STUDIES
on the Life-History and the Control of Zeuzera pyrina L. in Palestine.

by **F. S. BODENHEIMER and H. Z. KLEIN.**

The Leopard Moth (Zeuzera pyrina L.- Parpar hanamer in Hebrew) may be regarded as one of the most serious enemies of olive and apple tree cultivation in Palestine. Since the method of control in use locally—the destruction of the larva by means of a wire — yielded only very unsatisfactory results, and the Carbon bisulphide formerly recommended in literature on the subject also proved impractical, new methods had to be sought. The results of three years' experiments are published in this essay.

I. DESCRIPTION OF ZEUZERA PYRINA L.

1) The Moth.

The female is about 30 mm long, with a wing-span of 50-70 mm. It has large white forewings covered with numerous, roundish steely-blue spots, whence its Hebrew and English names (Parpar hanamer, Leopard Moth). The back is covered with white hairs, and bears three pairs of steely-blue spots, while the approximately spindle-shaped abdomen is blackish-grey with white hairs bordering the segments. During rest, the wings are folded lengthwise over the body in the manner of moths.

The male is much smaller than the female, but in other respects it is very similar. Its wing-span is only about 35 mm.

The abdomen is almost cylindrical and terminates bluntly. The antenna are much feathered.

2) The Eggs.

The eggs are oval-oblong in shape, reddish-yellow to brownish-red in colour. They are deposited singly or a few at a time. A female lays on an average 100—300 eggs, although Howard and Chittenden counted up to 800 from one female.

3) The Larva.

Prevailing colour whitish to deep yellow. Head, back, the first thoracic and last abdominal segments as well as the points of insertion of the hairs and portions of the thoracic appendages are dark brown to black. The spots around the insertion of the hairs (10—18 per segment) are particularly characteristic and easily recognised. The full-grown larva is about 50—55 mm. long and 8 mm. broad.

4) The Pupa.

Cylindrical, dark brownish-yellow, but somewhat darker at the extremities. It is about 35 mm. long and 6—8 mm. broad.

II. DISTRIBUTION.

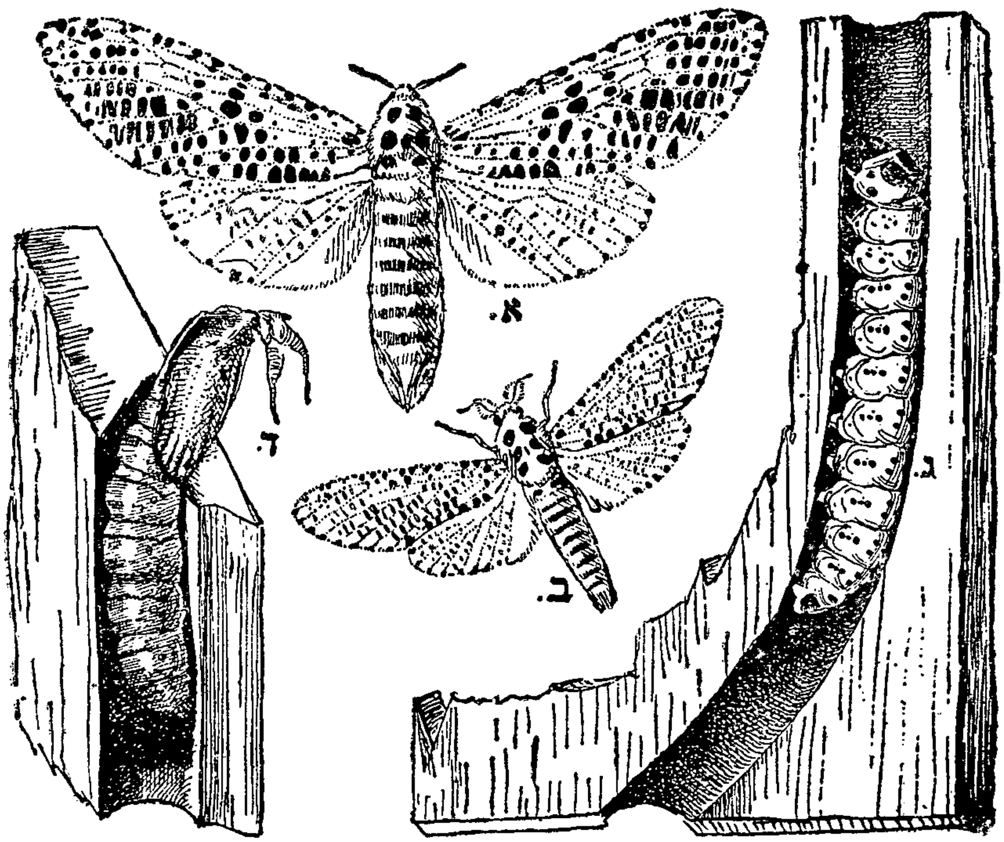
Europe, North Africa, Near East, Northern Asia, Northern America (introduced about 50 years ago).

III. HOST PLANTS.

The pest is familiar on all kinds of fruit, nut and ornamental trees, and even on vines. Altogether nearly 150 different kinds of trees are known up to date on which its larva is found. It appears to prefer hard woods.

In Palestine it has been met with till now on olive, apple, pear and plum trees, as well as on Platanus, although it certainly occurs on several other trees.

Fig. I.



Zeuzera Pyrina L. (from Howard and Chittenden) enlarged.
א. female; ב. male; ג. caterpillar; ד. pupa.

IV. LIFE HISTORY IN PALESTINE.

The moths' main period of flight is from the beginning of August to the end of October. Single specimens are found however soon after June or even earlier. On one occasion, it was observed that hatching took place at the beginning of December in Jerusalem (1924 Obs. Czizick). The eggs are deposited on the bark of the tree the majority during the main flight-period. The ovipositing females are very sluggish, and lay their eggs as far as possible on adjacent trees.

The moths remain quietly on the bark during the day time with outstretched wings. Flight and oviposition take place at night.

After about 10 days, the young larva emerges from the egg. It eats its way under the bark and feeds there in the immediate vicinity i.e. eats up a certain broad area of cambium near the surface. After 1—2 months, it begins to bore a passage into the wood. From this moment its existence can easily be recognised by its typical red to yellowish-brown mounds of excrement.

