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THE EFFECTS OF A PREVIOUS FIELD INFESTATION UPON *EPHESTIA CAUTELLA* (WALKER) AND *LASIODERMA SERRICORNE* (F.) INFESTING CAROBS

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Abstract—In laboratory trials, larvae of *Ephestia cautella* (Walker) successfully developed upon sections of the pods of the carob tree (*Ceratonia siliqua* L.) which had previously been infested in the field by *Ectomyelois ceratoniae* (Zeller), but failed almost completely to develop upon sections of the pods which had not been infested in the field. Significantly more eggs were laid by *Ephestia cautella* adults on previously infested carob than on previously uninfested carob, and when newly-hatched *Ephestia cautella* larvae were given a choice between previously infested carob and previously uninfested carob, significantly more of them selected the previously infested carob.

Larvae of *Lasioderma serricorne* (F.) developed successfully on both previously infested carob and previously uninfested carob, and neither adult nor larval *Lasioderma serricorne* could be shown to discriminate between previously infested and undamaged carob.

INTRODUCTION

THE CAROB (*Ceratonia siliqua* L.) is a tree which is distributed throughout the Mediterranean region. The pods produced by the tree are harvested and used mainly as a component of animal food. Several insect species infest the carob pods. Infestation by insects begins before harvest when the pods are beginning to ripen. At this stage cracking occurs and the cracked pods may become infested by the moth *Ectomyelois ceratoniae* (Zeller) (ASHMAN, 1967). It has been reported that they are attracted to the cracked pods by a mould (*Phomopsis* sp.) developing in the cracks (GOTHILF, 1964). After harvesting the carobs may become infested by a variety of stored-product pests, but the more important insects are *Ephestia cautella* (Walker), *Lasioderma serricorne* (F.) and *Oryzaephilus surinamensis* (L.) (ASHMAN, 1967).

In Cyprus, infestation of carobs in stores was generally associated with damage caused by a previous field infestation (ASHMAN, 1967) and so the work described in this paper was carried out on the behaviour of *Ephestia cautella* and *L. serricorne* infesting carobs with or without a previous field infestation.

GENERAL METHODS

All carobs were obtained from Cyprus and were freshly harvested. *Ectomyelois ceratoniae* larvae were found in the pods. The carobs were fumigated with phosphine, broken into small pieces, and sorted into insect-damaged and undamaged fractions. The undamaged parts of those which had been damaged by a field pest were mixed with completely undamaged pods. In this paper sections of carob damaged by a field infestation will be referred to as "previously infested carob", while sections of carob bearing no evidence of a previous field infestation will be referred to as "previously uninfested carob". The two types of carob were roughly ground using a large grain kibbler. The maximum dimension of pieces of pod after kibbling was about half a centimetre.

All experiments were carried out in a room maintained at 27°C and 70% r.h.

DEVELOPMENT OF *EPHESTIA CAUTELLA* AND *LASIODERMA SERRICORNE* ON PREVIOUSLY INFESTED AND UNINFESTED CAROB

Ten *Ephestia cautella* eggs were added to each of twenty 260 ml jars containing 10 g kibbled previously uninfested carob and also to each of 20 similar jars containing kibbled previously infested carob. The adults were removed from the jars and counted at frequent intervals (usually daily) as they developed. This entire process was repeated using eggs of *L. serricorne* but only ten replicates of each carob treatment were set up.

The mean number of *E. cautella* surviving to the adult stage in each jar of previously infested carob was 5.4 (S.D. = 1.39, range 3–8). The median development period for all of the surviving insects was 51 days. On previously uninfested carob only one of the total of 200 eggs had developed to adult after 150 days, and one other survivor was present as a larva.

The mean number of eggs of *L. serricorne* surviving to the adult stage in each jar of previously infested carob was 6.7 (S.D. = 2.41, range 3–10) and on previously uninfested carob was 5.2 (S.D. = 1.81, range 3–8). The median development period of all surviving beetles on the two types of carob were 51 days and 57 days respectively. The mean numbers of surviving *L. serricorne* on the two types of carob were not significantly different ($P > 0.05$ using Student's t).

