Israel Journal of Entomology vol. II, 1967,

A Contribution to the Biology of the Maize Borer Chilo Agamemnon Bleszynski in Israel *

by

E . R i v n a y

Volcani Institute of Agricultural Research

S U M M A R Y

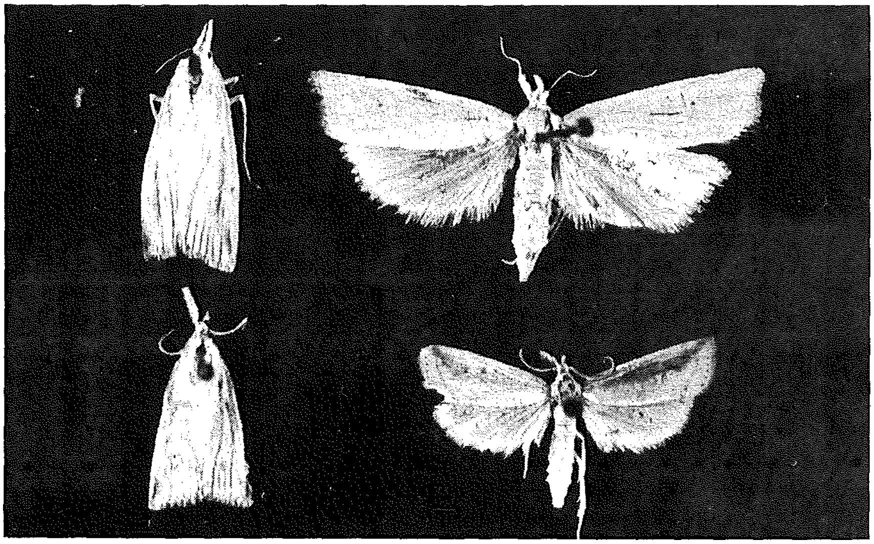
Chilo agamemnon is a new name for a notorious pest of sugar cane and maize in Egypt; it entered Israel recently, and in a short period has spread all over the country, causing damage mainly to maize.

The eggs, which are laid on the surface of the blades, develop under the prevailing summer conditions in the coastal plain within 4-7 days; the larva which bores in the stalk, develops within 15-17 days; the pupa, which is located in the stalk near the exit holes, develops within 5-7 days. Moths may lay from 200-300 eggs; fertile females, under favourable conditions, lay 500-700 eggs.
The most proliferous moths were those which emerged and laid in late June and early July. Moths reared in incubators laid, on the average, fewer eggs than did those reared outdoors.

The moths first appeared early in May, from which time to the end of September five generations may be raised, with a sixth during the winter.
The offspring of the September moths enter diapause in, the larval stage; some of these constitute the sixth generation, which is in hibernation. The percentage of diapausing larvae is low at the beginning of September and increase until October, whan all larvae enter diapause. No egg laying takes place late in October, except when extraordinary temperature conditions prevail.

I n t r o d u c t i o n

The name **Ch. agamemnon** Bleszynski may be new to economic entomologists and to agriculturists, for it was only recently given to a well- known pest which had been mistakenly identified for many years as Ch. **suppressalis** (= Ch. **simplex)**. The pest is a recent addition to the.fauna. of Israel. When it was first discovered in Israel in 1959, the writer identi- fied it as the species which is a well-known sugar cane pest in Egypt (Will- cokcs, 1922), Subsequently, specimens were sent for identification to Bleszynski and were correctly identified. According to that author, the real suppressalis (= simplex) is limited to the Far East, while the specimens from Israel belong to the newly described Ch. agamemnon which is distributed in East Africa, Egypt, Spain and in Israel (Bleszynski, 1962: and personal communications), Fig. 1.



The statement about the recent entry of this pest in Israel is contradictory to previous records dealing with the fauna of this country. Bodenheimer (1937) lists a few species of Chilo as occuring in Israel: Ch. brevipalpellus Zerny, Ch. hederalis Ams., Ch. simplex But., Ch. pulverosellus Rag and Ch. hypenalis Rbl. The presence of Ch. simplex (= suppresallis) in Israel was assumed because of its occurrence in Egypt, and it was accepted by Bytinski-Salz (1966), who added that it "has recently become a serious pest". The opinion of the present writer is based on the fact that since the damage of this species is so conspicuous, it surely would have been noticed had it been present in Israel before. Its recent entry is also evident from the site of its first discovery and the mode of its spread, as described by the writer in an earlier publication (Rivnay, 1963): "It was first recorded in 1959 in the northwest area of the Negev near the Gaza Strip. It reached Rehovot in 1961 and gradually spread northward", and today it is present throughout the country. As early as 1961, it had become a pest of considerable importance in the area of Beer Tuvia.

