LIFE CYCLE STUDIES OF THE CACTUS SCALE
Diaspis echinocacti (Bouche)

by

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A Thesis Submitted to the Graduate
Faculty of the School of Agriculture in Partial Fulfillment of
The Requirements for the Degree of
MASTER OF SCIENCE IN AGRICULTURE

Split Major: Entomology-Zoology
Minor: Plant Pathology

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1963

ABSTRACT

In the present investigation, life-cycle of Diaspis echinocacti (Bouche), a major pest of Opuntia ficus-indica in Lebanon, has been studied. The species is oviparous and exhibits sexual dimorphism. Each female lays about 100 eggs intermittently in batches. The duration of various life stages is variable in different parts of the year. The second nymphal stage is by far the longest one.

A survey of predators and parasites of Diaspis echinocacti has been made. The second stage nymphs and the adult females of this insect are preyed upon by a mite and by the larvae and adults of a beetle. At least two species of eulophid wasps parasitize the adult females.

The results of the investigations have been compared with what international literature on this insect exists and several new fields for further research have been suggested.

Cactus Scale D. echinocacti B.

Qureshi

ACKNOWLEDGEMENTS

I express with deep gratitude my thanks to Dr. A. S. Talhouk for his guidance and advice during the course of this investigation. He also helped me translate articles from French on this insect.

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INTRODUCTION

Cacti are important in various ways. They are grown in the green-houses in many parts of the world for their beautiful flowers. Their fruits are edible and according to Shurly (1959) attract large number of buyers in the markets of Mexico and Southern France. He also mentions that cactus candy is very popular in the United States of America. During the periods of the scarcity of fodder, cacti provide an alternative feed to the cattle. The prickly pear is planted for hedges around the farms and the gardens. Certain cacti are cultivated for their sweet juice which is used in the preparation of fermented beverages. Their woody fibres, after drying, are used as fuel by the natives of areas where wood is scarce but cacti are abundant. Their fibres are used for making baskets and mats also and spines are employed as hooks in fishing and also in the grafting.

Diaspis echinocacti (Bouche) is a major pest of cacti. Any part of the plant above the ground is vulnerable to the attack of this pest. However, comparatively

older phylloclads are preferred to young ones. In the case of a heavy infestation, the entire surface of the phylloclad is covered by the scaly encrustation of the insects. This must obviously interfere with the normal photosynthetic activity of the plant part concerned. In addition, there is a heavy drain on the sap-content of the affected segment which these insects are continuously sucking. Badly infested plants, therefore, wither away, dry and finally die. Balachowsky (1935) recorded complete destruction of Opuntia tomentosa in Algiers, Corsica and Spain as a result of the attack of Diaspis echinocacti.

In view of the fact that this insect can bring about death of cactus, single segments heavily infested with this pest were sold at two shillings each in the Union of South Africa to infest healthy plants in order to eradicate them (Brain, C.K. 1918).

The Department of Agriculture, Union of South Africa, distributed this insect to help the people eradicate prickly pear from their lands in 1925. Although the results were not encouraging so far as prickly pear was concerned, at Crootfontein it appeared as a pest of spineless cactus which was valuable as a fodder crop. Therefore it necessitated chemical control measures to suppress the pest (Anonymous, R.A.E. 13).

Although the taxonomy of the scale-insects has

received full attention of the early entomologists from the very beginning, life-history studies, however, have been neglected. Diaspis echinocacti has been described by many taxonomists including Brain (1918), Green (1920), Hall (1922) and Myer (1925) all of whom studied the morphological details of this insect; apparently no work has been done so far on the life-history of this important pest.

In view of its importance, common occurrence and relationship with parasitic insects and the lack of the biological studies concerning it, the present work was undertaken.

REVIEW OF LITERATURE

SYNONYMY

Ferris (1937) has collected the various names under which this insect has been described from time to time by various workers.

Diaspis echinocacti was first described by Bouche from southern Europe and named as *Aspidiotus echinocacti*.

Costa described this insect under the name *Diaspis calyptroides*.

Comstock named it *Diaspis cacti* while Cockerell described it under the name *Diaspis opuntiae*.

Finally Ferris (1925) reviewed the entire work done on the Coccidae. He proposed re-describing all genotypes. This, of course, could be done by the cooperation of a series of authors. Under this scheme the job of re-describing and figuring this insect was assigned to L. Emery Myer (1925) who described it under the name of *Diaspis echinocacti* (Bouche).

SYSTEMATIC POSITION

Ferris (1925) assigned to the old family Coccidae

the status of a superfamily under the name Coccidoidea which has later became Coccoidea. The former sub-family Diaspinae was accordingly given the family rank Diaspidae which has been replaced by the name Diaspididae. The generic name Diaspis given by Costa is retained by Myer (1925) who has redescribed this insect under the name Diaspis echinocacti (Bouche).

HOST PLANTS AND DISTRIBUTION

Diaspis echinocacti occurs as a pest exclusively on the members of the family Cactaceae.

Brain (1918) recorded it on Opuntia intthe Union of South Africa.

Balachowsky (1935) reported this insect infesting Cereus, Mammillaria, Echinocactus, Phyllocactus and Opuntia in Algeria.

Hall (1922) described this insect in Egypt from Opuntia.

Dodd (1927) recorded it infesting O. inermis and O. stricta in Australia.

Tempel (1929) found it on Opuntia in Germany, while Green (1920) recorded this insect on O. tuna in in the Madeira Islands off the west coast of Africa. Ferris (1937) mentions of its occurring on almost any species of the family Cactaceae in North America.

Diaspis echinocacti is believed to be a native of

the New World from where it has spread to all parts of the world along with its host plants.

Mac Gillivray (1921) mentioned it occurring in Europe, northern Africa, India, eastern United States, New Mexico, Arizona, Mexico, the West Indies and Brazil. In Lebanon this insect infests Opuntia ficus-indica.

NATURAL ENEMIES

Balachowsky (1935) reported larvae of Cybocephalus rufifrons (Nitidulidae) feeding on the eggs of Diaspis echinocacti. He also reported Aphytis diaspidis (Eulophidae) parasitizing this insect in large numbers in Algeria. He thinks that this parasite limits the size of its population in certain years in that country. On the other hand Priesner and Mahmoud (1940) bred Aphytis diaspidis in Egypt from Parlatoria oleae and from scale insects infesting apricot, pears, rose, oleander and Ficus but they did not find Aphytis diaspidis infesting Diaspis echinocacti. Rather they found two other species of Aphytis parasitizing this scale in Egypt. These are Aphytis maculicornis and A. mytilaspidis; the latter is more widespread in Egypt, is polyphagous and remains active practically all the year round.

MATERIALS AND METHODS

The phylloclads of Opuntia ficus-indica severely infested with Diaspis echinocacti were brought from the race course area, Beirut. The hatchability of the eggs was tested by transferring eggs obtained from these infested phylloclads to healthy ones. At the same time some eggs were kept on moist filter paper in petri-dish. A black paper was placed below the moist filter paper. This facilitated location of the eggs in the petri-dish under the binocular microscope.

The eggs transferred to the healthy phylloclads hatched as well as those kept on the moist filter paper in the petri-dish. Therefore the former method was employed for infesting directly the healthy stem segments. Slightly older segments were selected for infestation. An area of 49 square centimeter was enclosed on three segments by fixing sheets of plastic with molten paraffin wax. Freshly laid eggs were obtained from the infested phylloclads and were transferred to these enclosed areas and their development was followed with a binocular microscope.

These artificially infested stem segments were

kept in ordinary insect rearing cages.

Permanent microscopic slides for morphological studies were prepared by the standard method consisting of boiling the specimens in 10 percent KOH, staining in acid fuchsin, and mounting in Canada balsam.

RESULTS AND DISCUSSION

I. MORPHOLOGY

Taxonomists do not agree in their descriptions of Diaspis echinocacti but this may be due to the geographical variations of the species. Because of this variation in descriptions, it is appropriate to describe our local specimens.

A. EGG (Fig. 2, A)

The egg is oval and dirty white in color measuring 0.276 mm in length and 0.12 mm in width in the thickest part of the egg. No change in color was observed in the egg right up to hatching time.

B. CRAWLER (FIRST STAGE NYMPH) (Fig. 2, C,D)

In this stage the body is oval in outline and depressed. The color of the dorsum is mottled green and harmonizes with the stem color. The segmentation of the thorax and abdomen is distinct. On the abdomen four segments can be clearly made out; the remaining posterior part forms the pygidium which is also quite distinct (Fig. 2, C).

The crawler is provided with a pair of antennae (Fig. 2, E). Each antenna is composed of six segments. The basal segment is the broadest and carries a single seta. The next three are without setae but the fifth bears one. The sixth or the terminal segment is the longest and carries five setae. This last segment is not smooth but is constricted at places so that it appears to be made up of several fused segments.

Near the base of each antenna there is a red ocellus.

The piercing sucking type of mouth parts are large and distinct. They arise in the middle part of the cephalo-thoracic region on the ventral surface at the level of prothoracic legs (Fig. 2 D).

A pair of long caudal setae arise at the posterior end of the pygidium; they measure nearly one-fourth of the total body length which, on an average, is 0.28 mm while the width of the body is 0.16 mm.

Two pairs of pygidial lobes are present, the median pair is distinctly divided into two.

There are two pairs of minute spiracles, the anterior pair is situated behind the bases of prothoracic legs and the posterior pair is located in a similar position with respect to the mesothoracic pair of legs. There are no abdominal spiracles and no parastigmatic glands.

The legs are composed of normal segments (Fig.2,F). The femir is thick and somewhat spindle-shaped. The tibia bears five setae. Tarsus is small and two-jointed.