Before pupating the larva turns back, and so pupates near the opening of the passage. Here it remains for 2—3 weeks. With a few thrusting movements of the abdomen, the head and thorax succeed in completely getting out of the opening, the skin of the pupa bursts at the neck, and the moth works its way out. The empty pupal cases remain stuck in the opening and may be found in large numbers in autumn on attacked trees.

In contrast with Europe and North America, Zeuzera pyrina in Palestine develops completely in one year. This is due in part to its greater feeding activity in warmer climates, but may be due more particularly to the fact that the feeding period of the moth is not interrupted by hibernation. From December to February, heavy excretion of frass can be observed, especially easily on young apple or pear trees. As a result of these favourable climatic conditions, hatching and flight periods are greatly extended.

V. INVESTIGATION OF THE FEEDING-PASSAGES OF ZEUZERA PYRINA.

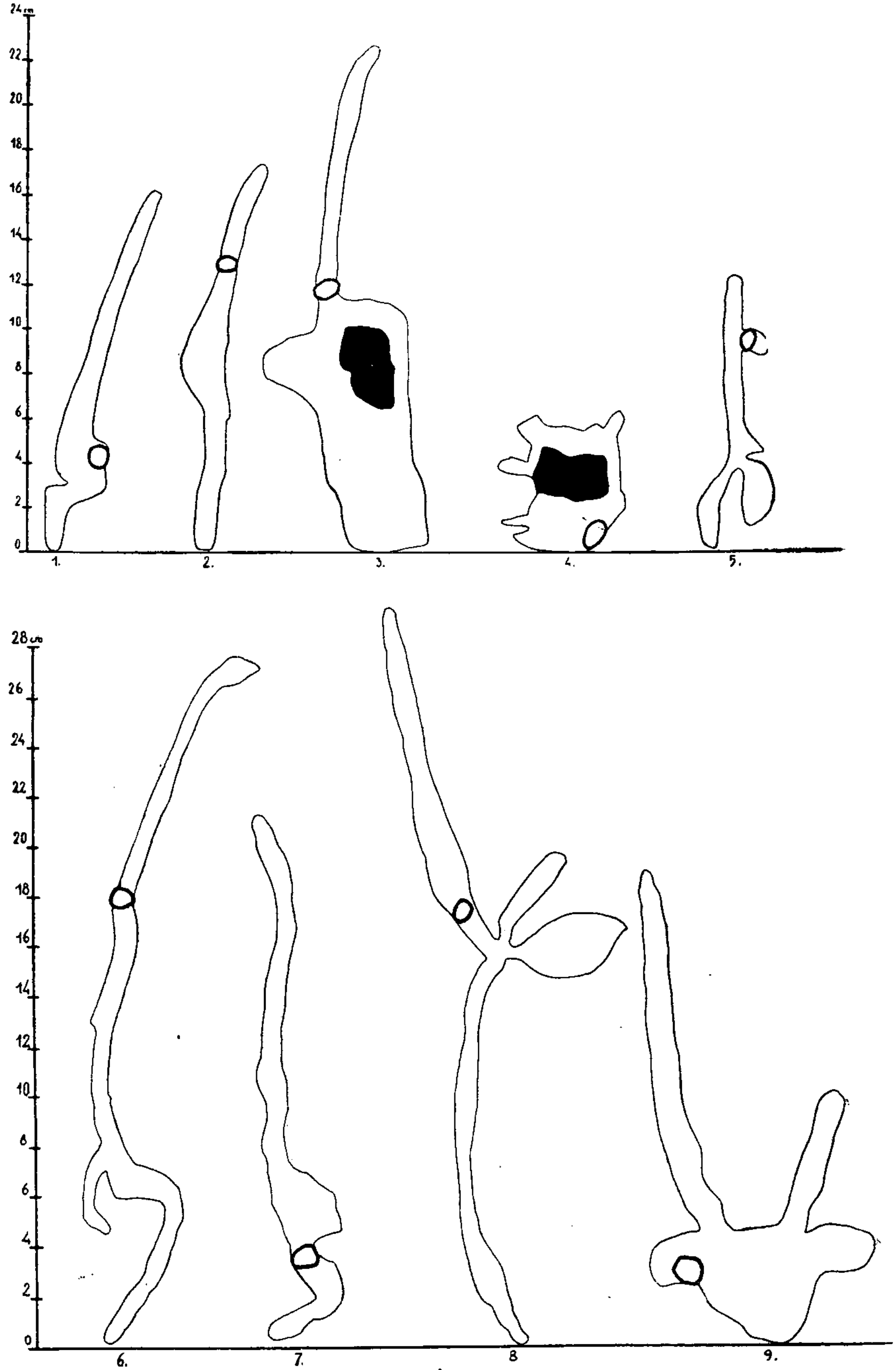
The bore-holes are distributed over the whole tree trunk. The following results refer to the olive tree only. The vertical distribution of the boreholes is given in Table I.

Table I.
Height of Bore-holes of Zeuzera pyrina about ground level. in c. m.

HEIGHT.	NUMBER OF HOLES.	HEIGHT.	No. OF HOLES.
0—9	13	150—159	21
10—19	58	160—169	12
20—29	44	170—179	9
30—39	16	180—189	11
40—49	16	190—199	10
50—59	24	200—209	3
60—69	16	210—219	3
70—79	16	220—229	2
80—89	18	230—239	2
90—99	31	240—249	1
100—109	19	250—259	1
110—119	28	260—269	—
120—129	22	270—279	1
130—139	26	280—289	—
140—149	18	290—299	1