The rapid spread of this pest is due in particular to the favorable food conditions prevailing in the country, namely, the continuous presence of fresh young plants, sown at intervals to maintain a steady supply of fresh fodder for the dairy cattle throughout the arid summer.

Damage Caused by Ch. agamemnon.

Due to the horizontal girdling tunnels by the larva close to and parallel to the circumference of the cane, the stalk breaks easily and sharply, as if cut with a saw. If not broken, the upper parts, usually half of the plant and often more, dry up. When the dried parts are pulled they are easily detached, exposing the tunnels and often larvae or pupae in them. The horizontal girdling is often incomplete, in such cases the plant does not dry up but its growth is stunted. Broken plants cause difficulties in the harvest. Dry plants may be noticed already in young fields 30-45 days old, but in older fields the straw colour of dried plants may be seen from distances.

During the late summer, infestation may reach 100%, i.e., every plant in the field may harbour one or more larvae. Infested fields yielded two tons of green fodder per dunam, as compared with an average of five tons in non-infested fields.

The intensity of the infestation by Ch. agamemnon as described above did not continue for a long time. After having been established for one or two years in a certain locality, the infestation became less severe than in newly invaded sites. This suggests that some biotic factors existed after the invasion, which checked the rapid increase of the pest. During the periods in which we collected larvae from the field, no parasite was obtained.* It is possible that predators or egg parasites played a role in this respect.

Methods of Laboratory Breeding.

The eggs were placed on moist blotting paper in petri dishes and the time and percentage of hatching were recorded.

Neonate larvae were placed first on soft young seedlings of maize. A week later they were transferred to older plants or to soft maize cobs.

The onset of pupation was recorded by exposing larvae in the feeding galleries. Locating them was facilitated by the exit holes which the larvae made prior to pupation. Pupae were kept in 600-ml jars over

* After this was written, some batches of eggs were found at Beer Tuvia parasitized by Trichogramma sp.

over a moist layer of sawdust at a humidity of 70-80% RH. The emergence of the moths, which marked the end of the period, was recorded.

The ensuing adults, whether obtained from field-collected material or from laboratory breedings, were paired, and placed in 600-ml jars; a 7% sugar solution was supplied as food. Their eggs were counted and removed every day or two.

The data on the phenology and diapause were obtained by collecting infested plants at various intervals in the late summer and autumn of 1962, and recording emerging moths and diapausing larvae. Generally, about 100 plants were collected at each date.

Biology of *Ch. agamemnon.*

The Egg.

1. Mode of egg laying.

The flat eggs are laid on the blade surface in small groups, one egg partly covering the other, like roof shingles, each group forming an irregular small patch. Before hatching, the eggs darken due to the black head of the embryo which becomes visible through the egg shell.

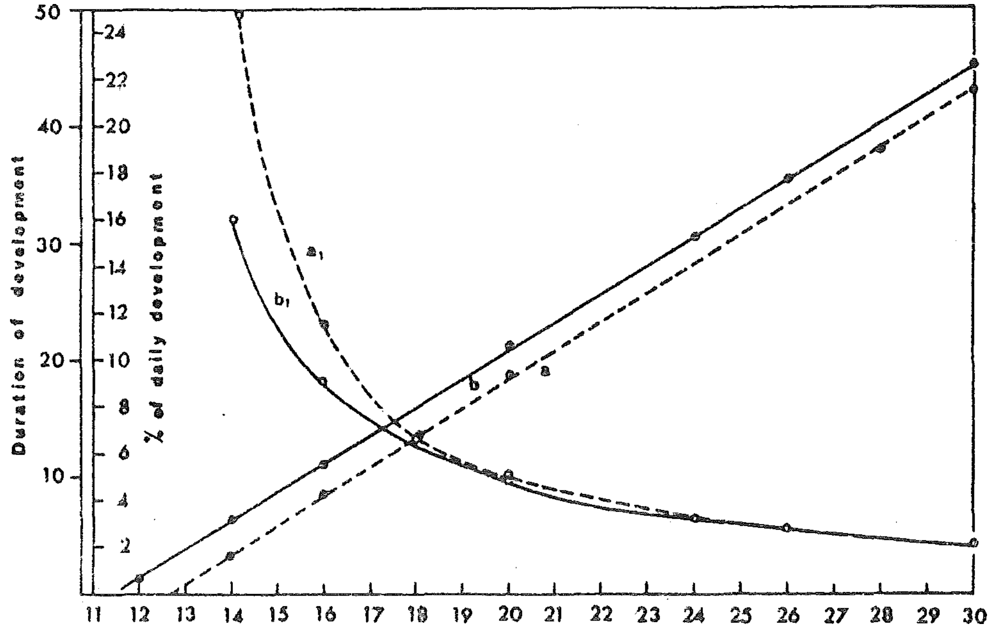
2. Incubation period.