A prominent circular opening, the anus, is located on the dorsal side of the pygidium

There is no morphological distinction between the individuals of the two sexes in this stage.

C. SECOND STAGE NYMPH (Fig. 3).

This stage is characterized by the absence of antennae, ocelli and legs but is marked by growth in size. At the beginning of this stage there are no morphological differences between the nymphs of the two sexes but after a period of growth morphological differences start to appear. The point of morphological divergence of the two kinds of crawlers is marked by a moulting in the individuals that are destined to become males. After moulting the male nymphs enter the third stage of their life-history. There is no such third stage in the life-history of the female nymphs. The latter continue to grow in size without showing any radical type of morphological change. The only change that occurs in the female nymphs is that eight tubular glands are formed and there is an increase in their size. The average size, based upon measurements of 10 individuals, selected at random, is 0.526 mm in length and 0.42 mm in width. The mouth parts become more elongated.

Their average length for the same ten individuals is 2.23 mm. On the whole second stage female nymphs resemble closely the adult females with the following differences:-

1. There are no paragenital pore groups in the second stage female nymphs.
2. The size of the nymphs is smaller than that of the adult females.
3. The pear-shaped body of the second stage nymphs is thin and flat.

D. THIRD STAGE (MALE) NYMPHS

After the second moult the body of the male nymph becomes elongated. According to Mac Gillivray (1921) the rostrum and rostralis are lost in this stage but this was not found to be true as all male nymphs of this stage were found in possession of well-developed mouth parts.

The legs, antennae and the ocelli become conspicuous enough to be recognizable.

Male nymphs in this stage measured on an average 0.58 mm x 0.24 mm.

E. FEMALE (ADULT) (Fig. 4, A)

Measurements of 10 adult females in millimeters were found to be as in the Table 1.

These measurements show that there is a lot of variation in the size of individuals. According to Myer (1925) the average size of an adult female is about 1 mm

in length. I found the ratio of length to the width of the body also variable. Some individuals were found to be broader than long.

Table 1. - Measurements of 10 adult females in millimeters

Serial No.	Length	Width
1.	0.80	0.83
2.	0.83	0.79
3.	0.88	0.81
4.	0.81	0.83
5.	0.90	0.87
6.	0.80	0.81
7.	0.80	0.77
8.	0.82	0.83
9.	0.91	0.87
10.	0.90	0.88
Average	0.84	0.82

The anterior half of the body is round, without any lateral lobes. This is the cephalothorax (prosoma of Ferris, 1925). The pre-abdomen is clearly composed of four segments which are more conspicuous on the dorsal than on the ventral side of the body. The posterior region of

the abdomen is modified into a pygidium with prominent lobes forming the pygidial fringe.

Ocelli and legs are completely lacking in the adult female. But on the ventral side of the cephalothorax there is a pair of small tubercle-like antennae, each bearing a small seta. Two pairs of spiracles are also present on the ventral side. Their location is approximately mid-way between the lateral margins of the cephalothorax and the antero-posterior body axis. No parastigmatic pores were found to be present in any individual. Balachowsky (1935) recorded four parastigmatic glands but Myer (1925) described his specimens without these glands.

The mouth-parts are very long, approximately three times the body length. The lengths in millimeters obtained by measurements of 10 individuals is given in Table 2.

The pygidium carries three pairs of lobes. The median pair is completely divided into two lobes and their margins are entire. The second and the third pairs are deeply notched. The second pair is smaller than the first (median pair) and the third smaller than the second.

The female genital opening is located on the ventral side of the pygidium. It is a slit-like opening and is not located easily. One good indication of its location is the feature that it is surrounded by five

groups of conspicuous rings. These are the openings of glands that are situated in groups or clusters around the vulva. Mac Gillivray (1921) has used the term genacerores for them while Myer (1925) refers to them as paravaginal pores (Fig. 4, B). The number of rings in each of the five groups varies with the individual specimen. Howevdr, in a large proportion of specimens the group situated anterior to the vulva is composed of 9 rings; each group in the antero-lateral pair consists of 25 rings and each group of the postero-lateral pair contains 13 rings (Fig. 4, B).

TABLE 2

Length of mouth parts of 10 adult females in millimeters

Serial Number	Length in Millimeters
1	3.60
2	3.22
3	3.34
4	3.40
5	3.49
6	3.00
7	3.00
8	3.10
9	3.40
10	3.50
Average	3.30

The anal opening is circular and is very conspicuous in stained specimens. It is situated on the dorsal side of the pygidium mid-way between vulva and the posterior margin of the pygidium.

F. SCALE OF ADULT FEMALE (Fig. 5)

The scale of an adult female is composed of two portions, a circular, opaque, convex, dorsal part and a membranous, transparent, ventral part. If the scale is pressed by a needle, the dorsal, opaque portion comes off easily exposing the adult female beneath it but the ventral papery part of the scale remains permanently attached to the surface of the phylloclad. The scale is made of a dirty white waxy material and the exuviae of the two moults are incorporated in it. The color of the exuviae is dirty grey.

A great deal of variance exists in the size of the scales of females. The diameters of 10 scales were measured. The average diameter, in millimeters, of a female scale is 2.096 as given in Table 3.

G. THE MALE (ADULT) (Fig. 6)

The adult male is provided with a pair of membranous cloudy-white wings and three pairs of long slender legs. The antennae are long and 10-jointed and are hairy. Eyes consist of six large ocelli. At the posterior

extremity of the abdomen is located a long tubular genital sheath (Stylus of Mac Gillivray, 1921).

Table 3. - Measurements of Diameters of 10 Scales of Females

Serial Number	Diameter in mm
1	1.920
2	2.400
3	2.220
4	2.376
5	1.800
6	2.160
7	2.064
8	2.340
9	1.860
10	1.824
Average	2.096

The measurements in millimeters of different body parts of five males are given in Table 4.

H. SCALE OF THE MALE (Fig. 7)

The scale of the male is an elongated, linear structure. The dorsal and ventral parts are equally thick. A slight pressure with a needle is enough to separate the

Table 4. - The Measurements of Body-parts of 5 Adult Males

Number	Length of Body (Without Antennae and Sheath) (mm)	Width of Body (mm)	Length of Wings (mm)	Length of Antennae (mm)	Length of Genital Sheath (mm)
1	0.66	0.21	0.72	0.67	0.24
2	0.64	0.20	0.69	0.66	0.21
3	0.65	0.21	0.72	0.66	0.21
4	0.64	0.21	0.70	0.67	0.24
5	0.64	0.21	0.73	0.64	0.25
Average	0.65	0.21	0.71	0.66	0.23

whole scale from the surface of the phylloclad. The sides of the scale are slightly sub-parallel, the distance increasing towards the posterior end. The color of the wax is chalky white. The anterior or cephalic end is rounded and bears a single exuvia of the first moult. A median dorsal ridge runs the whole length of the scale posterior to the exuvia.

The average length of the scale of male is 1.5 mm varying between 1.4 and 1.6 as given in the Table 5.

Table 5. - Measurements of 10 Scales of Males in Millimeters

Serial Number	Length of the Scale in mm
1	1.40
2	1.45
3	1.46
4	1.46
5	1.48
6	1.50
7	1.52
8	1.57
9	1.59
10	1.60
Average	1.50

II. LIFE-HISTORY

In order to study the life-history of Diaspis echinocacti in the laboratory, 250 freshly laid eggs were obtained and transferred to three healthy stem segments of Opuntia ficus-indica on July 22, 1962. This was done with a needle. The eggs were transferred to three segments, 100 eggs on one segment and 75 on each of the remaining two. The eggs were distributed to three stem segments to avoid unmanageable crowding of larvae on one segment; at the same time the number of the segments was also kept small, i.e., only three. These stem segments were kept in separate cages to be examined daily for the development of the eggs. The position of these eggs on the phylloclads was marked by a circle drawn round them by a needle to facilitate their location on the phylloclads.

The hatching of the eggs started on July 25, i.e. three days later; 7 crawlers hatched on one phylloclad, 11 on the other and 19 on the third. All the crawlers from the three stem segments were collected and transferred to a separate segment which was marked as the segment 'A' for reference.

Maximum hatching occurred by the evening of July 26, i.e., on the fourth day of incubation when 54 eggs hatched on one leaf, 49 on the other and 65 on the third.

These crawlers were collected and transferred to a second separate segment that was marked 'B'. This was the hottest day of the month as the maximum temperature was recorded as 32.7°C and minimum temperature as 25°C.

On the fifth day of incubation, i.e. on July 27, a total of 22 crawlers hatched on the three segments. They were transferred to a third separate segment marked as the segment 'C'.

The total number of crawlers on the segment 'A' was thus 37, on the segment 'B' 168 and on the segment 'C' 22 and their dates of hatching were 25, 26 and 27 July respectively. A total of 6 eggs remained unhatched. By transferring crawlers that hatched on the same day to a separate segment uniformity with respect to age was assured.

Between July 22 and 27 the maximum temperature ranged from 30.6°C to 32.7°C and the minimum temperature ranged between 23.4°C and 25°C. The highest maximum temperature of 32.7°and the highest minimum of 25°C were recorded on July 26 when the largest number of crawlers hatched.

Twenty-eight crawlers on the segment 'A' settled down by the evening of July 28, i.e. three days after hatching. The remaining 9 settled down by the noon of July 29, i.e. the fourth day after hatching. Out of 168 crawlers on segment 'B' 133 settled down by the evening of July 29, and the remaining 35 settled down by the morning of July 30.

All the 22 crawlers on the segment 'C' completed their settlement by the evening of July 30.

In order to differentiate between the crawlers settling on two different dates on the same segment, circles were drawn with blue ink around the early settlers.