CHOICE OF PREVIOUSLY UNINFESTED OR INFESTED CAROB BY EGG-LAYING *EPHESTIA CAUTELLA* AND *LASIODERMA SERRICORNE* ADULTS

Method. These experiments were carried out in a large open-topped polythene container measuring approximately 78 cm × 45 cm × 40 cm deep. Four rows of five 8 cm dia. × 4 cm deep crystallizing dishes were placed as far apart as possible in a grid pattern in the bottom of the container. Ten of the dishes were filled with previously infested carob and ten were filled with previously uninfested carob and the arrangement of these treatments was randomised using a table of random numbers. Twenty female and ten male *E. cautella* adults were introduced into the apparatus and at the same time a number of *E. cautella* adults were placed in a jar with a wire mesh top which was inverted over a petri dish in order to collect eggs. After three days the moths were removed from the apparatus and the eggs were collected from the petri dish. In order to eliminate the effects of differential mortality of the insects upon the two carob types the contents of each dish were mixed with 100 g. of food and placed in large glass jars (volume approximately 2.9 l). The food consisted of wheatfeed, yeast, glucose and glycerol in the proportions 80:9:15:5 by weight. At the same time the same volume of previously uninfested carob as had been in each crystallizing dish was placed in each of three large jars and fifty *E. cautella* eggs collected from the petri dish were added to each jar. One hundred grams of food as described above was mixed with the contents of each jar. This was repeated using previously infested carob.

The entire procedure was repeated using 50 randomly selected *L. serricorne* adults in the apparatus. The food consisted of wheatfeed and yeast in the proportion 10:1 by weight, the insects were allowed a 6 day oviposition period and eggs were collected by allowing adults to lay in finely sieved wheatfeed from which the eggs were removed by sieving.

The jars were left until the adult insects began to emerge, when they were removed and counted at frequent intervals.

Results

The number of *E. cautella* adults which emerged from the treatments of the choice experiment are given in Table 1, and the numbers of survivors from the fifty eggs placed on mixtures of carob and food are given in Table 2. The mean numbers of insects developing from eggs laid on the two treatments were significantly different ($P < 0.01$ using t test). The mean numbers of survivors from the 50 eggs added to

TABLE 1. THE NUMBERS OF ADULTS DEVELOPING WHEN ADULTS AND LARVAE OF *Ephestia cautella* AND *Lasioderma serricorne* WERE PERMITTED THE CHOICE OF INFESTING PREVIOUSLY INFESTED OR PREVIOUSLY UNINFESTED CAROB

	Adults				Larvae			
	Ephestia cautella		*Lasioderma serricorne*		*Ephestia cautella*		*Lasioderma serricorne*	
Carob type*	I	U	I	U	I	U	I	U
Number of replicates	10	10	10	10	8	8	8	8
Mean number of adults	128.5	73.4	33.9	23.9	17.1	6.5	15.4	7.5
Standard deviation	52.3	34.6	20.5	13.7	2.3	3.8	9.9	3.2
Range	23–230	29–153	11–67	7–46	16–22	2–14	7–18	4–13

* I = previously infested carob, U = previously uninfested carob.

TABLE 2. THE NUMBER OF SURVIVORS FROM 50 EGGS OF *Ephestia cautella* AND *Lasioderma serricorne* DEVELOPING ON A MIXTURE OF PREVIOUSLY INFESTED OR PREVIOUSLY UNINFESTED CAROB AND FOOD

	Controls from adult choice experiments				Controls from larval choice experiments			
	Ephestia cautella		*Lasioderma serricorne*		*Ephestia cautella*		*Lasioderma serricorne*	
Carob type*	I	U	I	U	I	U	I	U
Mean number of adults	38.0	31.7	35.0	41.3	21.3	22.7	37.7	31.0
Standard deviation	11.5	8.5	1.7	4.0	5.7	0.6	1.2	5.0
Range	29–51	22–38	33–36	37–45	15–26	22–23	37–39	26–36

* I = previously infested carob, U = previously uninfested carob.
These results refer to the controls from the adult and larval choice experiments, and all means are based on three replicates.

each carob treatment mixed with food were not significantly different ($P > 0.05$ using t test).