The incubation period in the summer is 4-6 days (Table 1). The line of regression (Fig. 2) of its development at various temperatures is based on data presented in that table. According to this line, the theoretical threshold of development lies between 11 and 12^{o}C, and the complete development requires 83 days degree. When eggs were kept at 10^{o}C, none hatched since all had died within one month's exposure at that temperature.

Table 1. Development and Survival of Eggs of *Chilo agamemnon.*

Temp. (°C.)	Number of Breedings	Number of Eggs	Hatching %	Length of Development (days)	Breeding Site
10	9	1003	0	-	Incubator
20	17	2534	52.3	10.8	"
22	7	547	63	8	"
24	10	1294	42	6.2	"
26	10	1081	62	4.7	"
30	11	893	23	3.4	"
34	14	2366	32	3.8	"
27.3	18	2643	41.7	4.7	Outdoors
28.5	26	4509	36.7	4.4	Laboratory
27.4	10	1691	66.4	4	"
25.3	27	5613	65.8	5.5	Outdoors
24.5	17	2772	64.2	5.5	"

Fig. 2. Duration and percentage of daily developmen of egg (complete line) and pupa (broken line) of Ch. agamemnon.



3. Survival.

Table 1 presents the percentage of egg survival under the conditions of incubation. Apparently, survival is a result not only of the effects of external conditions, but also of non-viability due to other reasons, or lack of fertilization.

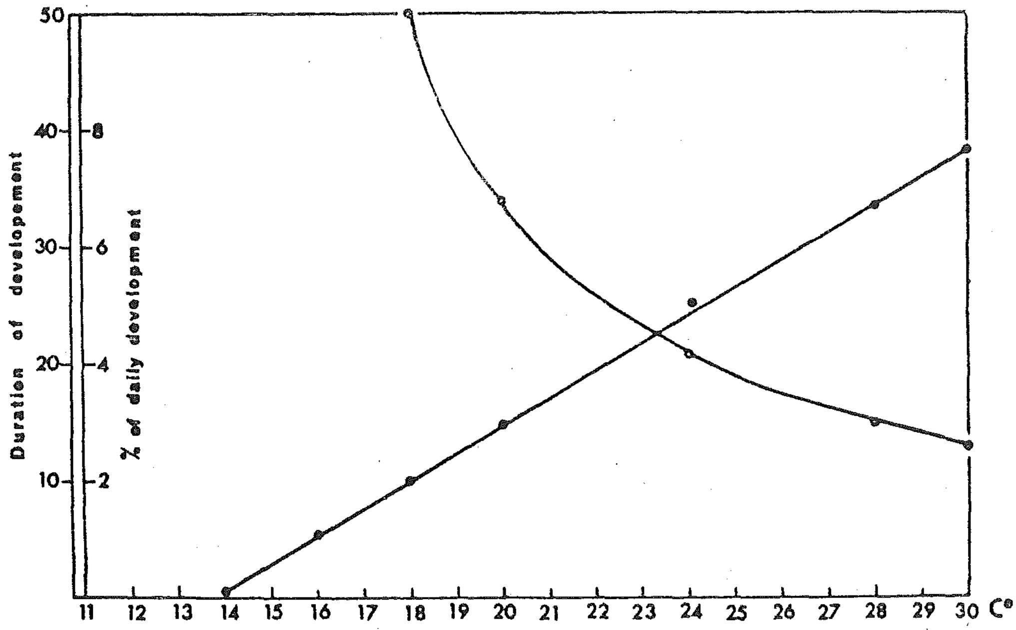
It is obvious, however, that in July and August, as the temperatures rose to 29°C and above (in the incubator to 30°C and above), the mortality also increased.

The Larva.