The first moulting occurred on August 4, in 17 crawlers of the segment 'A', i.e., a week after these crawler had settled down. On the segment 'B' 58 crawlers moulted on August 5, and by 6th August all the nymphs of the three segments had undergone the first moulting.

The moulting was followed by a gradual increase in the size of the nymphs. The exuvia of the first moult occupied a small place in the centre of the body, like a cap, while the body protruded beyond this covering. A new light grey and somewhat transparent covering invested the body of the nymph at this stage. This new covering was wrapped in a mesh of delicate white waxy threads.

Beginning from September 3 to September 10, i.e., 30 to 35 days after the first moult 13 second-stage nymphs of the segment 'A', 60 of the segment 'B' and 7 of the segment 'C' became elongated in an antero-posterior direction. This elongation was accompanied with heavy secretion of wax and resulted in the formation of typical, elongated male nymphs.

The remaining second-stage nymphs continued in

this condition till September 8 when they started moulting for the second time. The moulting was followed by heavy secretion of waxy material in a circular pattern. The exuviae of the first and the second moult were raised up on the top of the white waxy secretion. By 15th September all the nymphs had undergone the second moult and thereby became adult females.

The males started emerging from September 18, and continued to do so till September 20. A total of 70 males emerged from the three segments.

During the month of August the maximum temperature ranged between 31.2°C and 34.8°C and the minimum ranged from 23.1°C to 27.5°C whereas in the first 20 days of September these ranges were 32.5 to 29.4°C and 25.6 to 22.5°C. Thus the duration of different stages in this generation was as follows:

Incubation period lasted for 3 to 5 days.

First nymphal stage occupied 9 to 11 days.

Second nymphal stage lasted for 33 to 35 days.

Total life-history was completed in 45 to 51 days.

Some females of the first generation started ovipositing on September 27. First crawlers were observed hatching from the eggs on October 1 to October 4. First moulting started from October 14 to 18. The differentiation of male nymphs took place from November 18 to 23

while the second moult in the female nymphs occurred from November 23 to 30. The males emerged on November 25 and continued to do so till November 30.

The duration of incubation period, first and second nymphal stages in the second generation was thus 4 to 7, 13 to 15, 40 to 47 days respectively. This generation was, therefore, completed in 57 to 69 days.

The maximum range of temperature during October was 24.1°C to 31.9°C and the range of minimum temperature was 25.1 to 20.2°C, while in November these were 28.3 to 23.5°C and 17.0°C. to 21.0°C.

There were, however, much overlapping of different stages in this generation. Oviposition, hatching, settling of crawlers etc., all processes were going on simultaneously on the segments. It became practically impossible to follow the duration of various of various stages on these segments in the third generation. Therefore, in order to remedy this situation, 100 eggs laid on December 10 were obtained from four different females and transferred to a separate segment. The hatching of these eggs began on December 15; maximum hatching took place on December 18 (65 eggs) and the last eggs hatched on December 20; only three eggs did not hatch.

The crawlers started settling on December 22 and all of them completed settling by December 25. The first

moulting occurred on January 1, 1963 and by January 9 all individuals had undergone the first moulting. The second nymphal stage lasted till February 11 to 18. The males started emerging from February 18 and continued to emerge till February 25. The adult females of this generation started laying eggs at the end of the first week of March.

The range of maximum and minimum temperatures during December, January and February was as follows:-

	Maximum Temperature	Minimum Temperature
December	27.7°C to 14.5°C	20.5°C to 10.2°C
January	24.8°C to 12.2°C	17.5°C to 7.4°C
February	26.1°C to 16.3°C	18.2°C to 10.2°C

In these temperatures the various life stages occupied the following number of days:

Incubation period 5 to 10 days.

First nymphal stage 17 to 20 days.

Second nymphal stage 40 to 50 days.

Total life history was completed in 62 to 80 days.

LIFE-CYCLE AND HABITS

The female lays, on an average, 100 eggs in batches. The actual number of eggs in each batch was found to differ considerably but usually the number of eggs in

the preceding batch is more than in the suceeeding one although this is also not always true. The Table 6 gives the number of eggs laid by five females at different times.

As the female lays the eggs, she moves her abdomen to and fro. This movement helps to arrange the eggs in a semi-circular fashion around her abdomen. The incubation period lasted for 3 to 5 days in July-September generation, 4 to 7 days in October-November generation and 5 to 10 days in December-February generation.

At the time of hatching the egg splits at the level of the embryo head and the larva crawls out with the help of the fore-legs. A few crawlers were observed to be in difficulty in emerging out of the egg-shell. Such crawlers, with the anterior body protruding from the shell, continue to move their legs restlessly but apparently fail to detach their posterior end from the egg-shell. These individuals usually die. The crawlers that fall on their backs cannot correct their posture; this is probably because of their flat dorsum and comparatively small size of the legs. Such crawlers also usually exhaust themselves to death.

A perfectly normal hatching takes 3 to 5 minutes. After hatching the crawlers stay beneath the scale of the mother for a day or two. Following this quiescent period,

Table 6. - Number of Eggs Laid by Five Females of *D. echinocacti*

Serial No. of Female	Date of Egg Laying	No. of Eggs in One Batch	Total No. of Eggs Laid
	Oct. 3 - 4, 1962	53	
1	Oct. 7 - 8, 1962	35	
	Oct. 12, 1962	18	106
	Oct. 4 - 5, 1962	25	
2	Oct. 8 - 9, 1962	67	
	Oct. 14, 1962	6	98
	Dec. 11 - 12, 1962	50	
3	Dec. 16, 1962	30	
	Dec. 21, 1962	18	98
	Dec. 15 - 16, 1962	52	
4	Dec. 21, 1962	25	
	Dec. 26, 1962	25	102
	March 12- 13, 1963	55	
5	March 16- 17, 1963	38	
	March 21, 1963	10	103

they escape from beneath the scale and wander about on the stem segment. This stage in their life-cycle although extending only for 3 to 4 days, helps in the dissemination of the species. After the end of the wandering period the insects settle down, insert their stylets into the phylloclad tissue and start sucking the sap. At the first moult they lose the antennae, the ocelli and the legs.

The second nymphal stage is a period of feeding, growing and sexual differentiation. It is by far of the longest duration in the life-history of this insect. Towards the latter part of this stage, morphological differences become visible in the male and female crawlers. The bodies of the male nymphs become elongated and they develop antennae, ocelli, legs and a pair of wings. The males do not leave their scale immediately after completing their metamorphosis, but stay within the scale for 3 to 4 days and then escape from their scales through a slit cut on the ventral side of the scale. Each male is in possession of a long tubular genital sheath at the posterior end of the body through which the penis is extruded during copulation. For this purpose the male stands on the female scale and inserts the genital sheath below the margin of the female scale and reaches the genital opening of the female. This explains the unusual length of the genital sheath.

The adult female, on the other hand, lacks the eyes, legs and wings. A pair of small tubercle-like antennae are present. She remains anchored at one spot by her long stylets and after she has been fertilized, her main function is to lay the eggs. Following egg-laying, her body shrinks, becomes leathery stiff, and the female dies.

NUMBER OF GENERATIONS PER YEAR

Three generations were completed in the laboratory beginning from July 22, 1962 and ending on February 20, 1963. The first generation was completed on September 15, thus extending over a period of 45 to 51 days. The second generation began on September 27 and was completed on November 30. It thus required 57 to 69 days for its completion. The third generation took 62 to 80 days to be completed, beginning from December 10, 1962 and ending on February 18, 1963.

In retrospect, it would have been better to pursue this work until the end of the year, however, from these data it can be estimated that this insect may have up to five generations per year

PREDATORS AND PARASITES (Fig. 8, 9)

A survey was made of different predators and parasites that affect this insect in natural populations.

The second stage nymphs and adult females were found to have many natural enemies. Important among the predators were found to be an unidentified mite and a beetle, both as a larva and adult. At least two species of Eulophidae were found parasitizing the adult females.

The unidentified mite preys upon the adult female as well as on the second-stage nymph. The adult mite lays its globular egg-cocoon near the host and as soon as the young emerge from the cocoon they climb up the body of the host and start sucking its tissue fluid. As many as six young ones were observed feeding on a single host which reacts by swelling the body. The color of the host turns brown and it appears sickly.

A small beetle (probably Scymnus sp.) was found to be an active predator upon the second stage nymphs and adult females. As many as 150 beetles were counted in a single large colony of Diaspis echinocacti. The larva of this beetle punctures the body of the host by its mandibles and feeds on the body-tissues. If observed under a binocular microscope, the body-fluid is clearly seen passing into the stomach of the larva during the act of feeding. Clausen (1940) mentions Scymnus sieverini larvae feed mainly upon the young scales and adults preying upon the eggs of diaspine Coccidae.

At least two species of eulophids parasitize the

adult females of Diaspis echinocacti. The commoner one (which appears to be Aphytis mytilaspidis) is a very agile and beautifully colored wasp. The anterior wings of this insect are cloudy-white and the pattern of their pubescence is irregular. Three bright red ocelli are located on the head in a triangular fashion. The facets of the large compound eyes are greenish-blue. The eggs are laid on the dorsum of the host. The larvae, on emergence, stay on the back of the host and feed there. As many as three larvae may feed on a single host although generally only one is found parasitizing a single host. There is a remarkable color resemblance between the adult host and the parasite larva, and to a certain extent in the body outline of the two. As a result of the feeding of the parasite, the host gradually shrinks while the parasite grows in size. Towards the end of the larval period of the parasite, the size ratio of the host and the parasite is completely reversed. The parasitized females do not oviposit, or if parasitization has occurred late, the host may lay only a few eggs and then stops to lay further. Pupation of the parasite occurs below the scale of the host. The prepupal parasite larva voids black fecal pellets before pupation. The pupal stage is fairly long. The adult wasp, on emergence, spreads its wings and rubs its body with its fore-legs, then cuts a circular hole in the scale

of the host and escapes to the outside.

