OBSERVATIONS ON THE HONEYDEW MOTH (*CRYPTOBLABES GNIDIELLA* MILLIERE) IN ISRAEL

I. BIOLOGY, PHENOLOGY AND ECONOMIC IMPORTANCE

By

Z. AVIDOV AND S. GOTHILF

INTRODUCTION

For many years the honeydew moth (*Cryptoblabes gnidiella* Mill.) was considered to be one of the causes of citrus fruit drop in Israel (5). It is known that this moth lays its eggs and develops on fruit harboring the honeydew excreted by mealybugs. But the life history of honeydew moth had not been investigated in this country, nor were biological details concerning it known in other countries.

Recent years have brought reports of severe damage to citrus, particularly grapefruit, along the Coastal Plain of the country where large numbers of fruits dropped prematurely. The assumption was that this was caused by the mealybug, although some thought that the honeydew moth also affected these groves to no small extent, and was an additional cause of fruit drop. Lack of knowledge concerning the life history of the moth, its association with the mealybug, and the nature of its occurrence in the various groves made it impossible to confirm or disprove its role in causing fruit drop. We therefore undertook a study of the biology and phenology of the honeydew moth with a view to additional clarification of the nature of the damage involved.

In 1957 and 1958 the moth was reared under outdoor conditions, phenological observations in various groves in the coastal area were carried out, and fruit drop was recorded.

LIFE CYCLE

THE EGG

METHODS

The females were kept in glass test-tubes 15 cm long, with a diameter of 1.5 cm. The eggs were laid on the walls of the test-tube. This enabled easy observation of the rather small eggs. The test-tubes were kept under outdoor conditions, in the shade. Oviposition and hatching were recorded daily. The average temperature during the

Publication of the National and University Institute of Agriculture, Rehovot. 1960 Series, No. 347-E. Received September, 1959.

incubation period of each egg was calculated. Plotting the reciprocals of the length of incubation gives a straight line (1). The thermal summation equation (3) was calculated from the linear regression (Fig. 1).

INCUBATION PERIOD

Figure 1 shows the relationship between the period required for incubation and temperature. The hyperbola was fitted to the data by the usual reciprocal straight

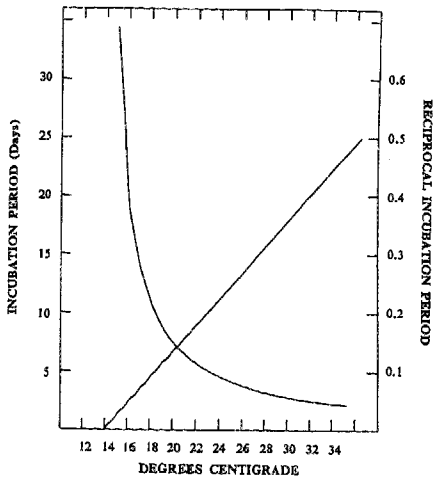

Fig. 1. The incubation hyperbola

line method. This figure, drawn from the rearing data of 1385 eggs during various months, shows that the development threshold of the egg is 13.7°C, and the thermal constant is 46.3 day-degrees.

PERCENTAGE OF HATCH

The percentages of eggs hatching from July to December appear in Table 1.

Table 1 shows a significant decrease in the percentage of hatching during December, apparently as a result of the drop in temperature. On many days during that month the temperature dropped below the threshold of development (mean minimum : 9.9°C). Many embryos developing within the egg, even those which had reached the fully-developed larval stage, were unable to hatch. October also showed a decline in the percentage of hatching. There were many hot dry days during this month and it is likely that the low humidity was responsible for the reduced hatching.

TABLE 1

PERCENTAGE OF EGGS HATCHED

Month of oviposition	Temperature °C			No. of sharav days*	No. of eggs laid	No. of larvae hatched	Hatching %
	Average	Mean maximum	Mean minimum				
July	26.5	32.5	20.4	3	169	125	77.8
August	27.6	33.6	21.5	2	184	149	80.9
September	26.5	32.5	20.5	4	348	277	79.5
October	23.6	28.7	18.4	8	468	322	68.8
November	19.4	24.7	14.0	3	379	319	84.1
December	14.8	19.7	9.9	0	67	33	49.2

* Days wherein the humidity was below 50% and the average temperature above 30°C were designated "sharav" (caused by the dry and hot khamsin desert winds).