1. Habits.

In its first day or two the larva feeds on the blade, leaving the so-called pin holes. In the field, these holes often serve as a criterion of infestation before other signs become noticeable. The larva enters the stem either through the whirl or gnaws its way from the outside into the cane. In the stem the larva tunnels longitudinally, but before pupation it girdles the stem from inside, and prepares an exit hole which it covers with a bit of frass and silk.

Fig. 3. Duration and percentage of daily development of larva of Ch. agamemnon.



The girdling may be from one half to one meter above the ground. In the autumn, as the temperature drops, the larva penetrates deep below the surface of the ground and gnaws a cell in the root crown in which it hibernates.

2. Duration of development.

For all breedings, the period of development at the various temperatures was recorded (Table 2). In the early summer, outdoors, at an average temperature of 24°-26° C, the larva completed its development on an average in 17 days; in mid-summer, at an average temperature of 27-28°C, in about 15-16 days. The development at the respective constant temperatures in the incubators was about the same. The data given in Table 2 served also to calculate values and to draw the line of regression presented in Fig 3. The line cuts the temperature axis at 14, 0°C, which should be considered the theoretical threshold of development. To complete the larval stage, 216 days degree were required, at lower temperatures, 230 were needed.

Actually, all of the 284 larvae in the breedings at 16°C died before pupation within a period of six months. In nature, in the autumn, below 18°C, larvae enter diapause.

Table 2. Development and Survival of Larvae of Chilo agamemnon at Various Temperatures and Seasons.

Temp. (°C)	Month	Year	Number of Breedings	Total Number of Larvae	Percentage which survived to pupate	Average period of Development (days)	Breeding site
20	XII	1963	3	60	28.3	31	Incubator
22	IX	"	10	439	19.3	30	"
24	IX-X	"	9	431	25.7	22.6	"
26	X		2	42	26	17	"
30	X-XI		14	536	19.75	13.4	"
34	X-XI		25	1018	2.6	15	"
24	VI(l)*	1963	13	713	51.3	17	Outdoors
26	VII(l)	"	21	1162	50.8	16.4	"
27.8	VIII(l)	"	16	690	32.7	15.2	"
25.5	XI(m)**	"	9	550	35.2	18.4	"
22.5	IX(l)	1962	2	25	16		"
21.6	X(m)	1963	11	450	5.1		"
19.3	XII	"	4	99	1		"
19.8	XII	"	8	198	0		"

* l = late in the month
** m = in the middle of the month

3. Survival.

Many of the larvae die before reaching the pupal stage.

As we follow the percentage of survial under the various circumstances (Table 2), it is noted that under controlled conditions of temperature and in darkness, survival was much less (the highest rate being 28% at at 28°C), than when the larvae were reared under natural conditions outdoors (the highest being over 50% at 24-26°C).

The temperature range of 24-26°C seems to be the optimum for the larvae. As the season advanced, and the temperatures decreased, survival also decreased. The lowest survival occurred with diapausing larvae; the later in the winter larvae entered diapause, the greater was their mortality (see Table 2).

The Pupa.

1. Duration of development.

Pupa were also reared both under controlled temperature conditions and outdoors. As a rule, the development of the pupa throughout the summer, in the outdoor breedings, averaged 5-7 days. The data of the development period (Table 3) were employed for calculating the regression line as shown in Fig. 2. The line cutes the temperature line at 12.5°C, which is the theoretical threshold of development for the pupa. For complete development, 77 days degree were needed.

2. Survival.

About one third, and often more, of the pupae did not survive, but the dependence of survival upon temperature could not be proven.

Table 3. Development and Survival of Pupae of Chilo agamemnon.

Temp. (°C.)	Month (1963)	Number of Breedings	Number of Pupae	Percentage survival	Length of Development (Days)	Breeding site
22		14	80	61.5	8.4	Incubator
24		20	112	50	8.4	"
24		14	30	76	8	"
26		8	40	32.5	4.7	"
26		13	31	45	6	"
30		15	81	50.6	4.6	"
34		3	10	60	5.3	"
24.8	VI	29	297	72.3	5.8	Outdoors
25.5	VI	10	64	87.5	5.8	"
27	VII	18	245	71	5	"
28	VIII	30	199	66.8	4.9	"
25.3	IX	12	103	70	5.7	"
24	X	12	89	54	7	"

The Adult.

1. Fecundity.

Within one or two days after emergence of the adults, the moths copulate and begin laying eggs. Generally, moths reared in incubators laid fewer eggs than did those reared outdoors (Table 4).