Balachowsky (1935)[+] reported Aphytis diaspidis parasitizing this insect in large numbers in Algeria. According to him this parasite limits the size of its population in certain years in that country.

DISCUSSION

The life-cycle studies on Diaspis echinocacti have been made by rearing insects on isolated stem segments in the laboratory. The fact that these insects were not reared on living plants is likely to create doubt with respect to the applicability of the data to the natural conditions of the insect, particularly in view of the known fact that to a large extent the osmotic pressure within a living plant is responsible for the ascent of plant juices into the proboscis of aphids.

In this connection it is appropriate to mention here again that Diaspis echinocacti prefer to infest old phylloclads in their natural state probably because of little metabolic activity in the old stem segments. The aphids occupy the place of primary parasites in the sequence of succession and prefer young shoots to feed on because of high metabolic activity of these shoots. The excess of water and sugar that enters their alimentary tract owing

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[+]Page 1599.

to high osmotic pressure within young foliage is excreted in the form of honey-dew by a special mechanism of filter chamber.

Diaspis echinocacti do not secrete honey-dew; they do not have a filter chamber and probably this is why they do not feed on young phylloclads.

In view of this it is unlikely that the data obtained in the laboratory may not be applicable to t he insect in its natural environment.

The scale of the female Diaspis echinocacti forms a dome-like covering over the body of the insect. It is not attached to the body and can be lifted easily by a needle without disturbing the insect. Later it can be pressed into its former position again without difficulty. This method was employed for counting the eggs laid by a female; the females concerned were not distrubed at all and continued to oviposit normally. The same method of lifting and afterwards returning back into normal position of the scale was employed in taking observation on the parasites of these insects.

One interesting observation during these studies pertains to the sex ratio in a colony of Diaspis echinocacti. It was found that whenever the population density increases over a certain maximum (150 individuals or more per square inch) the sex ratio tilts in favour of

the males which then constitute more than 50 % of the total individuals. Such counts were made by detaching all the scales present in an area of one square inch and by counting the scales of male and female individuals. But it requires further work for confirmation. If this proves to be true, it will throw light on the ingenious way of adjusting population balance and thereby the population pressure on food resources as practiced by these insects.

The evolutionary significance of the protective scale covers in these insects becomes apparent when one considers the heavy parasitization of them by their natural enemies. The scale covering provides practically no protection against the parasites and predators. It must have, then, arisen as a consequence of selective pressure exerted by inanimate components of the environment like heat, cold and humidity and the consequent need of establishing a micro-climate of their own around their bodies.

The predator and parasite complex of Diaspis echinocacti presents a fascinating field of research. Many parasites of this insect parasitize other pests of valuable crops and fruit trees. Thus these parasites can be artificially bred and multiplied on this scale insect and can be liberated in the fields and gardens. Such a study of this insect is likely to be rewarded with results of great economic importance.

SUMMARY AND CONCLUSIONS

Diaspis echinocacti (Bouche) is a major and specific pest of the family Cactaceae. The purpose of the present work was to study the life-cycle of this pest under laboratory conditions. The morphology of this scale was studied by preparing permanent microscopic slides, using the standard procedure of boiling the desired stages of the insect in 10 percent KOH, washing, staining, dehydrating and mounting them in Canada balsam.

An adult female, after copulation, lays on an average, 100 eggs. They are oval and dirty-white in color, and measure 0.276 x 0.12 mm. The eggs hatch in three to ten days beneath the scale of the mother. The crawlers remain quiescent for a day or two. This is followed by a wandering period that extends over two to three days. Dispersal of the species and extension of the colony occurs in this stage. The crawler, like other members of the Diaspidinae, shows a distinct segmentation of the thorax and abdomen; it is provided with a pair of 6-jointed antennae, a pair of ocelli and three pairs of legs. The piercing-sucking type of mouth-parts are well developed.

The crawler has a pair of long caudal setae located at the posterior end of the abdomen. There is no morphological distinction between the two sexes in this stage. The average size of a crawler is 0.26 x 0.16 mm. This stage lasts over two to four days. The first nymphal stage extends over a variable period of 9 to 20 days.

The second stage nymph is characterized by the absence of antennae, ocelli and legs and by the enlarged body size. This is the period of feeding and growth. During the later part of this stage visible sexual differentiation takes place. The female nymphs simply continue growing in size and after the second moult transform into the adult females. The male nymphs, on the other hand, after the second moult become elongated in an antero-posterior direction, develop eyes, antennae, legs and a pair of wings. After completing this metamorphosis they emerge as winged adults. The average size of a full-grown female nymph is 0.526 x 0.42 mm while that of a male nymph is 0.58 x 0.24 millimeters. This is by far the longest stage in the life-history of this insect and extends over 35 to 50 days.

The adult females exhibit variations with respect to size, the average being 0.84 x 0.82 mm. The body of the female consists of a cephalothorax and an abdomen. The latter is further divisible into an anterior segmented pre-abdomen and a posterior pygidium. The cephalothorax

carries a pair of tubercle-like antennae and two pairs of spiracles, there being neither eyes nor legs. The pygidium bears a slit-like vulva surrounded by five groups of paragenital pore glands on the ventral side and a circular anus on the dorsal side. The presence of paragenital pore glands distinguishes an adult female from the second stage female nymph which otherwise is very similar to the former.

The adult male measures 0.65 mm on an average, excluding antennae and genital sheath, and is provided with a pair of large membranous wings, a pair of long 10-jointed antennae measuring on an average 0.66 mm, and three pairs of long slender legs. Eyes are composed of six ocelli. The posterior end of the abdomen bears a long tubular sheath, through which the penis is protruded during copulation. The genital sheath measures on an average 0.23 mm. The male scale is elongated, linear structure; both dorsal and ventral portions are thick. The exuvia of the first moult is embedded in the cephalic end of the scale. There is a median dorsal ridge running the whole length of the scale caudad to the exuvia. The average length of the scale is 1.5 mm. The female scale is composed of a circular, opaque and convex dorsal portion in which are embedded the exuviae of the last two moults and a membranous transparent ventral part. The average diameter of the scale is 2.096 mm.

Several predators and parasites feed upon the second-stage nymphs and adult females. The important ones include an unidentified mite and a tiny black beetle which appears to be Scymnus sp. Both the larvae and the adults of this beetle prey upon the second-stage nymphs and adult females.

Among the parasites the commoner one appears to be Aphytis mytilaspidis which parasitizes the adult females of Diaspis echinocacti.

CONCLUSIONS

Diaspis echinocacti (Bouche) is a major pest of Opuntia ficus-indica in Lebanon. The duration of its life stages varies in different parts of the year; the second nymphal stage being the longest of them. The species is oviparous and exhibits sexual dimorphism.

This insect sustains a large number of predators and parasites which need to be studied further as they may be useful in controlling other diaspidid pests of more economic plants.

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APPENDIX

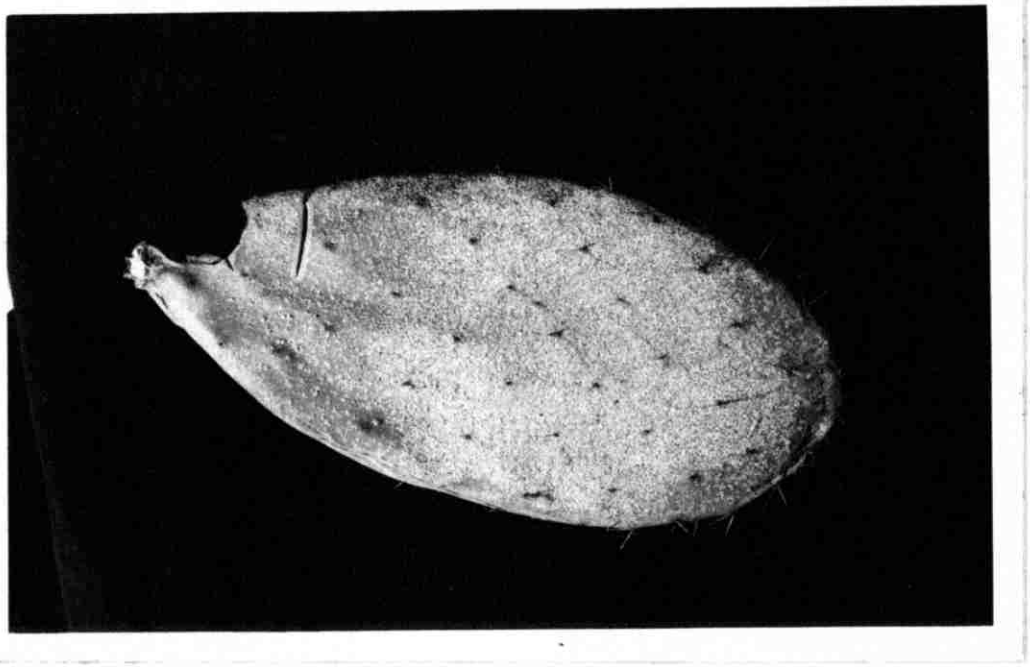
EXPLANATION OF ABBREVIATIONS

Abbreviation	Explanation
an.	Anus
ant.	Antenna
Em. Sl.	Emergence Slit.
Exu. I.	Exuvia of the first moult
Exu. II.	Exuvia of the second moult
f.g.o.	Female genital opening
l_2	Pygidial lobe 2
l_3	Pygidial lobe 3
m.l.	Median pygidial lobe
m.s. I.	Mesothoracic spiracle
m.s.II.	Metathoracic spiracle
Med.dor.rid.	Median dorsal ridge
Oc.	Ocellus
p.v.p.	Paravaginal pores
py.	Pygidium
Sty.	Stylus = genital sheath