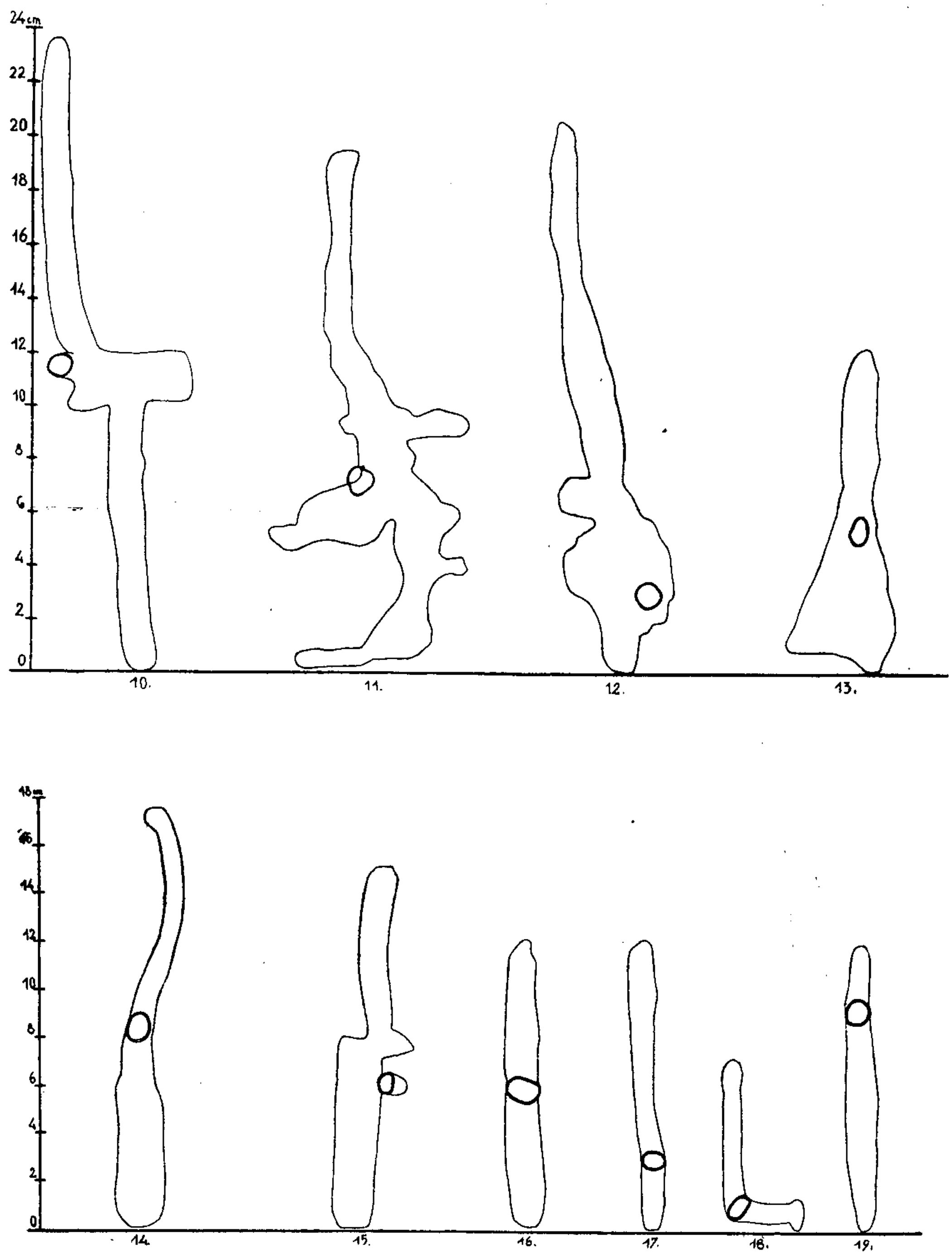
To give a better summary, the results have been grouped in Table 2.

Fig. II.



9 galleries of Zeuzera pyrina L. in Olive Trees; Ben Shemen 1926.
O Entrance hole, ● Not eaten wood.

Fig. III.



10 galleries of Zeuzera pyrina L. in Olive Trees; Ben Shemen 1926.
O Entrance hole.

Table 2.

HEIGHT OF TREE in cm.	No. OF HOLES	PERCENTAGE
0—49	147	34.8
50—99	95	22.5
100—149	103	24.5
150—199	63	14.9
200—249	11	2.7
250—259	3	0.7

The results therefore show that Zeuzera pyrina attacks olive trees from the ground level up to a height of 3 metres. The lowest half metre with 35% of the total number of boreholes was clearly preferred; the next two portions from ½ to 1½ m. show about 23%. Then further up, the attack decreases rapidly till from 2 to 3 metres in height only 3½% of the number of boreholes are present. The following table shows the distribution of the bore-holes on the trunk and branches.

Table 3.

Distribution of the Bore-holes of Zeuzera pyrina on the Trunk and Branches.

LOCALITY	On Branches	On Trunk	% on Branches	% on Trunk
Gan-Shemuel I.	111	64	63.4	36.6
,, ,, II.	57	37	60.6	39.4
Ben-Shemen I.	33	31	51.6	48.4
,, ,, II.	65	43	60.7	39.3
Total	266	175	60.3	39.7

The structure and course of the passages are extremely variable. On young apple and pear twigs they are naturally compelled to run vertically, and, as far as could be observed, always upwards. Their length amounted to 20 cm., and often also 30—35 cm. In olive trees, it is quite otherwise. The sketches 1—19 give sufficient idea of the variability met with in the olive.

EXPLANATION OF THE SKETCHES OF THE FEEDING PASSAGES.

The small circle in each picture denotes the bore hole.

No. 1. The hole is 19 cm. above ground. The tunnel above it goes deeply into the tree (to over 3 cm.) otherwise it lies from 0,5 to 1 cm. beneath the surface of the trunk. At the hole the feeding place is 1 cm. in depth, but otherwise the diameter of the tunnel is from 7—9 cm. (measured deep inside).

No. 2. Hole 15 cm. above ground. Feeding place 2×2×1 cm. passage 1×1 cm. The upper part up to 2 cm. beneath the surface of the trunk, otherwise 1 cm.

No. 3. Hole 28 cm. above ground. The black spot is uneaten wood. The upper part over 2 cm. beneath the surface, otherwise 0,8—1 cm.

No. 4. Hole 17 cm. above ground. The black spot is uneaten wood. 0.6 cm. below the surface.