Summarizing Table 1 we may say that hatching is generally in the vicinity of 70 to 80%.

Larva and Pupa

The larvae of honeydew moths choose hidden places among the fruits or between the fruit and leaves, and there envelop themselves in webs and waste-matter. This behavior renders them invisible during pupation. The data referring to the larval and pupal stages have therefore been combined.

METHODS

At the inception of the rearings we were confronted with two important phenomena: 1) In the absence of the mealybug or its waste-matter, we never succeeded in raising newly-hatched larvae on grapefruit even when the fruits had been previously injured by some other agent. 2) The larvae of the moth fed on the waste of the mealybug were capable of reaching adulthood, in the absence of fruit (on condition that the substrate was periodically sprayed with water). These factors were thus taken into consideration for the rearing methods on grapefruit.

Immediately after hatching, larvae were placed in ordinary 2 to 6 liter glass jars which were covered with cloth. The following food was given: a) grapefruit previously infested by the citrus mealybug, so that by the time the larvae were introduced the fruit was well populated by mealybug colonies and b) grapes.

The jars with the larvae breedings were kept out of doors (in the shade). They were examined daily and the emergence of adults was immediately recorded.

LARVAL AND PUPAL DEVELOPMENT ON GRAPEFRUIT INFESTED BY MEALYBUGS

The curve shown in Fig. 2 was plotted from data on the development of 150 individuals.

The hyperbola shows the development threshold to be 12.7°C. and the thermal constant 454.5 day-degrees.

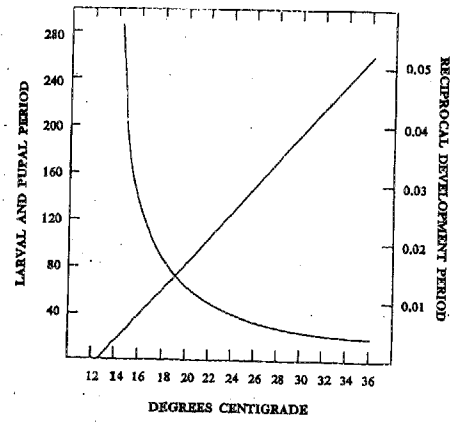

Fig. 2. Hyperbola of development period of larva and pupa on grapefruit infested by mealybugs.

LARVAL AND PUPAL DEVELOPMENT ON GRAPES

The rearings on grapes were done during the harvest season, i. e. from July to September.

TABLE 2

DEVELOPMENT PERIOD OF LARVA AND PUPA ON GRAPES

Temperature (°C)	*Development period (days)*			*No. of individuals*
	Average	*Maximum*	*Minimum*	
26	28.5	34	27	13
27	24.5	33	21	47
28	24.6	30	21	24
29	20.5	26	15	102
				186

Table 2 shows that the development period on grapes is from 6 to 8 days shorter than in rearings on grapefruit. Since the pupal stage in both cases is of the same duration, the development of the larva of the moth reared on grapes appears to be more rapid.

Pupal Stage

Calculation of average temperatures and length of pupal development shows: the pupal stage lasted 34—42 days in winter at 14—15°C (5 individuals), 19—29 days in spring, at 16—17°C (10 individuals) and 6—8 days in the summer at 27—28°C (21 individuals).

It should be stressed that both in experimental rearings and with pupae gathered from nature, emergence of moths during the months of January and February was very infrequent. Moths emerged in large numbers only from the beginning of March.

Adults

Methods

The adults were first kept in 3/4 to 1 liter jars, one male and one female to each jar. When no mating occurred, one newly-emerged female was placed in a 5 to 6 liter jar for 24 hours with a number of males. After 24 hours the female was transferred to a glass test-tube (15/1.5 cm). The mouth of the test-tube was covered by cotton saturated with a sugar solution or honey. The adults were kept out of doors and in constant shade. The test-tubes were examined daily.