Fig. 1.- Phylloclads of *Opuntia ficus-indica*

A. Showing severe infestation by *Diaspis echinocacti*

B. An aggregation of males



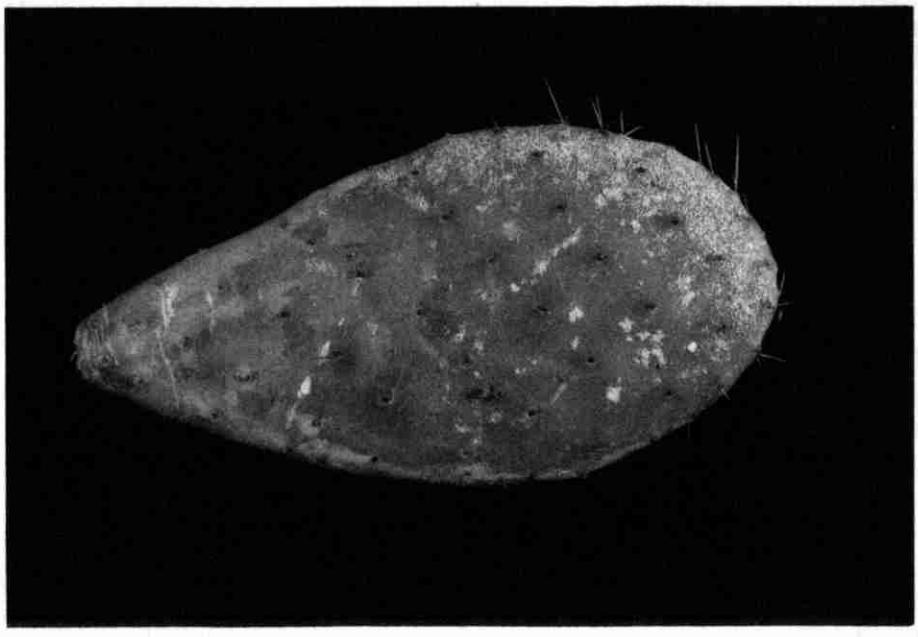


Fig. 2.- The eggs and the crawler of *Diaspis echinocacti*

A. Eggs

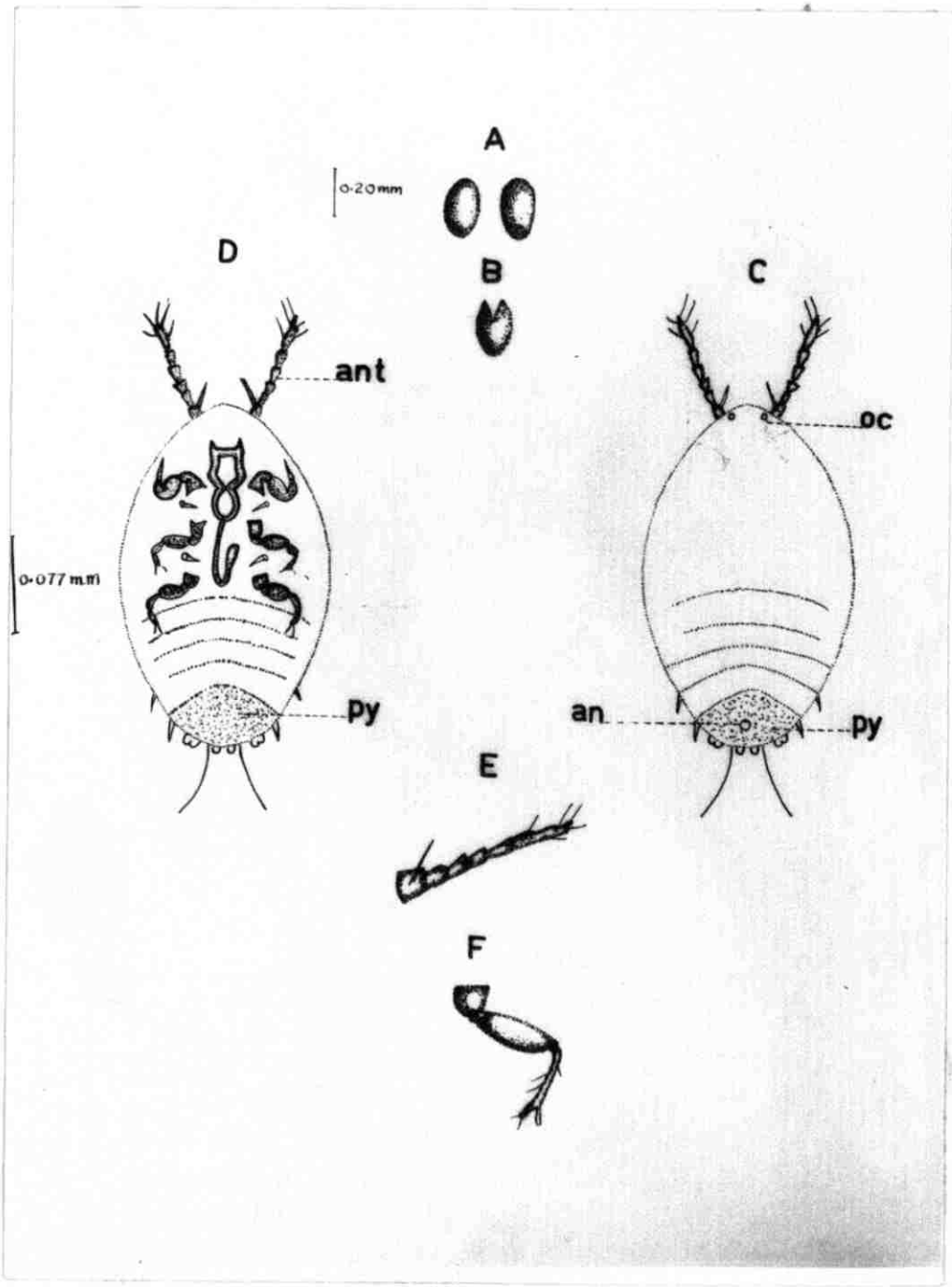
B. An egg shell left after hatching

C. Dorsal view of the crawler

D. Ventral view of the crawler

E. The antenna of the crawler

F. The hind leg of the crawler


A
0·20mm
B
C
D
ant
oc
0·077 mm
py
an
py
E
F

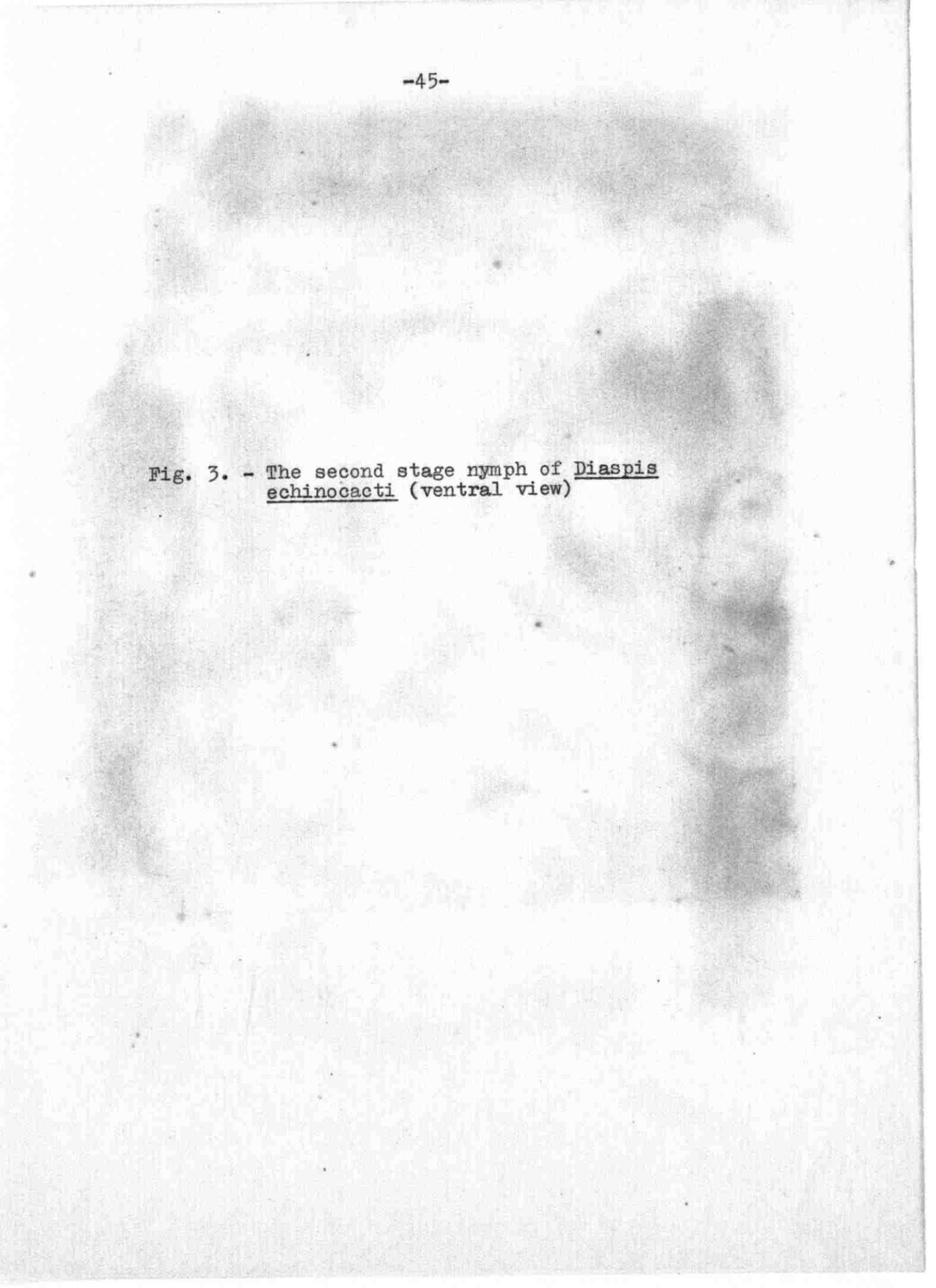


Fig. 3. - The second stage nymph of Diaspis echinocacti (ventral view)