No. 5. Hole 6 cm. above ground. Passage 0.6—0.8 cm. in depth, 1—1.5 cm. beneath the tree-surface.

No. 6. Hole 6 cm. above ground. Passage 1.5 cm in depth; upper part goes deep into the wood, lower part 1—2 cm. beneath the surface.

No. 7. Hole 5 cm. above ground. Feeding-place at the holes. 7 cm. Tunnel 0.6—1.2 in depth. Upper part 2 cm. otherwise 0.5—1 cm. beneaththe surface.

No. 8. Hole 10 cm. above ground.
No. 9. „ 60 cm. „ „
No. 10. „ 16 cm. „ „
No. 11. „ 23 cm. „ „
No. 12. „ 33 cm. „ „
No. 13. „ 27 cm. „ „ 0.5—1 cm. below surface.
No. 14. „ 16 cm. „ „ Feeding-place 1.8 cm. Passage up to 1 cm. in depth. upper part of passage up to 4 cm. elsewhere 0.6—1 cm. beneath the surface.
No. 15. Hole 30 cm. above ground. Feeding-place 1.2 cm. passage 1 cm. in depth. Passage up to over 2 cm. in upper part, but otherwise 1—1.2 cm. beneath the surface.
No. 16. Hole 10 cm. above ground. Passage 1.2—1.5 cm. in depth, 0,6—1 cm. beneath the tree surface.
No. 17. Hole 31 cm. above ground. Passage 1 cm. in depth, upper part up to 1.5 cm., otherwise 0.6—0.8 cm. beneath tree-surface.
No. 18. Hole 37 cm. above ground. Passage 0.5 cm. in depth. Upwards it extends very deep into the tree (over 4 cm.), otherwise 1 cm. beneath the surface.
No. 19. Hole 9 cm. above ground. Passage 0.8—1 cm. deep. Above ground, 0.5—0.8 cm., below ground 1—1.2 cm. beneath the surface of the tree.

The length and breath measurements are given after the illustration.

Table 4 clearly illustrates the fact that in older trees, the direction of the passage is by no means invariably upwards. Part of the passages — on an average about 40% — always occurs below the entrance hole. The proportion between the numbers of larva which during control were found head upwards and those head downwards (44:33=1.30) corresponds fairly closely with that between the total length of the passages

Table 4.

Measurements of Lenght and Direction of Passages.

No.	LENGTH OF PASSAGE FROM THE HOLE: Upper portion in cm.	Lower portion in cm.	TOTAL LENGTH in cm.	
1	12	4	16	
2	5	13	18	
3	11	12	23	**Total length:**
4	5	2	7	
5	3	10	13	maximum 31 cm.
6	11	18	29	minimum 7 cm.
7	19	4	23	Average 16.0 cm.
8	13	18	31	
9	15	4	19	
10	11	12	23	
11	12	7	19	**Length of Passage above entrance hole.**
12	16	4	20	
13	7	6	13	
14	9	8	17	maximum 19 cm.
15	9	6	15	minimum 3 cm.
16	7	6	13	Average 9.1 cm.
17	9	4	13	
18	6	2	8	
19	3	10	13	**Length of Passage below entrance hole.**
20	9	7	16	
21	12.5	3	15.5	
22	10.5	5.5	16	maximum 18 cm.
23	9	7	16	minimum 2 cm.
24	3.5	5	8.5	Average 6.9 cm.
25	5.5	3	8.5	
26	5	2	7	
27	6	2.5	9	
28	13	11	24	
29	7	4	11	

above and below the boreholes (9.1:6.9=1.32). The passages for the most part, extend 1—2 cm. beneath the bark; in about 1/3 of the cases the feeding passage went deeper into the tree, up to over 4 cm. beneath the surface. The passages are tortuous in parts which greatly hinders control by the wire method. Especially striking is the widespread occurrence of large feeding places even in older stages, which until now has never been recorded in the case of Zeuzera pyrina. Roughly one half of the passages investigated showed them more or less pronounced.

The regularity of the feeding-passages in young apple twigs allow the total quantity of food to be measured. The results based on the formula $r^2 \pi h$ are:—

Table 5.

Length of Passage	Diameter of feeding Passage		
	8 mm.	10 mm.	
20 cm.	10.06 ccm.	15.09 ccm.	Quantity of food
30 cm.	15.70 ccm.	23.55 ccm.	

The normal amount of food fluctuates between 10 and 25 ccm. Calculations with the olive tree based on the same formula, give similar or some what higher values. The volume of the full-grown larva amounted to about 0.4 ccm. The larva eats 35 to 65 times its final volume of cambium. In those passages which extend into the deeper layers of the wood (c. f. sketches No. 6 and 8), their greater length can be traced to the smaller feeding value of those layers.

During the whole larval period the Zeuzera passages are quite clean. By active pushing movements, the excrement is regularly ejected and collects in typical heaps outside.

VI. THE NATURE OF THE DAMAGE.

The most serious harm caused by Zeuzera pyrina springs from the fact that it has so far prevented the successful introduction of foreign varieties of olive trees, and in many cases the success of apple and pear culture. Thus, for example, in large olive plantations in Rehoboth, all the French and Italian varieties have died out, while the Arab varieties are in good condition. Local varieties were grafted on the roots of the dead foreign trees. Fifteen years ago, a Rehoboth settler attempted to introduce apple and pear trees in his garden. All the trees died in the first years as a result of the attacks of Zeuzera pyrina.

VII. NUMBER OF BOREHOLES.

On young apple and pear trees, the attack of one caterpillar is sufficient to cause the death of the whole branch. A few statistical results for olive trees are given in the following table. Out of a total of 224 trees attacked there were 1508 holes i.e. 6.7 holes per tree.

The distribution of the holes on individual trees is shown in Table 6.

These numbers give an approximate idea, when we observe in addition that about 50% of the trees on an average were not attacked. In one garden in Gan Shmuel for example which was moderately attacked, 51% of the trees did not suffer injury; the average number of holes per tree was 3.1 for all the trees and 6.4 for the attacked trees. In another place in Gan Shmuel, more seriously attacked, the holes averaged 13.4 per affected trees, while in a moderately attacked place in Ben Shemen the average number was 8.2.