The lack of difference between the treatments to which eggs were added indicates that mixing food with the carob eliminated the problems of differential mortality on previously infested and uninfested carob, therefore the number of insects breeding out of the contents of the crystallizing dishes should be directly related to the number of eggs originally laid in these dishes. Therefore significantly more eggs were laid on the previously infested than on the previously uninfested carob.

The numbers of *L. serricorne* developing from eggs laid in previously infested and previously uninfested carob and subsequently mixed with food are given in Table 1 and the numbers of survivors from the 50 eggs placed on mixtures of carob and food are given in Table 2. Neither the mean numbers of insects developing from eggs laid on the two treatments were significantly different from each other, nor were the mean numbers of survivors from the fifty eggs added to each carob treatment and mixed with food ($P > 0.05$ in each case using t test). There is therefore no evidence that more eggs were laid in the crystallizing dishes containing previously infested carobs than in those containing previously uninfested carob.

CHOICE OF PREVIOUSLY UNINFESTED OR PREVIOUSLY INFESTED CAROB BY FIRST INSTAR LARVAE OF *EPHESTIA CAUTELLA* AND *LASIODERMA SERRICORNE*

Method

The apparatus used was a modified "dividing tray" consisting of a square plastic frame 28 × 28 × 5.3 cm divided up into 100 cells each 2.5 × 2.5 × 5.3 cm deep. Fifty of these cells were closed at their top ends by a piece of plastic which formed a platform for insect eggs. The positions of the open and closed cells alternated in a chess-board fashion. Each platform had a small depression drilled into it to accommodate the eggs. A sheet of paper was glued over the bottom of the apparatus so that the open cells formed cups into which roughly ground carob was placed (Fig. 1).

Fifteen grams of roughly ground previously infested carob was placed in each of 25 of the cells and fifteen grams of previously uninfested carob was placed in each

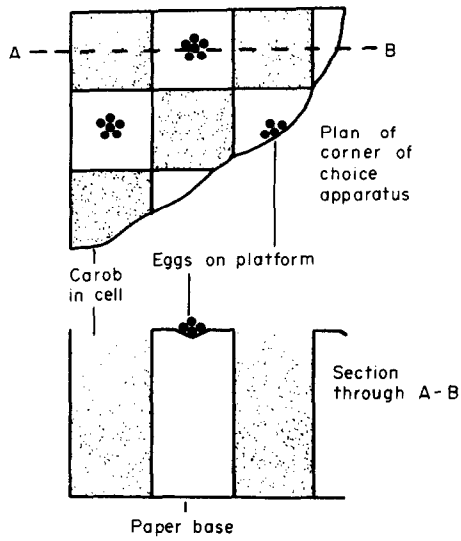

FIG. 1. Plan and section of part of the apparatus used in the larval choice experiment.

of the remaining cells. The arrangement of the previously infested and uninfested treatments was randomized using a set of random number tables. Ten *E. cautella* eggs which had been laid over the previous 24 hr period were placed in the depression in each platform. Forty-five grams of roughly ground previously infested carob was placed in each of three large glass jars and 50 *E. cautella* eggs of the same age as those placed on the choice apparatus were sprinkled over the carob in each jar. This was repeated with previously uninfested carob.

After nine days the contents of the cells were removed by cutting away their paper bases. The contents of the cells were then randomly bulked into lots of three within treatments, the contents of the remaining two cells being discarded. One hundred grams of food mixture, as described in the previous section, was added to each of the bulked samples from the cells and placed in a large glass jar. The same amount of food was also added to the 45 g lots of carob already placed in jars along with the *E. cautella* eggs.