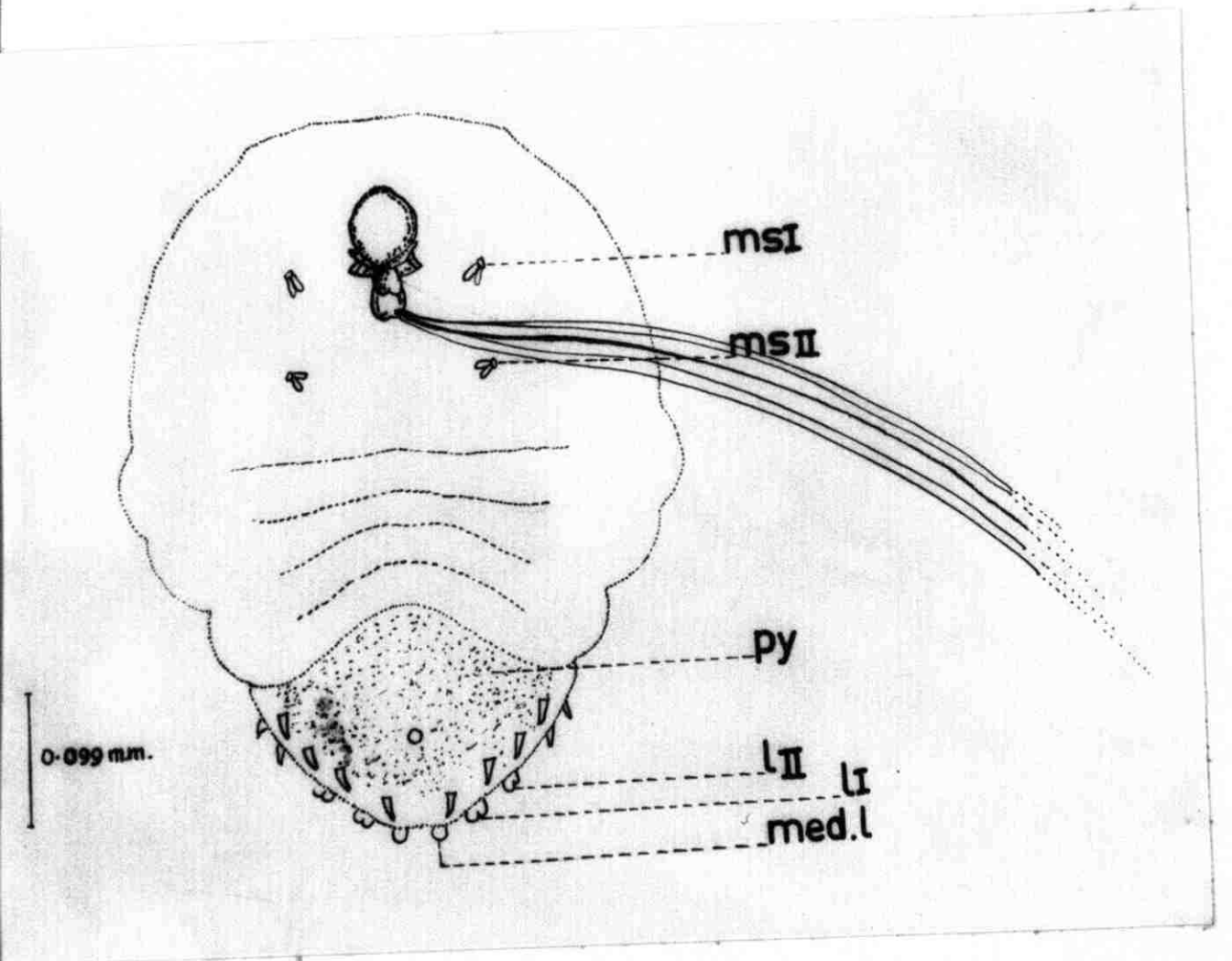

msI
msII
py
lII
lI
med.l
0·099 m.m.

Fig. 4. - The adult female of Diaspis echinocacti

A. Ventral view

B. Pygidium

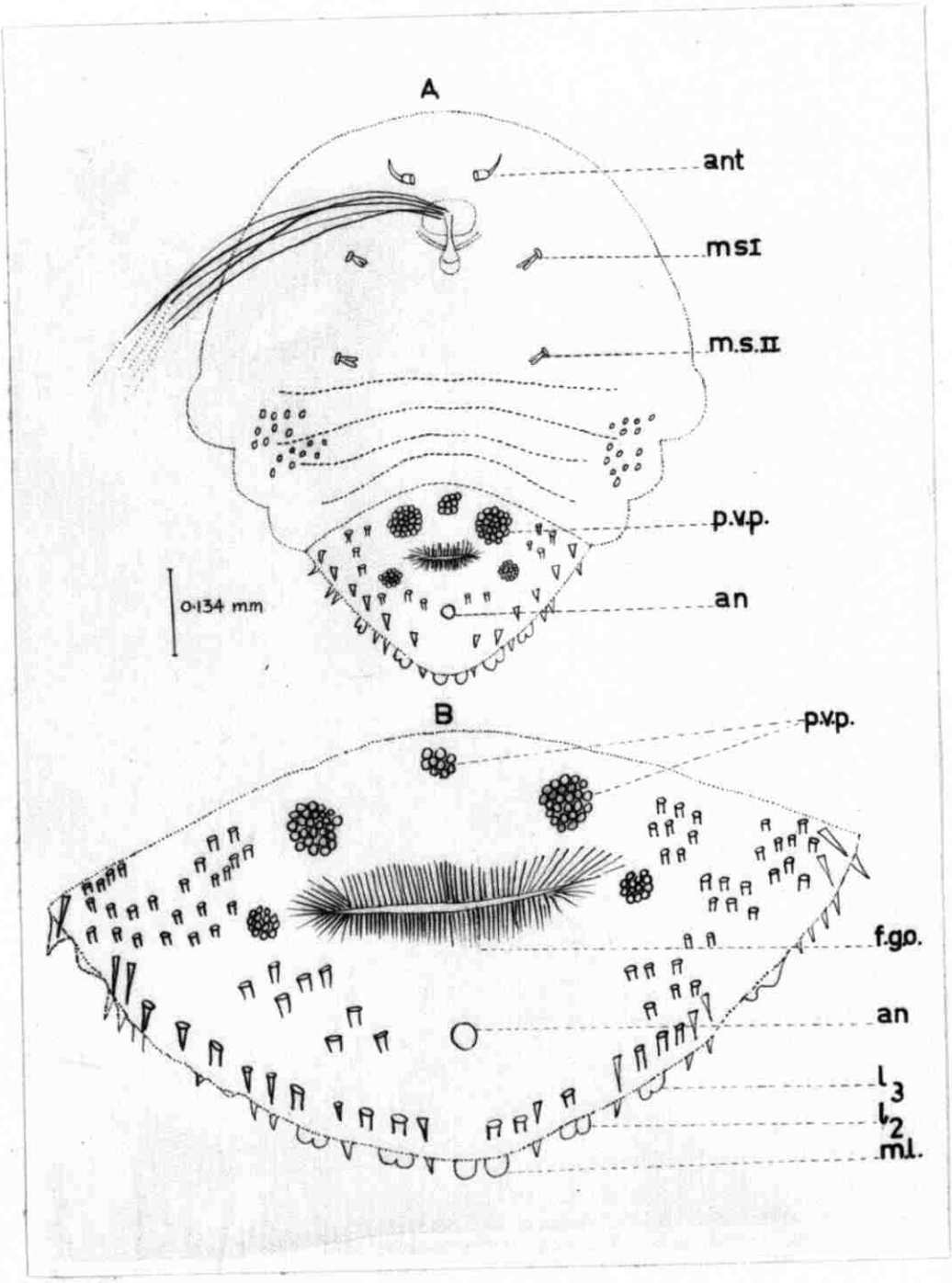

A
ant
ms I
m.s. II
p.v.p.
an
0·134 mm
B
p.v.p.
f.g.o.
an
l 3
l 2
m.l.