Behavior of Adults

The adult moth is active at night. Owing to the method employed, it was possible to ascertain that both mating and oviposition took place at night. The adult in captivity may be fed on sugar solution, honey solution, or the honeydew of mealybugs, etc. It may be assumed that the presence of the honeydew of the mealybug colonies caused the oviposition on citrus trees, and that the honeydew of aphids caused oviposition on various other plants (sorghum, corn, etc.). The presence of the larvae of honeydew moth, on grape bunches previously affected by the grape berry moth (*Polychrosis botrana*), is apparently a result of the attraction of the adult to the juice of these infested bunches.

Adult Longevity

The life-span of adults as observed during various months of the year is presented in Table 3.

From Table 3 it is clear that the life-span of the adult in the cold season is a month or more, whereas in the warm season it is from 8 to 10 days.

Sex Ratio

Sex ratio of the adults emerging from the rearings remained almost the same throughout the year. From a total of 378 adults emerging during this period 47.9% were males.

TABLE 3

LONGEVITY OF THE ADULT (DAYS)

Month of emergence	*Temperature (°C) monthly average*	*Longevity*			*No. of individuals*
		average	*maximum*	*minimum*	
1957					
July	26.5	11.5	19	5	21
August	27.6	7.8	18	2	97
September	26.5	11.6	24	6	53
October	23.5	16.2	36	9	88
November	19.4	35.1	40	24	8
December	14.8	35.1	44	26	6
1958					
January	14.3	19.3	23	17	3
March	17.6	24.8	34	15	20
April	21.5	16.3	19	13	6
					302

Note: The above data refer to the life-span of both males and females; most of the females were unfertilized.

PREVIPOSITION, OVIPOSITION AND SENESCENCE

Most of the females mate on the night of emergence and they begin to lay eggs on the following night which gives a preoviposition period of one day. The oviposition period varies from 4 days during the summer to 15 days at the beginning of winter. Senescence lasts from 1 to 2 days during the summer and reaches 7 days at the beginning of winter. There was no oviposition during the winter.

FECUNDITY

Due to the reluctance of the moth to mate in captivity, we have data on the egg-laying of only 22 fertilized females. The average number of eggs laid by fertilized females during the autumn was 149 eggs, the minimum being 28 and the maximum 284.

It is interesting to note that the average number of eggs laid by 130 non-fertilized females was 47.6 per female (19.2% of these females did not lay at all).

ANNUAL CYCLE

The honeydew moth develops on various hosts, but its larvae are most prevalent on grapes and in citrus groves. The following is a list of the hosts on which the larvae were found during different times of the year:

Month	*Hosts*
January	Citrus
February	Citrus
March	Citrus
April	
May	
June	Grapes (4)
July	Grapes (4)
August	Grapes (4), citrus, sorghum (4), maize (4), pomegranate (4)
September	Citrus, pomegranate (4)
October	Citrus, cotton (7), loquat (10)
November	Citrus, cotton (7), loquat (10)
December	Citrus, loquat (10)

The hosts of the larvae during the months of April and May have not yet been discovered but it may be assumed that they are present on citrus during these months as well. During this period the larvae can develop among the colonies of *Pseudococcus citriculus*, and we have found them during February and March among colonies of these scales on citrus leaves. It should be pointed out that since the mealybug is found in groves all year round (7) there is nothing to prevent the larvae of the moths developing in their vicinity throughout the year.

An additional host—as yet a theoretical one—for the honeydew moth during April and May, may be the mango. In Egypt (9) the larvae of the moth were found on mango blossoms. At Rehovot (during April and May 1957) we attached recently hatched larvae of the honeydew moth to mango blossoms. They developed well and reached the adult stage. To the best of our knowledge, the larvae have not so far been found on mango in this country, but the matter deserves careful examination. Calculations of temperature prevailing from the beginning of August to the middle of March, (the period during which we found the larvae in the citrus groves) indicate that the moth raises three generations (a generation is measured from the egg until the new individual lays the first egg). Five to six generations will develop in a grove during an entire year.