Table 4. Egg laying and longevity of Chilo agamemnon moths at various temperatures.

Temp. (°C)	Period of emergence and laying	Number of females which laid eggs*	Eggs: Average number per female	Eggs: Range	Life Span: Days	Life Span: Range	Breeding site
20	13-23 IX 62	10(10)*	284	19-600	5.5	1-8	Incubator
22	27 X-11 XI 63	11(15)	58	3-328	4.4	1-6	"
24	17-21 IX 62	10(10)	215	3-422	3.0	2-4	"
24	17-12 XI 63	11(14)	78	3-171	4.5	3-6	"
26	20-25 IX 62	10(10)	208	30-540	3.0	1-4	"
26	9 XI-1 XII 63	6(8)	97	5-141	4.5	2-8	"
30	12 X-25 X 63	11(14)	110	6-257	3.0	2-5	"
34	21-27 IX 62	9(10)	261	10-664	3.0	2-5	"
24.5	22 V-1 VI 63	7(10)	388	126-781	4.0	2-7	Outdoors
26	2 VI-16 VI 63	8(10)	389	90-532	4.3	3-8	"
25.5	26 VI-2 VII 63	15(15)	530	381-742	3.7	3-6	"
27	23-28 VII 63	14(15)	238	8-582	3.3	1-5	"
28	18-23 VIII 63	11(15)	115	16-300	2.3	1-5	"
26	11-20 IX 63	8(10)	209	28-381	2.3	1-4	"
25.5	18-25 IX 63	9(10)	299	120-440	2.3	1-4	"
24.7	7-20 X 63	15(15)	223	67-341	3.8	2-5	"
15	13-23 XII 63	0(7)	0	0	5.0	3-10	"

* In parentheses - total number of females.

Table 5 shows that most of the laying moths in the incubators laid fewer than 200 eggs each, whereas two-thirds of the moths reared outdoors laid over 200 eggs each. 15% laid as many as 500-700 eggs each, and some even over 700. The female moths of the first generation in June all laid over 300 eggs each. The highest egg-laying numbers with moths reared in incubators were at 20-22 °C (Table 4).

Table 5. The Distribution of Moths with reference to number of Eggs laid at certain seasons and temperatures.

Number of Eggs	0	1-4	5-50	51-100	101-200	201-300	301-400	401-500	501-600	601-700	above 700	Total number of Moths
Month												
X	0	0	0	1	2	6	1					10
IX 1st half	1	0	1	1	4	1	2	5	0	0	0	15
IX 2nd half	2	0	2	1	3	2	4	0	0	0		14
VIII	4	0	2	2	5	2	0	0	0	0	0	13
VII	1	0	3	0	0	7	3	0		0	0	15
VI 1st half	0	0	0	0	0	0	4	1	6	2	2	15
VI 2nd half	2	0	0	1	1	2	1	2	1		1	11
V	3	0	0	0	2	2				1	1	
Incubator Temperature (°C)												
34	0	0	1	1	1	2	3	0	1			
30	2	1	2	4	3	2						
26	0	0	4	1	1	1	0	2	1			
24	0	1	0	2	1	3	2	1				
24	3	1	3	3	4							
22	4	1	8	0	1	0	1					
20	0	0	1	1	2	2	2	0	1	1		
10	0	0	3	2	2	2						

The highest egg laying with moths reared outdoors took place with the first generation individuals, namely those which emerged and laid in late June or early July. Next come the moths which had developed from hibernating larvae. Moths which emerged and laid in August (third generation), laid the least. Those of September (fourth generation), egg laying increased as the season advanced till October.

2. Lifespan.

Chilo agamemnon is a short-lived moth. Under the most favourable conditions, the adults did not live longer than 7 days. At 13-17 ^{o}C, non-laying females lived 10 days. As seen in Table 4, the average lifespan was 3-4 days, with no significant difference between the sexes.

3. Phenology and number of generations.

From infested maize stalks brought from the field and kept in cages outdoors, the first moths emerged on 7-9 May 1963; emergence of moths from these stalks continued until June 23.

At the temperatures prevailing in the coastal plain of Israel, and in accord with the data presented in Tables 1, 2 and 3, a generation of the insect (including the short preoviposition period) will develop within 32 days in May or October, 30 in June or September, 27 in July, and 25 in August. Thus, from May 7 to about the end of September, moths enter diapause and from the over-wintering sixth generation. Under natural conditions in this study, five generations were raised during the summer and autumn, the first commencing to oviposit at the end of June, the fourth early in October. The percentages of diapausing and non-diapausing moths in the varous plant samples collected in the fields are shown in Table 6.