Fig. 5. - The scale of an adult female of *Diaspis echinocacti*

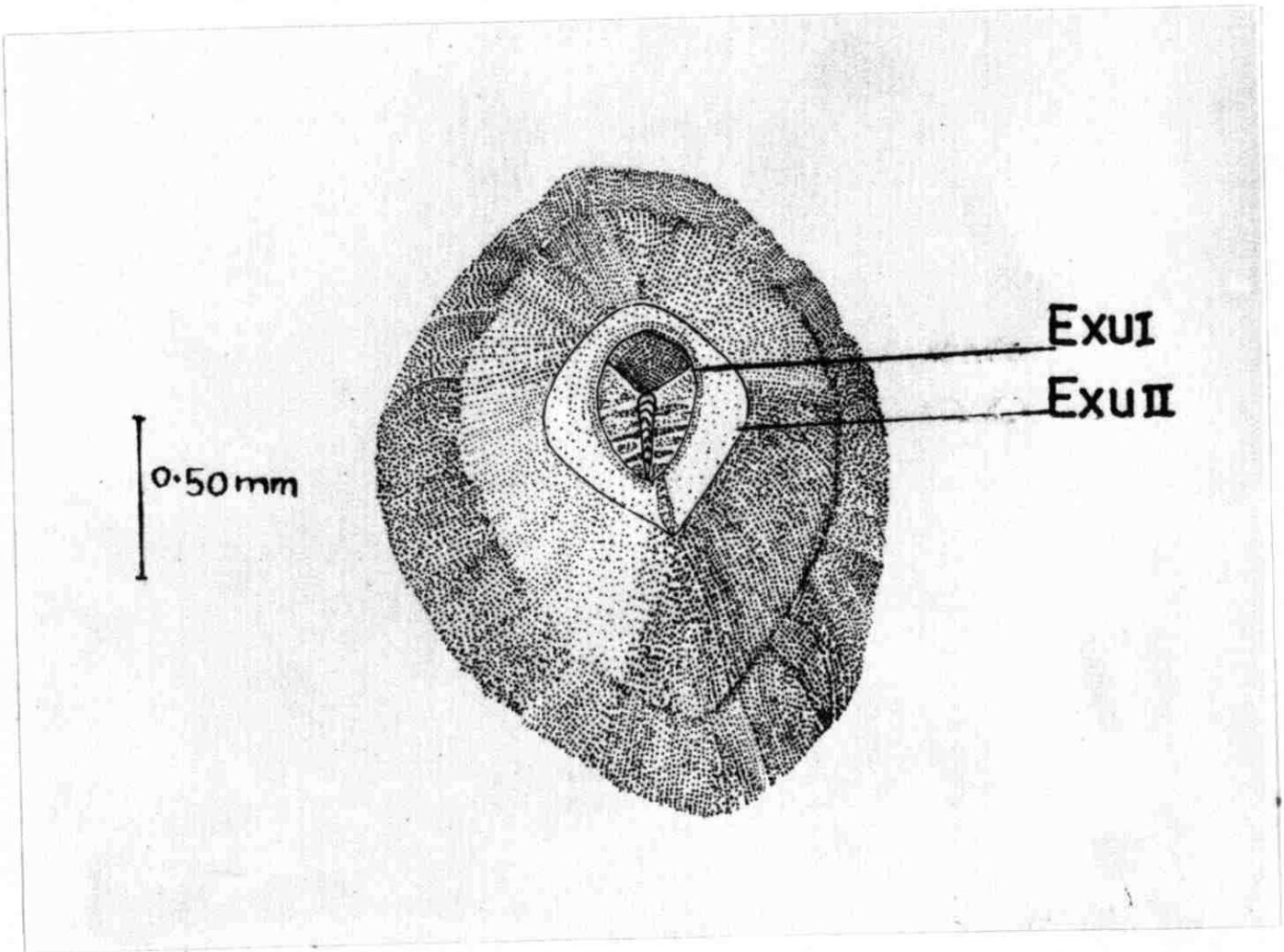

ExuI
ExuII
0·50mm

Fig. 6. - The adult male of *Diaspis echinocacti* (Dorsal view)

