THE SOURCES OF EPHESTIA INFESTATION OF STORED CACAO IN CEYLON

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As far back as 1921, Knapp made mention of the tendency of Ceylon cacao to be " slightly grubby ". The percentage of insect-damaged beans in Ceylon exports at the time was in the neighbourhood of 2·0 per cent.; the average for the world's production was 1·6 per cent. The question of insect infestation assumed unpleasant prominence in 1934, when Ceylon's largest individual customer, the Philippine Islands, insisted on the fumigation against insect damage of all cacao imports from Ceylon.

The insects associated with the spoilage of stored cacao in Ceylon include the cacao moth (*Ephestia elutella* Hb.), the fig moth (*Ephestia cautella* Walk.), the rice moth (*Corcyra cephalonica* Staint.) and the Tephrosia beetle (*Araecerus fasciculatus* DeG.). In an examination by Munro and Thomson (1929) of 143 bags of Ceylon cacao received at the Port of London, 49 bags were observed to be infested with *E. elutella*, six with *C. cephalonica* and four (three doubtful) with *A. fasciculatus*. That species of *Ephestia* constitute the major pests of Ceylon cacao and, for that matter, of cacao from most parts of the world, is now generally appreciated.

Hutson (1932) estimates the duration under tropical conditions of the incubation period of the egg, the larval period, the pupal period and the total life-cycle of *E. elutella* at five to nine days, eight to ten weeks, nine to twelve days and ten to thirteen weeks, respectively. In cacao spoilage, it is of course the larval phase that is of especial interest. The *Ephestia* larva is unable to penetrate the hard shell of a fermented cacao bean and can invade only cracked and broken beans. The larva of *Araecerus*, on the other hand, is able to rupture the cacao shell and may accordingly prove an important accessory to *Ephestia* invasion. The *Ephestia* larva consumes the cotyledon substance of the bean, replacing it with characteristic frass, *viz.*, large fæcal pellets held together by fine webbing. Apart from cacao, the larva can subsist on an extremely varied diet, ranging from dried vegetables, tobacco, various kinds of seeds and cereals to the dead bodies of its own parents. These polyphagous habits make *Ephestia* control extremely difficult.

In 1936, the British Association of Research for the Cocoa, Chocolate, Sugar Confectionery and Jam Trades, London, in collaboration with the Department of Agriculture, Ceylon, initiated an investigation into the sources of *Ephestia* infestation of stored cacao in Ceylon, as an essential preliminary to the application of control measures. A description of the methods employed in that investigation and the results obtained are presented below.

EXPERIMENTAL MATERIAL AND METHODS

Ceylon has an acreage of approximately 34,000 under cacao (*The Ceylon Blue Book*, 1936). Nearly the whole of this area is in the Kandy, Dumbara and the Matale Districts. The trees are Forastero-Criollo hybrids. Ceylon cacao had, at one time, a large admixture of Criollo in its composition. Recent years have seen a gradual replacement of the Criollo strains by predominantly Forastero types. The main or autumn crop is ready for picking during the period November–January. A small spring crop is available in May, June and July.

Cacao plantations in Ceylon fall into two rather well-defined classes; the large European-owned estates—a single estate of this type may cover as much as 2,700 acres—and the peasants' small-holdings averaging one to three acres each. A few estates owned by Indian Tamils constitute a class intermediate in type and extent. The small-holdings contribute nearly 70 per cent. of Ceylon's total output of cacao, and are accordingly of especial interest in the present connexion. The pre-fermentation history of small-holders' cacao has been described by Fernando (1938). The small-holder sells his cured cacao to a local petty dealer in quantities ranging from about 3 lb. to 30 lb. To carry the process of curing to completion ten to fifteen days may be necessary. Many villagers, however, sell their cacao after partially drying it for two to three days; the drying is completed by the dealer. The local dealer's collections are allowed to pile up till their proportions warrant sale to a larger dealer. Small-holders' cacao passes through a relay of dealers of progressively increasing importance—nearly all of them Moors—till it eventually reaches a trader in the Pettah, Colombo. In the course of these successive transfers, the cacao is subjected to a considerable amount of bulking and grading, and to attempts at improving the complexion of the shell with annatto or brick-dust. Furthermore, this cacao remains in storage at each dealer's warehouse for periods varying from a few days to several weeks. When favourable market conditions obtain, the Pettah dealer sells his cacao to one of the large firms of European exporters. The cacao undergoes an elaborate process of regrading at the hands of the exporters, and is eventually shipped abroad.

Estate cacao follows a rather different procedure. The estate technique of cacao curing has been described by Fernando (1938). The cured cacao is subjected to elaborate hand-grading on the basis of bean-size, and is stored in bags till a sufficiently large bulk has accumulated, when it is transported to the estate agents in Colombo. During the height of the cacao season, the period of storage on the estate may not exceed two to three days. On receipt in Colombo, the cacao is either sold by the estate agents to a local firm of exporters or despatched directly abroad. In the event of the cacao passing into the hands of local exporters, it may be subjected to further grading and to further storage in anticipation of a rise in prices, before being finally consigned abroad.