Table 6

The number and ratio of diapausing larvae of Chilo agamemnon in samples of 100 stalks of maize collected during autumn 1962.

Date of collection	Total number of moths	Emergence			
		before winter		after winter	
		No.	month	No.	month
9.VIII 62	305	305	VIII-IX	0	-
28.VIII	45	45	IX	0	-
5.IX	284	238	IX-X	46	V-VI
31.X	104	2	XI	102	V-VI
11.XI	24	0	-	24	V-VI
18.XI	5	0	-	5	V-VI, in roots & crowns
26.XI	19			19	V-VI

Samples collected on August 28th all contained non-diapausing larvae, whereas samples collected eight days later - on September 5th - already had 16% diapausing larvae. The number of larvae in the 100 stalks decreased as the season advanced, and by November 18th, no larvae were found in the stalks except in the root crowns.

Discussion.

Although the insect is native to warm countries, it seemed susceptible to the temperatures prevailing during the warm months in Israel. This susceptibility is manifested in higher mortality and reduced egg laying. In connection with this latter factor, as pointed out by Rivnay and Meisner (1966), the breeding conditions influenced the subsequent egg laying of the adult. As seen in Table 4, moths emerging in early September laid less than the moths which emerged in the latter part of September, probably because they had been exposed in their larval stage to the high temperatures of August. The discrepancies in egg laying of moths reared at constant temperatures may also have been due to the difference in the breeding conditions. Moths kept at 24°C in 1962, and which were reared from larvae collected in the field, laid an average of 215 eggs, whereas in 1963 the moths were obtained from larvae reared in incubators, and they laid an average of 78 eggs (even though as adults they were kept at the same temperature as had been used in 1962). Similar results were seen with moths kept at 26°C. In 1962, an average of 208 eggs were laid by each female by moths reared from larvae collected in the field, and only 97 were laid in 1963 by moths reared in the incubators.

The temperature may influence the moths directly (Table 4). The reason for the differences in the fertility of the moths was not the season in which the generation developed, but rather the temperature which prevailed during their existence. The temperature during May-June was most favourable. However, during late May and early June, when the hibernated individuals emerged and laid, very hot and dry desert winds prevailed, which resulted in a lower fertility than that of the subsequent generation. From 22-30 May, there were three days whose respective maximum temperatures were 39.4°, 35° and 36°C; during the early part of June there were three days with maximum temperatures of 40°, 39.4° and 40°C; during the week June 26 to July 2, one day had a maximum temperature of 33°C, and the rest were 31°C or below.

In July the temperatures rose, and in August the highest average temperature was recorded and hence the lowest egg laying occurred during that month. The egg laying during the latter part of September was higher than during the earlier part of that month; the reason may be that the larvae and pupae of the early part of the month developed during the adverse temperature conditions which prevailed in August.

As the temperatures decrease, the moths cease to lay. No egg laying took place during late October - early November. In 1966, October and November were extraordinarily warm, and thus eggs were discovered as lat as November 19th.

References.

1. Bleszynski, S. 1962. Studies on the Crambidae (Lep.) (Pt.XXXVI) On some species of the genus Chilo Zincken. Act. Zool. Crac. VII (7): 119-123.

2. Bodenheimer, F.S. 1937. Prodromus Faunae Palestinae Mem. Inst. d'Egypte 33: 286 pp.

3. Bytinski-Salz, H. 1966. An annotated list of insects and mites introduced into Israel. Israel J. Ent. 1: 15-48.

4. Mesiner, J. and Grünberg, S. 1965. The maize borer Chilo agamemnon Blesz. and its control. Hassadeh 45(9): 1029-1031 (in Hebrew).

5. Rivnay, E. 1963. Present status of Lepidopterous pests of maize and other Graminaceous crops in Israel. F.A.O. Pl. Prot. Bull. 11(1): 1-3.

6. Rivnay, E. and Meisner, J. 1966. The effects of rearing conditions on the immature stages and adults of Spodoptera littoralis (Boisd.). Bull. ent. Res. 56(4): 623-634.

7. Willcocks, F.C. 1922. A survey of the more important economic insects and mites of Egypt. Sultanieh Agr. Soc. Bull. 1, 477 pp.