VIII. THE COURSE OF THE ATTACK.

In olive gardens which have been attacked for many years, the course of the attack can be followed clearly. On account

Table 6.
Number of Boreholes per tree.

No. of Holes	No. of Trees	No. of Holes	No. of Trees	No. of Holes	No. of Trees
1	62	12	4	25	1
2	36	13	1	27	1
3	26	14	3	29	6
4	16	15	5	31	1
5	13	16	3	37	1
6	10	17	—	44	1
7	13	18	3	48	1
8	4	19	2	50	1
9	2	20	1	51	1
10	3	21	1	54	1
11	4	23	1		

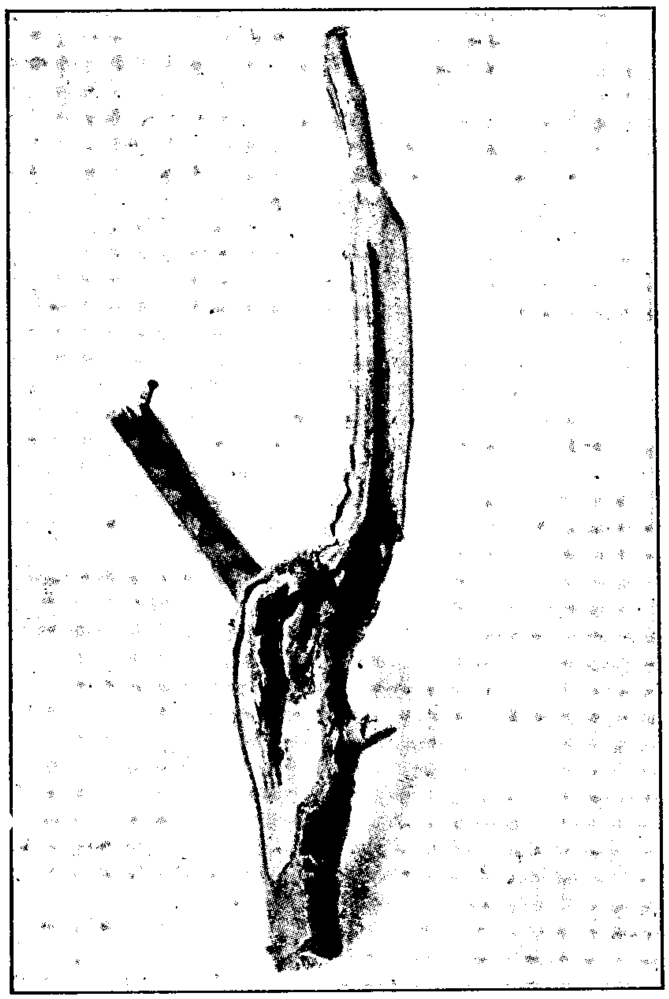
Total 1508 holes on 224 trees = 6.7 holes per tree.

of the sluggish flight of the females the spread of the attack is extremely slow. In Table 6, the number of boreholes per tree in an olive garden in Gan Shmuel are shown. The primary centre of infection can be easily recognised. A few years later, secondary centres formed on all sides. With the death of the badly-attacked half of the garden, the infection passes slowly over into the uninjured portion.

IX. STRENGTH OF ATTACK IN DIFFERENT VARIETIES, AND SELF-PROTECTION THE TREE.

We have already mentioned the difference in the severity of the attack on local and on foreign varieties of olive trees. For example, in Gan Shmuel, on 15 trees of a local variety there were 6 bore-holes (including 1 new one) and on 15 French olive trees there were 90 bore-holes (including 13 new ones). In Ben Shemen on 20 olive trees of local varieties there were 45 bore-holes, and on a like number of trees of foreign varieties 413 holes were counted. The average numbers of bore-holes therefore amounted here to 2.25 in the local varieties, and 20.65 in the foreign varieties.

Fig. IV.



Boring Hole of Zeuzera pyrina L. in Platanus.

The same distinct difference between the severity of the attack and the mortality of local and of foreign varieties of olives is apparent everywhere. Occasionally a radical resistance to the Zeuzera larva takes place in the trees. During the spring of Summer of 1925, the phenomenon of „gumming" appeared over the whole country. Drops of gum as large as peas or hazel nuts exuded from the tree. When they were opened a Zeuzera pyrina tunnel about 5 cm. long was seen inside. The larva were in part inbedded in the gum and suffocated, and in part expelled by the exuding gum and when outside, perished through adverse climatic conditions. Owing to some unknown cause, olive trees were particularly sappy this year. It may perhaps be noted here, that altogether insufficient attention has been paid until now to the connection between the physiological behaviour and condition of the tree in relation to the number of its insects. In Palestine, neglected orange trees immediately become covered with scale insects which disappear with renewed care and attention. Similar effects can be observed in other trees. The extremely severe attacks of Capnodis carbonaria in almond plantations may in great part be traced to the low sap content of this tree in summer. Investigations are planned on these lines with the co-operation of the Division of Plant Physiology.

As a result of the exudation of gum, the larval death-rate according to our estimates amounted to 50—70% in 1925, and about 20% in 1926. However, such a form of self-protection on the part of the tree does not appear every year, nor is the sluggish flight of the female sufficient explanation of the relatively slow spread of Zeuzera pyrina. No parasites of this pest have been observed in Palestine. Predatory animals, especially birds, assist to a certain extent in the extermination of the moth, the woodpecker occasionally perhaps in the caterpillar stage, but the greatest mortality occurs among the eggs, exposed to the inclemency of the weather, changes in the humidity of the atmosphere and to the action of the direct rays of the sun. We have been able to prove briefly this mortality during the egg stage in another insect, Chaerocampa celerio.

The olive trees withstands damage by Zeuzera pyrina for a much longer period than do young apple or pear trees. Twigs of 5 cm. in diameter die only from 7 or more holes. The danger of attacks of Zeuzera lies in their cumulative injury, year after year. When sure and convenient methods of control have been devised in the present work, this pest can be weakened at the outset. In Palestine the damage done to the technical value of the wood is only of secondary importance.