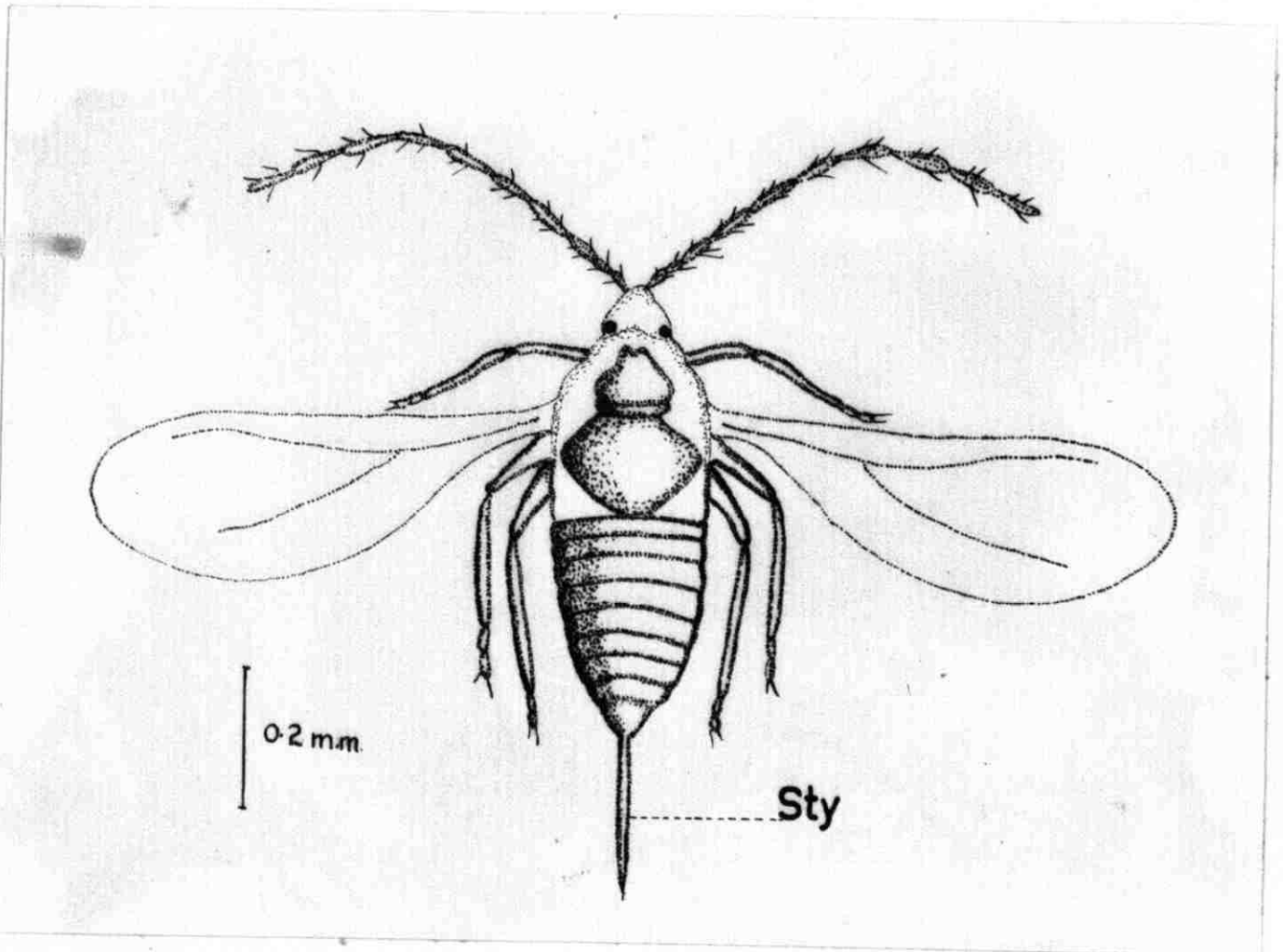

0·2 m.m.
Sty

Fig. 7. - The scale of male nymph of Diaspis echinocacti

a. Dorsal view

b. Ventral view showing emergence slit

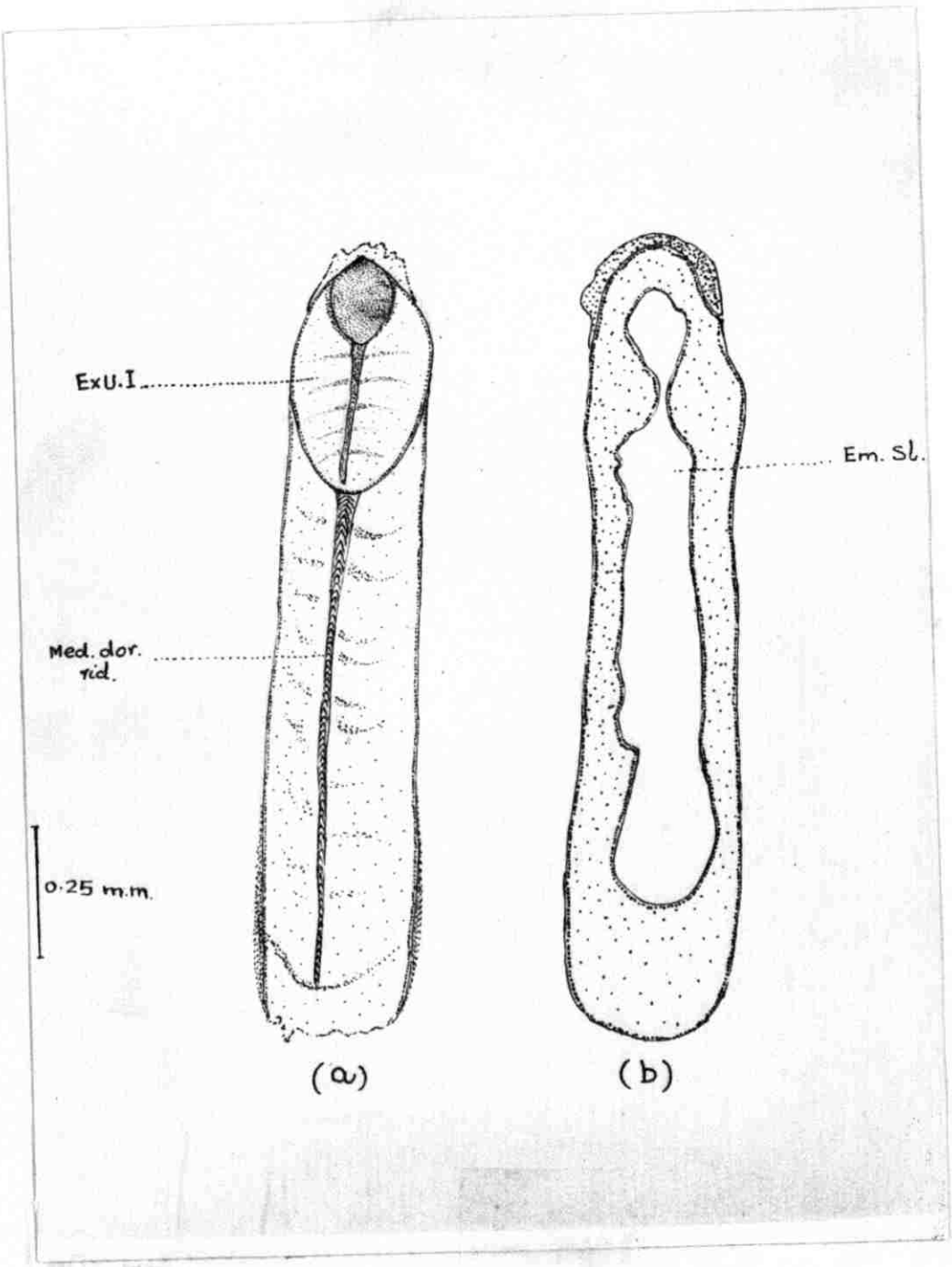

Exu.I
Med. dor. vid.
0·25 m.m.
Em. Sl.
(a)
(b)

Fig. 8. - The larva and the pupa of the parasite

A. The larva

B. Pupa (ventral view)

C. Pupa (dorsal view)

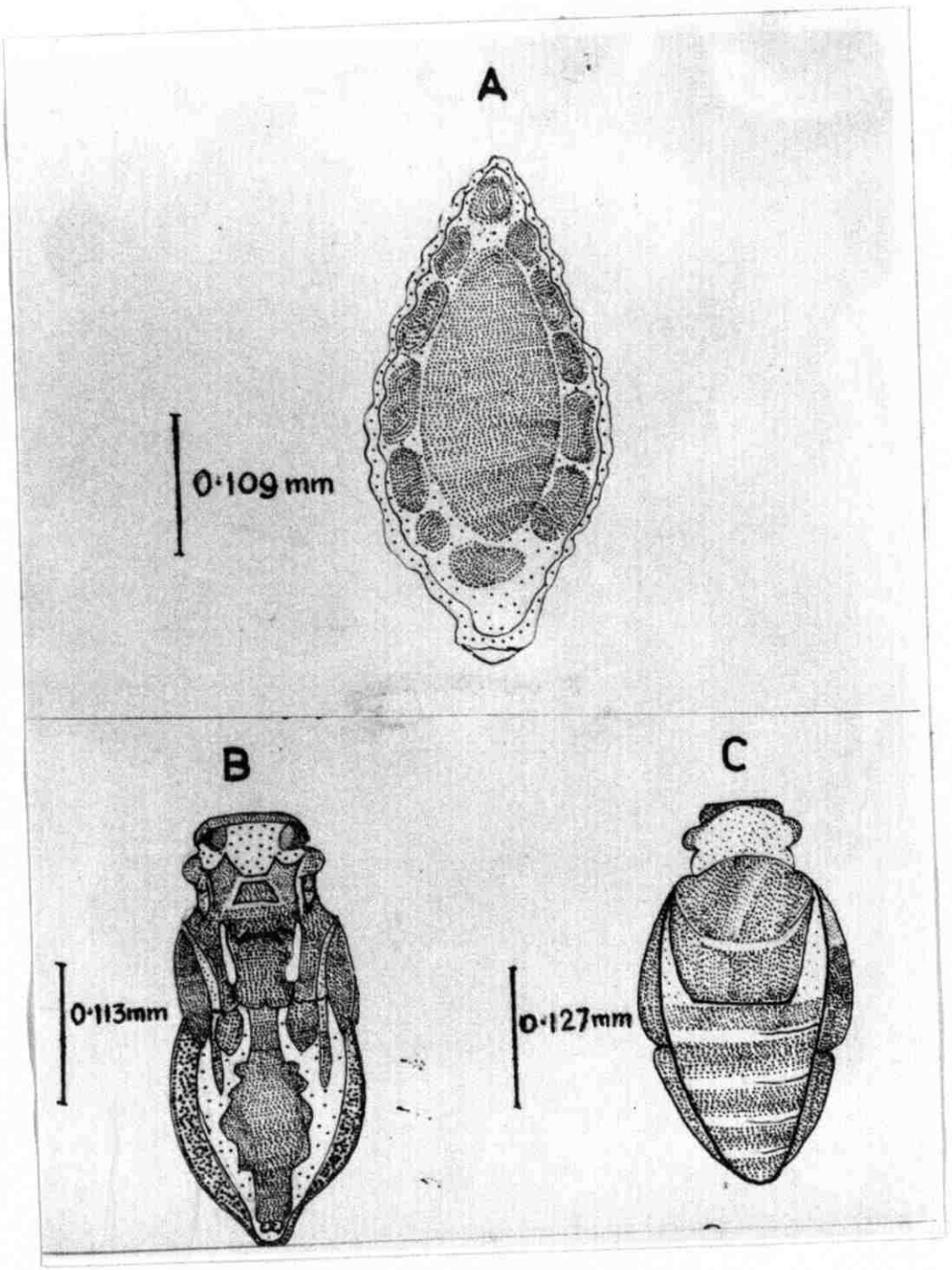
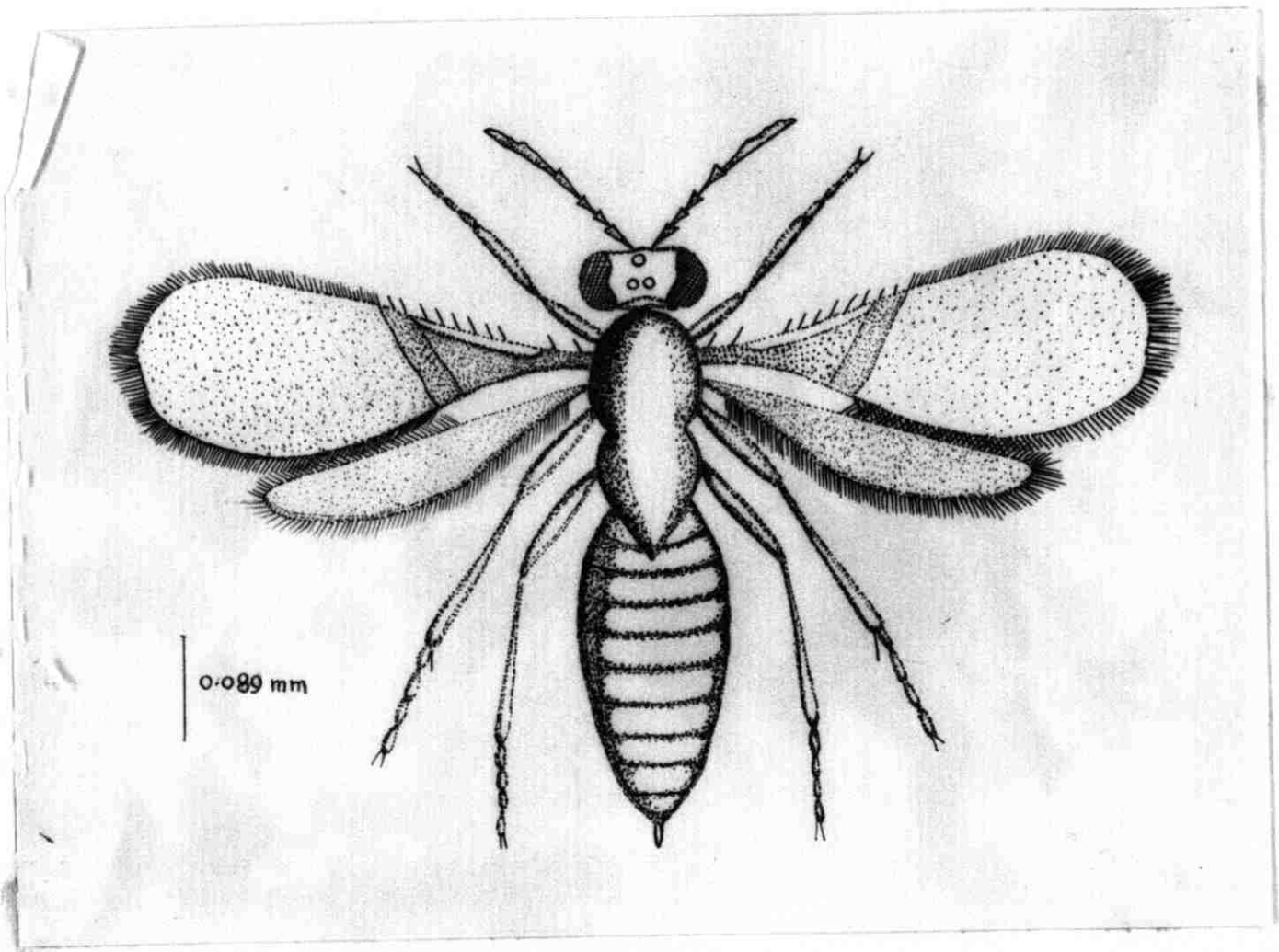

A
0·109 mm
B
0·113mm
C
0·127mm

Fig. 9. - The adult parasite (dorsal view)


0·089 mm