In the rearings on citrus fruit we found that all the larvae which hatched at the end of October achieved adulthood by the end of December. All those which hatched after October passed the winter in the larval and pupal stages and the adults began to emerge only at the beginning of March. As the winter was a relatively warm one (November 19.4°C., December 14.8°C., January 11.6°C., February 14.1°C.), it may be assumed that after a colder winter emergence of adults would start later in the spring.

From June through August the larvae develop on grapes. Here the development is more rapid than on citrus (see Table 2). In the vineyards the moth is capable of raising three generations during these months.

Taking into consideration that the moths develop in vineyards during July and August and on citrus during the rest of the year, we arrive at the figure of 6 to 7 generations per annum.

OBSERVATIONS ON THE APPEARANCE OF THE PEST ON CITRUS TREES

NATURE OF SEASONAL INJURY TO CITRUS FRUIT

Among citrus trees, grapefruit is most subject to attack by honeydew moth. The larvae of the honeydew moth is found on grapefruit from the beginning of August until picking season. Until the end of October the larvae can usually be found on grapefruit settled singly, under the calyx, feeding on mealybug refuse, viz. skins, corpses, wax, honeydew etc. They burrow sometimes slightly into the sepals, leaving a round hole. This hole heals readily and does not damage the fruit. It should be stressed that until the end of October the larvae do not attack healthy fruit. Only insofar as the fruit is attacked from some other source (drying of the branches, carob

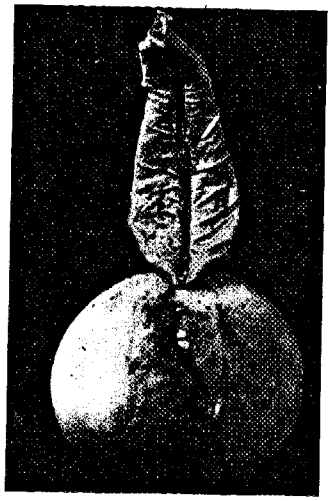

Plate 1. Larvae of the honeydew moth, which develop among the mealybugs, become visible when the leaf is raised.

moth, fruit fly, etc.), and yellows prematurely, may it become infected by the honeydew moth earlier in the season. From the beginning of October, as the fruit begins to ripen, signs of burrowing by the larvae can also be found on healthy fruit. The riper the fruit, the easier it is for the larvae to attack. In every case, the essential prerequisite for the larvae of the honeydew moth is the presence of the mealybug or its refuse. The damage usually appears on the side of the fruit, and this is related to the behavior of the citrus mealybug during the fall and winter. During these seasons colonies of mealybug appear at the point of contact between adjacent fruits or where the fruit touches the leaves. In such concentrations the larvae of the honeydew moth can be found in groups of up to 10 larvae per fruit (Plates 1 and 2). The infested fruit has usually been found to attract beetles (*Carpophilus* spp.) and fungi of blue and green mold. The mold generally appears on the fruit after it drops.

Plate 2. Later development stage–rotting of the fruit. *Carpophilus* spp. and various fungi have penetrated the fruit as a result of the boring of the larvae of the honeydew moth

Climatic conditions restrict the development of the honeydew moth population during the winter. The larvae develop slowly, new larvae are not added to the existing population (in the rearings we saw that oviposition ceases in December), and during the winter months the groves are populated by fall-hatched larvae and pupae. The mealybug colonies which the honeydew moth inhabit are eliminated by the picking and fruit drop. Further development of the larvae in the groves is possible only

within colonies of mealybug (particularly of the *Pseudococcus citriculus* Green), which have survived on the leaves. During March adult honeydew moths emerge from the pupae of the winter generation. These are the parents of the first generation to rise in the spring.

COMPARISON OF INJURY ON GRAPEFRUIT CAUSED BY HONEYDEW MOTH AND CAROB MOTH

Full discussion of the honeydew moth is impossible without mentioning the carob moth (*Myelois ceratoniae* Z.), particularly in view of the fact that these two pests have been confused until now (see Discussion and Conclusions). The presence of the carob moth in a grove also appears to be associated with the attraction of the mealybug's honeydew; the eggs of the carob moth are found near mealybug concentrations. The larvae—usually one, though occasionally more—hatching from these eggs, penetrate the fruit. They enter beneath the calyx with the object of reaching the diaphysis. Occasionally they enter the side of the fruit, where adjacent fruit touch one another.