The more seriously damaged branches are occasionally broken by the wind.

The attack of Phloeotribus oleae F. on olive trees may be considered secondary. The three trees in Table 5 which were attacked by Phloeotribus, show 29.13, and 48 holes respectively of Zeuzera pyrina.

X. DIAGNOSIS.

The first diagnosis is established by the typical heaps of excrement in spring and summer, and by the empty pupal cases of the moth on the flight-holes. A caterpillar or a moth is necessary to confirm the diagnosis. (see Fig. V, p. 78).

XI. CONTROL.

The most important requirement for successful control is repeated systematic inspection from February to June, of all trees on which an attack is anticipated. In order to arrest the early damage, control measures must be put into operation immediately.

Table 7.

Course of Attack in an Olive Plantation in Gan Shmuel.

Row. No.	TREE No. 1	2	3	4	5	6	7	8	9	10	11	12
1	2	—	1	—	4	1	1	29	—	2	1	
2	—	—		2	5			8	18	18	29	
3	3	—	7	4	3	5	12	5	10	4	21	1
4	2	6	16	—	19	1	6	37	12	2	3	
5	4	19	6	8	5	3	3	29	7	1		
6	1	7	4	—	1	12		4	1	5	3	7
7			—	9		12	—	6	14		2	
8				5	6	1	—	7	8		1	
9		1	54					2	3		29	1
10		—		2					2	1	13	—
11		1	—			—	1		2	1	1	—
12		1				—	2					—
13	—	—									—	1
14		4		—	1				2		3	—
15	1	1			—	—		2			1	
16	—				5	1	1			1		—
17	—				1							
18					—	1						—
19										—		
20				1	1	—						
21	—							—	—	—	—	
22		—	—									
23		—										
24												

— denotes where a tree is missing.

Fig. V.

The typical excrements
of Zeuzera pyrina L.

Four years ago we recommended the use of a pointed wire passed into the feeding-holes as a means of destroying the larva. This simple method appeared the most suitable for the small plantations and was adopted in practice nearly everywhere. We recommended filling the passage immediately afterwards with some powdered Naphthalin, or a teaspoonful of either Benzine or a 5% solution of creosote solution (by means of a small syringe) and plugging the hole with wax or clay to prevent rotting later. If the larva is removed by means of the wire, great care must be taken that it really dead, for otherwise a full-grown larva can pupate and the emerging moth will lay new eggs on the tree. Our experience shows that this frequently occurs, and conduces not a little to the failure of this control method.

The use of the wire, however, possesses such great disadvantages, that other methods of control had to be sought. The length of time necessary is the greatest disadvantage. At most, 20 trees a day i. e. 1000 trees (= 3000 boreholes) in about 55 days can be despatched. On account of the irregular structure of the boreholes, which is not known at the time, the work is often very wearisome, and notwithstanding, does not always succeed in its aim.

Since 1924 control experiments with paradichlorbenzene were carried out, and also in 1926 a series with calcium cyanide. For the sake of brevity the record of our control in 1926 only is given.

a) Treatment: Paradichlorbenzene; 0.15—0.25 g. per hole.
Inspection: after 2 days (Ben Shemen, July).

1) dead (old dried larva).
2) dead (about 4 cm.) Larva above entrance hole.

b) Treatment: Paradichlorbenzene; 0.15 - 0.25 g. per hole.
Inspection: after 9 days. (Ben Shemen, June).

3) dead. Larva below hole, head upwards.
4) ,, ,, above ,, position of head not established.
5) ,, ,, below ,, head upwards, quite fresh.
6) ,, ,, ,, ,, ,, ,, larva small.
7) ,, ,, ,, ,, ,, ,, ,, ,,

c) Treatment: Paradichlorbenzene; 0.15—0.25 g. per hole.
Inspection: after 20 days; (Ben Shemen, July).

8) dead (3 cm.). Larva above hole, head upwards.
9) ,, (2.5 cm.). ,, below ,, ,, downwards.
10) ,, (3.5 cm.). ,, at the hole in lower part, head downwards.
11) ,, (4 cm.). ,, ,, ,, ,, ,, upper ,, ,, ,,
12) ,, (3 cm.). ,, above hole, head upwards.
13) ,, (3.5 cm.). ,, ,, ,, ,, ,,

d) Treatment: Paradichlorbenzene: 0.4—0.7 g. per hole.
Inspection: after 24 hours. (Gan Shmuel, July).

14) alive (3 cm.). but weak. Larva below hole, head downwards.
15) „ (3 cm.). strong. „ „ „ „ „
16) dead (2 cm.). dried. „ „ „ „ „
17) alive (3 cm.). „ above „ „ „
18) alive (3 cm.). very weak. „ „ „ „ „
19) alive (3 cm.). „ „ at hole, head upwards.

e) Treatment: Paradichlorbenzene 0.4—0.7 g. per hole.

Inspection: after 32 hours. (Gan Shmuel, July).

20) alive (3.5 cm.). Larva above hole, head upwards.
21) „ (4 cm.). weak. Larva above hole, „ „
22) dead (3.5 cm.). „ „ „ „ downwards.
23) alive (3,5 cm.). strong. „ „ „ „ upwards.
24) alive (3 cm.). very weak. Larva at hole in lower part, head upwards.
25) „ (4 cm.). „ „ „ in lower part of hole, „

f) Treatment: Paradichlorbenzene: 0.4—0.7 g. per hole.

Inspection: after 40 hours (Gan Shmuel, July).

26) alive (3.5 cm.). very weak. Larva above hole, head downwards
27) „ (3 cm.) „ „ „ „ „ „ upwards.
28) „ (3 cm.). „ „ „ below hole, (side-passage) head upwards.
29) „ (3.5 cm.). „ „ „ „ „ head upwards.
30) „ (3.5 cm.). „ „ „ above „ „ downwards.
31) „ (3 cm.). „ „ „ below „ „ „
32) dead (3 cm.). Larva in upper part of a side passage, below hole, head upwards.
33) alive (5 cm.). strong. Larva below hole, very far from the hole, sideways, head upwards.

g) Treatment: Calcium cyanide; 0.05—0.10 g. per hole.

