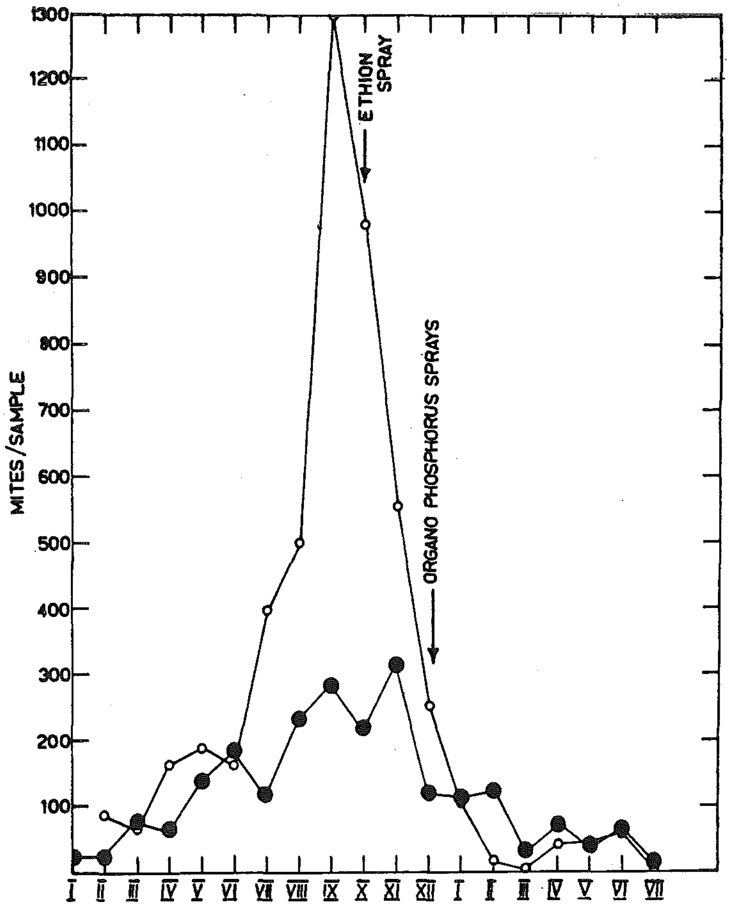

Figure 8: Population trends of Cheletogenes ornatus on citrus trees at grove B. According to numbers obtained in the alcohol extraction method (0_____0); and in the direct counting method (●_____●).

The bark, from which varying numbers of C. ornatus were recovered the year around, was sampled for a period of 19 months. The results are presented in Figure 7 and 8, which also compare the numbers obtained by the 2 sampling methods. From these it can be seen that larger numbers of mites were usually obtained by the alcohol extraction method. This method is also more impartial and seems to supply the total - as compared, in the other method, to the relative number of C. ornatus on the unit of bark area sampled. Therefore, the results obtained from the alcohol extraction method are considered to better represent the population trends of the predator. A qualitative and quantitative examination of all extracted mites confirmed earlier reports (Gerson, 1967a) that C. ornatus is the dominant mite species on citrus bark.

Large colonies of the chaff scale seldom occur on citrus leaves, but are the rule on the bark. Hence it is reasonable to assume that the abundance of C. ornatus on the latter tree parts, as compared to the rareness on the former, are density-related phenomena.

Among the various stages, females and deutonymphs occurred on the bark the year around. Eggs and larvae, on the other hand, were extremely rare during a 6-month period, from October to March, indicating that no reproduction took place throughout the autumn and winter. From late March on, eggs and larvae were observed, and they were abundant during July-August. Some overlapping of stages occurs at this period.

In winter high mortality was also noted. At grove A the percentages of dead mites were above 20% during the period from October to February, reaching a peak of 41% in December. At grove B these values were higher, reaching 74, 60 and 48% during October, November and December, respectively. Subsequently the population declined and did not recover by the next spring. This is attributed to the many pesticide treatments given to this grove.

Discussion: The laboratory rearings have shown that at 28°C C. ornatus requires about 3 months to complete a generation. This finding, taken in conjunction with the presented phenological data, suggest that under field conditions this mite has 2 annual generations. The eggs of the first are deposited in the spring, the hatching mites maturing and laying the eggs of the second, overwintering generation in late summer.

Two peaks in mite abundance, during August and November, are evident at grove A (Figure 7), but only one, higher and more prolonged, at grove B (Figure 8). Experiments have already shown the extreme toxicity of chlorobenzilate to C. ornatus, and as grove A was sprayed with this acaricide early in September, it is assumed that the autumnal decline there was caused by this compound. Therefore, the situation prevailing at grove B(during the first year) is considered to conform better to the natural population trends of C. ornatus, and the prolonged peak is thought to reflect the numbers of mites belonging to both the spring and autumn generations.

By September and October the populations begin to decrease. This decline seems to be caused by the following factors:

1. Pesticides applied during the autumn, whether acaricides or wide-range insecticides. Their effect might be direct, the mites themselves coming into contact with the pesticides, or indirect, through touching or feeding on poisoned scale-insects or other arthropods. This appears to be the initial autumnal mortality factor, and will be further discussed below.

2. The absence of reproduction during the autumn and winter, which may well be caused by a winter diapause. The total lack of reproduction under controlled 28°C temperature in the laboratory during that period, lends some support to this theory, which was not, however, studied in the context of this investigation. Whatever the cause for the decline, the outcome is that the winter populations of C. ornatus consist of deutonymphs and females only, no

younger stages being added before spring. As the older members of the population die off, or mites of all stages are rinsed off the trees, their total number declines.

Lack of food by itself cannot be considered a mortality factor, because there are large numbers of chaff scale crawlers available on the bark throughout the year (Gerson 1967c), as well as tydeid and tarsonemid mites, on which C. ornatus also feeds readily. Cannibalism, though sometimes observed, generally appears to be negligible. Also no natural enemies of this predator, which, as noted, is the dominant mite on citrus bark, were encountered. Therefore, it seems reasonable to assume that the populations of C. ornatus are depressed by a combination of the above factors.

The main findings of this study as they pertain to an evaluation of C. ornatus as a biological control agent are:

(a) C. ornatus is the dominant acarine predator of chaff scale crawlers on the bark of citrus trees throughout the year.

(b) The populations of this predator peak in late summer, at the critical, ebb period of the chaff scale's populations (Gerson, 1967a).

(c) C. ornatus is capable of surviving for modest periods under conditions of low relative humidities as well as starvation.

(d) C. ornatus is very density-dependent, occurring mainly in crowded, incrusted chaff scale populations.

(e) This mite is an inactive predator, apparently well satisfied with 1-2 crawlers a day, and also feeding on any other small animal within its grasp.

(f) C. ornatus has a relatively low rate of increase, as a result of its slow development and low number of progeny, and only 2 annual generations (as compared to 3-4 of the chaff scale). It also has a pronounced winter ebb in its populations.

(g) C. ornatus is highly susceptible to acaricides widely used in citrus groves.

(h) This predator is very unsuitable for rearing and manipulating under laboratory conditions.

In conclusion it is evident that C. ornatus has some serious disadvantages as a biological control agent, and that it cannot be considered to be a regulating factor of the chaff scale by itself. However, the timing of the predator's population surge (see (b) above) as well as its great abundance indicate that it is an chaff-scale enemy of some importance. And whilst it is not our intention to suggest that C. ornatus be reared in the laboratory and disseminated in the groves, we do suggest that efforts be made to conserve its populations. The obvious target for such efforts would be the development of a modified spray program of citrus orchards.

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