The fruit attacked by the larva of the carob moth turns yellow prematurely. Where the larva penetrates—usually near the stem—gum is exuded (Plates 3 and 4).

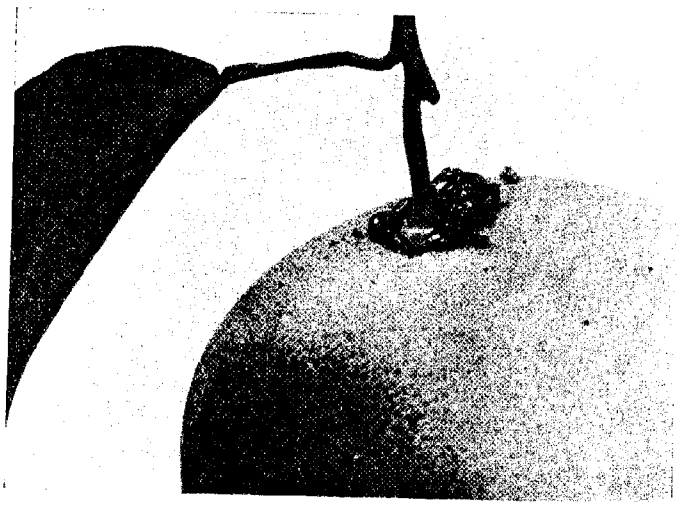

Plate 3. Typical appearance of gum exuded at the stem of the grapefruit as a result of penetration of larvae of the carob moth

Plate 4. A cut in the upper part of the fruit shown in Plate 3. The gummy dark spot is a result of the breakdown of the cells surrounding the tunnel where the carob moth larvae had penetrated.

A diagnostic comparison between the two pests is given in Table 4.

TABLE 4

DIAGNOSTIC COMPARISON BETWEEN THE HONEYDEW AND THE CAROB MOTH

	Honeydew moth	*Carob moth*
Color of larvae	Light brown; two darker stripes running the length of the body on both sides	Pinkish
Size of grown larvae	8 to 13 mm	About 15 mm and more.
Site chosen by larvae	On surface of fruit. Until October beneath calyx leaves. From October, where fruit and leaves are in contact. Always near the mealybug or its refuse.	Within the fruit.
Site chosen for pupal stage	On surface of fruit and particularly on folds of leaves touching the fruit.	Within the fruit.
Number of larvae in infested fruit	From August to October usually one larva (under calyx leaves). From October on, 10 and more.	Usually only one larva.
Dependence of early larva on mealybug or its refuse	Mealybug essential. In its absence larva will die.	Does not need the mealybug. Can penetrate directly into the fruit.
Signs of damage	Superficial boring on side of fruit (particularly from October on).	Deep boring into inner rind, usually under the calyx. The fruit yellows early in the season. Larva usually destroyed by the gum which is externally visible.

Grapefruit drop as a whole occurs during two seasons, May–July and September–December. Between these two periods, about the month of August, there is a puase in the drop. The moths have no connection with spring drop, but only with autumn drop.

Table 5 demonstrates the role of the two insects on grapefruit drop in various groves. From the data recorded in Table 5 the following conclusions may be drawn:

1. The moths caused only a part of the large fall drop.

2. The extent of drop varies greatly from grove to grove (from 12 fruits per tree in grove e to 50 in grove a).

TABLE 5

THE RÔLE OF HONEYDEW MOTH AND CAROB MOTH IN FALL DROP OF GRAPEFRUIT IN VARIOUS GROVES
(*Average per tree*)

Grove	*Year*	*No. of fruit dropped*	*Fruit dropped because of moth*		*Percentage of role of moth**		
			number	*% total drop*	*honeydew moth*	*carob moth*	*other burrowing signs***
a	1957	50.3	19.4	38.7	1.0	18.5	80.5
b	1957	27.0	6.1	22.6	10.8	24.3	64.9
c	1958	38.9	20.9	53.7	0	93.3	6.7
d	1958	21.4	11.8	55.1	0	100.0	0
e	1958	12.0	7.0	58.3	0	88.1	11.9
f	1958	41.0	17.4	42.4	0	74.7	25.3

* From fruit dropped because of moths.