The entire procedure was repeated using *L. serricorne* eggs which were left in the choice apparatus for eleven days.

RESULTS

The numbers of adult *E. cautella* developing from the bulked samples mixed with food is given in Table 1. The mean number of adults from the previously infested carob was significantly greater than the mean number from the previously uninfested carob ($P < 0.01$ using t test). There was no significant difference between the mean numbers of adult *E. cautella* developing from the eggs added to roughly ground carob in large jars and subsequently mixed with food (Table 2). The numbers of adults developing in the contents of the cells of the choice apparatus mixed with food therefore reflect the numbers of larvae in the cells when the contents were removed from the apparatus, and therefore at that time there were significantly more young larvae in the previously infested carob than in the previously uninfested carob.

The data involving *L. serricorne* are also given in Tables 1 and 2. The variances of the data for larval choice are high and no difference between treatment effects were found. There is therefore no evidence that more or fewer young larvae were in the cells containing previously infested carob when the cell contents were removed from the choice apparatus.

DISCUSSION

ASHMAN (1967) has described the succession of Phycitinae infesting carobs starting with the attraction of *Ectomyelois ceratoniae* to cracked pods infested by the mould

Phomopsis sp. and ending with the observation that infestation in store was usually associated with damage previously caused by a field pest. The present work indicates that there are sound biological causes of this association between field and store pests.

The presence of damage from a previous infestation has a considerable effect upon the suitability of carob as a food for *Ephestia cautella*. Whereas there was negligible survival of *E. cautella* larvae on previously uninfested carob, over 50% of introduced eggs survived to the adult stage on previously infested carob. This effect was not found with *L. serricorne*.

Both first instar *E. cautella* larvae and ovipositing *E. cautella* adults selected previously infested carob significantly more often than they did previously uninfested carob. It would appear that either an arrestant is operating to retain first instar larvae and adults on previously infested carob in preference to previously uninfested carob or that an attractant is operating (DETHIER *et al.*, 1960).

No significant arrestant or attractant action was found with *L. serricorne* first instar larvae and ovipositing adults.

As all carobs used in these experiments were roughly ground, the increased survival on, and selection of, the previously infested carob cannot be attributed to the mechanical damage caused by the field infestation. Also, since the undamaged parts of the carobs bearing field infestation damage were mixed with wholly undamaged pods, then any characteristics of individual pods which may have affected both the field and store pests were eliminated from the experiment. It must therefore be postulated that there are factors in previously infested carob directly associated with the field infestation which aid the development of *E. cautella* and arrest or attract *E. cautella* first instar larvae and adults.

Limitations of time did not permit more work in this field, but further investigations of the associations between *E. cautella* and other storage pests including *L. serricorne* may give more information concerning the ecological succession of species infesting carobs. For instance, as the reported association between *L. serricorne* and insect damaged carob pods (ASHMAN, 1967) cannot be explained in terms of a biological association between *L. serricorne* and field pests, then it would be interesting to ascertain whether or not there were any biological association between *L. serricorne* and *E. cautella* in the store. Similar research on other crops may reveal important inter-specific relationships, a knowledge of which could be of assistance in understanding and controlling store infestations.

REFERENCES

ASHMAN, F. (1967) The control of infestation in carobs (*Ceratonia siliqua* L.) with special reference to Cyprus. *Europ. Medit. Plant Protection Organisation, Report of the International Conference on the Protection of Stored Products, Lisbon, Series A, 46E*, 117–120.

DETHIER, V. G., BARTON BROWN, L. and SMITH, C. H. (1960) The designation of chemicals in terms of the responses they elicit from insects. *J. econ. Ent.* **53**, 134–136.

GOTHILF, S. (1964) Studies on the biology of the Carob Moth (*Ectomyelois ceratoniae*) in Israel. *Natn and Univ. Inst. Agric. Res., Dept. Plant Prot., Special Bull. 76.*