Inspection: after 2 days. (Ben Shemen, July).

34) dead (3.5 cm.) Larva above hole, head upwards.
35) „ (3 cm.). „ below „ „ downwards.
36) alive (3 cm.). „ above at end of the passage, head upwards.
37) dead (3 cm.). „ „ hole, head upwards.

h) Treatment: Calcium cyanide; 0.05—0.10 g. per hole.
Inspection: after 17 days (Ben Shemen, June).

38) dead. Larva above hole, head upwards.
39) „ „ „ „ „ downwards
40) over 4 cm. long. Larva above hole, head downwards, dead (but apparently killed during the opening of the passage).
41) dead. Larva below hole, head upwards.
42) „ Small larva (1.5 cm.). rather dry, above hole in a side-passage.
43) dead. Larva at the hole, in upper part, head downwards.

i) Treatment: Calcium cyanide; 0.2—0.4 g. per hole.
Inspection: after 24 hours. (Gan Shmuel, July).

44) dead. (5 cm.). Larva below hole, head downwards.
45) „ (3.5 cm.). „ „ „ „ „
46) „ (4 cm.). „ „ „ „ upwards.
47) „ (5 cm.). Larva at hole in upper part head upwards.
48) „ (3 cm.). „ above hole, head downwards.
49) alive (3.5 cm.). Larva above hole, head downwards. Upper part of passage apparently stopped up.
50) dead (4 cm.). Larva below hole, head downwards.
51) „ (4 cm.). „ „ „ „ upwards.
52) alive (3.5 cm.). weak. Larva very far up above hole, head downwards. Calcium cyanide had fallen down.

k) Treatment: Calcium cyanide; 0.2—0.4 g. per hole.
Inspection: after 30 hours. (Gan Shmuel, July).

53) dead (4.5 cm.). Larva at hole, in upper part, head downwards.

54) alive (3 cm.). Larva above hole, head upwards. Calcium cyanide dropped down.
55) dead (3 cm.). Larva above hole lying horizontally in a side passage.
56) ,, (4 cm.). ,, at hole in upper part, head upwards.
57) ,, (4 cm.). ,, at the hole in upper part, head upwards.
58) ,, (4 cm). ,, below hole, head upwards.
59) ,, (3 cm.). ,, above ,, ,, downwards.
60) ,, (2 cm.). ,, ,, ,, ,, upwards.
61) ,, (2 cm.). ,, ,, ,, ,, downwards.
62) ,, (4.5 cm.). ,, sideways in hole (feeding-chamber), head downwards.
63) ,, (4 cm.). ,, at the hole in upper part head ,,
64) ,, (4 cm.). ,, near the ,, ,, ,, ,, ,, upwards.
65) ,, (3.5 cm.) Larva above hole, head downwards.
66) ,, (4 cm.). ,, ,, ,, ,, ,,
67) ,, (3 cm.). ,, ,, ,, ,, upwards.
68) ,, (4.5 cm.). ,, below ,, ,, ,,

l) Treatment: Plugging with grafting wax.

Inspection: after 40 hours. (Gan Shmuel, July).

69) dead (5.5 cm.). quite fresh. Larva below hole, head upwards. Tunnel in upper part only about 1 cm. long.
70) alive (3 cm.). strong. Larva above hole, head upwards.
71) alive (3.5 cm.). Larva above hole, head upwards.
72) ,, (4.5 cm.). strong. Larva above hole, head downwards.
73) alive (4 cm.). ,, ,, ,, ,, ,,
74) ,, (3 cm.). strong. ,, at the hole (feeding chamber).
75) ,, (4 cm.). Larva above hole.
76) ,, (3.5 cm.). ,, ,, ,,
77) ,, (4.5 cm.). ,, ,, ,,
78) ,, (4.5 cm.). ,, ,, ,, head downwards.

79) alive (3 cm.). Larva below hole, head upwards. Upper part of passage only 1.5 cm. long.

m) Treatment: Plugging with grafting wax.
Inspection: after 20 days. (Ben Shemen, July).

80) alive (3 cm.). strong. Larva above hole, head upwards.
81) dead (3.5 cm.). ,, below ,, ,, ,,
82) dead, completely dried, rotted larva (2.5 cm.). above hole.
83) alive (3 cm.). Larva in the hole in upper part, head downwards
84) dead (3.5 cm.). ,, ,, ,, ,, ,, lower ,, ,, upwards.
85) alive (3 cm.). strong. Larva above hole, head downwards.
86) dead (4 cm.). hole open ,, below ,, ,, upwards.
87) alive (2.5 cm.). strong. Hole opened. Passage quite short in upper part. Larva below hole, head downwards.
88) dead (2.5 cm.). Passage only about 1 cm. in lower part. Larva above hole, head upwards.
89) alive (2 cm.). Tunnel downwards only. Larva above hole, head downwards.

The effect of each individual remedy is compared in Table 8.

Out of 141 controlled holes, only 89 contained caterpillars; the remaining 52 were empty. In view of the fact that opening the holes involves some danger for the tree even with subsequent stopping up with grafting wax, experiments over a longer period must be considered.

By using paradichlorbenzene, the larva were destroyed with certainty within a few days. Even after 24 hours, the majority of the insects were weak or very weak and the number of weak ones increases relatively rapidly with a longer duration of action, so that with this method of control, death may be depended on to set in after two or three days. The larvae labelled „weak", do not pass out any more excrement, so that at the time stated, no feeding takes place. Those still living

Table 8.

REMEDY	Quantity in g.	PLACE	Inspection after	Dead	ALIVE	Died from doubtful causes
Paradichlor. benzene	0.15—0.25	Ben Shemen	2 days	1	—	1 dried up
			9 „	5	—	—
			20 „	6	—	—
	0.4—0.7	Gan Shmuel	24 hours	—	5 (3 weak)	1 dried up
			32 „	1	5 (4 weak)	—
			40 „	1	7 (6 weak)	—
Calcium cyanide	0.05—0.1	Ben Shemen	2 days	3	1	—
			17 „	5	—	1
	0.2—0.4	Gan Shmuel	24 hours	7	2 (1 weak)	—
			30 „	15	1	—
Plugging with grafting wax		Gan Shmuel	40 „	1	10	—
		Ben Shemen	20 „	5	5	—

insects not marked „weak" still pass out excrement. Those insects still alive and vigourous, are always found farthest away from the hole, and therefore still feeding. The two shrivelled larvae were undoubtedly killed ea lier through unknown factors.