** Fruit showing a tiny spot sometimes accompanied by gum near the stem, suggestive of burrowing by the carob moth.

3. The drop caused by larvae of moths also varies greatly from grove to grove (from 6 to 21 fruit per tree).

4. There is no correlation between the total drop and that caused by the moth.

5. From the detailed analysis of the role of the moths we see that the important pest is the carob moth, while the honeydew moth causes only light damage.

HOST RELATIONSHIPS

THE GRAPE VINE

The grape vine serves as an important host to the honeydew moth (4). We did not conduct systematic observations on the incidence of the honeydew moth's population, but the insect seems to prefer the vine to the citrus during the ripening period (in the coastal area during June, July and August). The larva of honeydew moth is considered a secondary pest on bunches already damaged by the grape berry moth. The development of honeydew moth larvae reared in the laboratory on the skin of whole grapes was satisfactory. The larvae always penetrated the berry at its stem end.

Rearing of honeydew moth larvae on bunches of grapes infested by the mealybug as compared to non-infested berries showed no difference in duration of larval development. The young larvae were not attracted to the bug, but immediately turned to the grapes.

OTHER HOSTS

A list of local host plants appears under Annual Cycle. In other countries the larvae were found on: cotton, wheat, corn, millet, amboyana, castor plant, beets, poplar (Egypt (13)). In other Mediterranean countries (11) the larvae have been found on citrus, figs, vines, peaches, gnidium and various wild and cultivated plants. In New Zealand (2) the larvae were found on vines.

DISCUSSION AND CONCLUSIONS

From the data in Table 5 we see that in certain groves 50% of the fall drop results from attack by moths. Fruit drop not caused by moths was very heavy and was observed in all groves under consideration and the question remains: what is the cause of this drop?

Our observations showed that this fruit drop is caused primarily by drying of the branches, a condition most prevalent in densely-planted groves. The problem of drying branches, however, is not an entomological one.

The only record in this country of autumn fruit drop, to determine the damage caused by the honeydew moth, was made in Hadera in 1930 by Bodenheimer (5). According to this author, from the end of August through September and October, 1211 fruit dropped per dunam,* of which 67% (809) was caused by the honeydew moth. There is a wide discrepancy between these data and ours, in which we found that drop as a result of the honeydew moth was light. The discrepancy would seem to be due to mistaken identification of the true cause of drop. The same error is apparent in all previous publications discussing the damage caused by the honeydew moth (4, 5, 6, 7,). Most of the descriptions of the damage, attributed to honeydew moth, apply to the carob moth (the size of the larvae and pictures of infested fruit are likewise typical of carob moth). Carob moth has not in fact been considered as a pest of citrus in Israel at all (although its existence in this country has been known), and its attacks have been generally attributed to the honeydew moth. One possible reason for this confusion is that the young larva of carob moth which penetrates the fruit is destroyed or repelled by the gum. The larvae of honeydew moth, on the other hand, live primarily on the surface of the fruit and are readily visible in the groves. They may also be found on fruit previously attacked by the carob moth.

In 1953 Rivnay (8), in discussing the carob moth as a pest of grapefruit in Cyprus, mentions it for the first time as a citrus pest found in this country as well. Subsequently, however, Grünberg (6) pointed out that there is as yet no certainty that the carob moth attacks citrus in this country. In his opinion, the local moth which develops in the *Acacia* hedge is not a potentially dangerous pest.

As shown in this work, the damage caused by the honeydew moth does not reach the extent where control measures become essential. On the other hand, the carob moth caused significant economic damage in all groves.

SUMMARY

1. The honeydew moth completes its life-cycle (from the egg until the new individual lays the first egg) in five weeks during the summer as compared to five months during the winter. The moth can breed 5—6 generations in a citrus grove during a year.

* 1 dunam=1000 m^2=approx. 1/4 acre.

2. Adult life span varies from a week in the warm season to four weeks in colder weather. The females can mate on the night of their emergence and oviposition usually begins a day after mating. The female lays an average of 150 eggs (maximum 284).

3. The young larvae are incapable of developing on citrus—even on damaged fruit—unless the mealybug or its refuse is present. The larvae however, are capable of developing on mealybug refuse alone, in the absence of citrus fruit, provided the honeydew is adequately diluted. The development of the larvae on whole grapes free of mealybug is similar to the development on infested grapes.

4. Larvae of the honeydew moth are found on citrus fruit from the end of August until picking time, but do not cause damage to the fruit until the beginning of October and thereafter.

5. The larva of the honeydew moth burrows only superficially and only within the area populated by the mealybug, whereas the larva of the carob moth penetrates deep into the fruit, usually beneath the calyx. The fruit yellows and gum is exuded at the point of penetration, which generally destroys or repels the larva.

6. Larvae of the honeydew moth caused the drop of single fruit here and there and these only in some of the groves observed. The larvae of the carob moth caused the drop of large numbers of fruit.

ACKNOWLEDGMENTS

This work was subsidized in part by the Citrus Fruit Marketing Board within its grant for the study of the citrus mealybug.

Dr. E. Swirski and Dr. I. Moore of the Department of Entomology of the Agricultural Research Station, and Dr. I. Harpaz of the Faculty of Agriculture of the Hebrew University assisted with suggestions and information.

Mr. I. Nathan assisted in performing the tabulations in the groves. Messrs. Greenblatt, Senegalia as well as "Agudat Haorez" permitted us to use their groves for tabulation and observation.

The authors express their gratitude to all of them.

REFERENCES

1. **Allee, W.C. Emerson, A.E., Park, C., Park, T.** and **Schmidt, K.P.** (1950) Principles of Animal Ecology. Saunders Co. Philadelphia and London. p. 108.

2. **Anderson, S.F.** (1917) Outdoor culture of the grapevine in New Zealand. *N.Z. J. Agric.* **14** (4) : 278—292. (*R.A.E.* **6** : 95).

3. **Blunck, H.** (1923) Die Entwicklung des *Dytiscus marginalis* L. vom Ei bis zur Imago. II Teil. *Z. wiss. Zool.* **121** : 173—391.

4. **Bodenheimer, F.S.** (1930) Die Schaedlingsfauna Palaestinas. Paul Parey, Berlin. pp. 166—168, 251, 277, 301, 302.

5. ———(1951) Citrus Entomology. Dr. W. Junk, The Hague. pp. 55—58.

6. **Grünberg, A.** (1957) Pests of Citrus Trees and their Control. Yehoshua Chechik Publ. Co., Tel Aviv. pp. 149, 150—151. (Hebrew).

7. **Klein, H.Z.** (1940) Citrus Pests in Israel. Hassadeh Library Publ. Co. Tel-Aviv. pp. 126, 143—146. (Hebrew).

8. **Rivnay, E.** (1953) On Pests of citrus and carob in Cyprus. *Hameshek Hahaklai* **14** (5): 28. (Hebrew).

9. **Sayed, M.T.** (1946) *Aceria mangiferae* Nov. Spec. (*Eriophyes mangifera* Hassan MS) (Acarina-Eriophyidae). *Bull. Soc. Fouad Ent.* **30** : 7—10. (*R.A.E.* **36** : 409).

10. **Schwelg, K.** (1950) Pests of the Vine and Fruit Trees. Hassadeh Library Publ. Co., Tel-Aviv. p. 47. (Hebrew).

11. **Silvestri, F.** (1939) Compendio di Entomologia Applicata. *Tipografia Bellavista*, Portici, **2** : 610.

12. **Wigglesworth, V.B.** (1953) The Principles of Insect Physiology. Methuen, London, pp. 41, 342—343.

13. **Willcocks, F.C.** (1922) A survey of the more important economic insects and mites of Egypt. *Bull. agric. Soc.*, Cairo, pp. 29, 57, 65, 72, 135, 291, 293, 348.