The maximum effect of calcium cyanide sets in after 24 hours. In cases where living larvae were found, it was always possible to establish in control, either that the upper part of the passage in which the larva was found, was stopped up with grafting wax, or that the calcium cyanide on account of its powdery nature, had fallen down, the larva remaining at the top of the passage. In one case here even, the larva was weak, so that from this it can only be supposed that the effects of this remedy are more lasting. In order to increase the usefulness of calcium cyanide as a means for the control of Zeuzera, it should be used in a firmer consistency, so that it does not fall into powder when put into the passage. Perhaps it would be possible to scattcr it into both the passages conce ned.

Where simply plugging with grafting-wax had been carried out, it cannot be stated for certain that those larvae marked ;,,dead" had died as a result of this measure. It is striking that even after being sealed for 20 days, the insects continued still to pass out excreta, that is to feed, and here it is a case of specimens in the early stages (2—3 cm), while just the larger ones (2.5—4 cm.), are found dead.

Several substances have been used to seal up the holes:

1) Soil (moistened)
2) Dr. Jewnin's grafting wax 1924 dry.
3) ,, ,, ,, ,, 1924 moist.
4) ,, ,, ,, ,, 1925
5) Grafting wax obtained from the Pflanzenschutzgesellschaft, Austria.
6) Mastic L'homme Lefort No. 3, obtained from Herz, Haifa.

As summer is the time for control, Nos. 1 and 2 proved quite inadequate, becoming dry in a short time and falling out. No. 3, also, was unsatisfactory. No. 6 readily becomes fluid and runs backwards, so that in several cases the holes are reopened. Nos. 4 and 5 turned out well and fulfilled all their claims.

We are also able to report on the epidemiological effect in a case of systematic control of Zeuzera attack during the following years. The attack is illustrated in Table 3, in an olive plantation in Gan Shmuel, which was completely controlled in April 1924. 111 trees out of 229 were attacked with 719 holes. The report for 1925 runs:

6

May 1925.

Plantation 1 : 82 new holes. Much exudation of gum.
,, 2 : 12 ,, ,, . Fairly large gum exudation.
,, 3 : 3 ,, ,, . Almost no gum exudation at all.

(Plantation 3 is the one which was completely controlled in the previous year).

September 1925.

Plantation 1 : 77 new holes.
,, 2 : 14 ,, ,,
,, 3 : 2 ,, ,,

July 1926. Report: In Plantation 3, controlled in 1924 no new holes were found.

In Garden No. 3 (229 trees) which was controlled in April 1924 there were found:

IV. 1924 719 holes, of which 51 had living caterpillars.
V. 1925 3 new holes.
IX. 1925 2 ,, ,,
VII. 1926 0 ,, ,,

There can be no doubt therefore of the practical importance of both the remedies Paradichlorbenzene and Calcium cyanide.

XII. ESTIMATION OF COSTS.

Table 9 shows the use of material and time for 1000 trees (=3000 holes).

The advantage of control by means of Paradichlorbenzene or by Calcium Cyanide compared with the use of the wire method is demonstrated quite clearly in this table. The cost of both chemical substances is very low.

Control by Sulphur (Carbon bisulphide) will only be touched on briefly here. It has been found by observation that this remedy is expensive on account of its high cost of transport on the ground of precaution against explosion risks; moreover extra cans and injection apparatus are necessary for control purposes which render the use of this remedy still more costly. Also this substance requires special attention and precautionary measures, which render the work more difficult.

Table 9.

Estimation of Material and Time for the Various Methods of Control.

Method of Control	AMOUNT USED:			Time taken in hours.
	Paradichlor-benzene in g.	Calcium Cyanide in g.	Grafting wax in g.	
Paradichlorbenzene	900		4500	160
Calcium Cyanide		450	4500	200
Sealing with Grafting wax			4500	150
Wire method				450

XII. METHOD OF CONTROL.

If the presence of the larva is recognised from the known signs (fresh larval excrement), the holes are slightly opened with an iron wire, and Paradichlorbenzene or Calcium cyanide is pushed into the passage. As far as is possible a little of these remedies must be placed in both the upper and lower portions of the hole. Then the hole with the surrounding area is sealed, without however stopping up the passage within. 0.1—0.2 gm. Calcium cyanide and 0.2—0.4 gm. Paradichlorbenzene is used for each hole. For sealing purposes, only solid non-melting tree wax should be used. In searching for holes attention must be paid also to the branches and twigs.

Summary.

1. Zeuzera pyrina causes great damage in Palestine, especially to olive and apple trees. It served as a reason for the failure of imported olive varieties.

2. Owing to the favourable conditions of the country it concludes its period of development in Palestine in a single year.

3. The form of its boring holes, ways of attacking the trees and its epidemiology have been carefully studied.

4. As means of control have been tried: destroying with iron wires, Carbon-bisulfide, Paradichlorbenzene and Calcium cyanide.

5. To summarise the results of our experiments in the control of the caterpillars of Zeuzera pyrina in Gan Shmuel during the course of a few years, we may state that Paradichlorbenzene and Calcium cyanide are both the best remedies and the easiest to handle.

P. Z. E. Agricultural
Experiment Station,
Division of Entomology.
Tel-Aviv, Palestine.

ERRATA.

Page 73 line 2 below Table 6 instead of: In Table 6 read: In Table 7.
„ 76 „ 7 instead of: In Table 5 read: In Table 7.
„ 78 penultimate line instead of: In about 55 days read: In about 50 days.
„ 84 Table 8 read: Paradichlorbenzene 0,4–0,7 g, Gan Shmuel 32 hours 1 dead, 5 (4 weak) alive.
„ 85 line 4 from below instead of: In Table 3 read: In Table 7.