It should be emphasized that, in some instances, the contents of a bag of estate cacao may remain untampered with during the whole of its journey from the estate to the foreign buyer. Small-holders' cacao, on the other hand, is heterogeneous from the start, and the series of bulkings and re-gradings that this cacao experiences prevents its retaining its individuality for any considerable period. The scheme of research drawn up by the British Association of Research for the Cocoa, &c., Trades consisted in the transport to the exporters' warehouse, in Colombo, of a bag of cacao beans collected from the growers' drying-floor, and the withdrawal at various stages in the transport of samples for examination for *Ephestia* infestation. Transport in this way of an experimental bag of small-holders' cacao does not reproduce the course normally followed by small-holders' cacao ; but the method serves the purpose of the present investigation, *viz.*, the determination of the sources of *Ephestia* infestation. It is conceded that the figures for the extent of *Ephestia* damage of small-holders' cacao provided by this method, will be an under-estimate.

The details of experimental procedure were as follows : In each series, about one cwt. of cracked and broken beans was selected from one or more drying-floors ; the broken shells predispose the beans to *Ephestia* attack. The beans were well mixed and a random 7 lb. sample was withdrawn, packed in an insect-proof tin and despatched for examination to the British Association of Research for the Cocoa, &c., Trades, London. The remainder of the cacao was sterilized by exposure to dry heat at 150°F. (65·6°C.), which temperature is lethal to all stages of *Ephestia*. A small electric oven with a capacity of 33,000 cc. was used. The sterilized cacao was placed in a bag of the type normally used for transporting cacao. This bag was subjected to the routine storage and transport. At selected points in the transport, further 7 lb. samples were withdrawn and the rest of the bag was sterilized at 150°F.

immediately after each sampling. Eventually the experimental bag reached the exporters' warehouse in Colombo. A last 7 lb. sample was removed and the remainder of the bag was finally sterilized almost immediately before its transference to the boat for shipment to the British Association of Research for the Cocoa, &c., Trades, London. It was possible, by an analysis of the series of samples, to reconstruct the story of the infestation of cacao in storage and transport. Sterilization by dry heat was preferred to sterilization by the use of fumigants as the latter might have had a residual repellent action upon *Ephestia*. Apart from a certain amount of dehydration, the heat treatment did not affect the cacao materially.

RESULTS

The collection of four series of samples—two series from the estates and two from the small-holders—was undertaken. Of the two estate series, one passed through a firm of exporters prior to shipment; the other series represented the type of estate cacao consigned directly abroad by the estate agents.

Estate Series 1.—The detailed history of this series is recorded below. The cacao belonged to the latter part of the small spring crop.

June 24, 1936.—One cwt. of cracked and broken beans was selected from a drying loft of the factory of Estate A. The age of the beans varied from ten days to one month from the time of picking. A 7 lb. sample (series 1, sample 1) was withdrawn.

July 1.—The remainder of the bag of cacao was sterilized and transferred to the estate stores. The store-room had 3,000 sq. feet of cemented floor-space and formed the ground floor of a four-storeyed building, the upper floors of which functioned as drying-lofts. The presence of drying lofts above and of an adjacent copra-dryer resulted in a rather high air temperature. Approximate estimates of average day temperatures of various floors were: ground floor 80°F., 1st floor 100°F., 2nd floor 120°F., 3rd floor 120°F. The store-room was well-lighted, well-ventilated and comparatively clean. Illumination and cleanliness of stores are of importance in view of the negative phototropism and the omnivorous habits of *Ephestia*. Copra was stored alongside the cacao.

August 17.—Sample 2 was withdrawn from the experimental bag which was then sterilized and despatched by rail, along with other bags of estate cacao, to the estate agents in Colombo.

August 21.—The bag arrived in Colombo.

August 22.—Sample 3 was withdrawn.

August 24.—The sterilized bag was transferred to the estate agents' warehouse, where it was stored along with other bags of cacao. A few damaged beans filled with the frass characteristic of *Ephestia*, were observed on the premises.

September 29.—Sample 4 was withdrawn.

October 3.—The sterilized bag was placed in storage in the warehouse of exporters.

November 9.—Sample 5 was withdrawn and the sterilized bag placed again in storage in the exporters' warehouse.

December 8.—Sample 6 was withdrawn and the sterilized bag placed again in storage in the exporters' warehouse.

December 15.—It was anticipated that the exporters would attend to the despatch of the bag. As the exporters' shipments were unexpectedly delayed, the bag was transferred back to the warehouse of the estate agents who undertook to forward the bag to London.

December 24.—The bag was removed from the estate agents' warehouse.

December 26.—The bag was shipped to London.

The results of the analysis by the British Association of Research for the Cocoa, &c., Trades, of the 7 lb. samples which constituted the above series are given in Table I.

The most noteworthy feature in the analysis is the apparent freedom of the drying floors from *Ephestia* infestation. The following experiment provided further evidence of the cleanliness of the drying floors. A representative 2 lb. quantity of cracked and broken beans removed from a drying loft of Estate A was incubated under conditions of protection from further insect infestation. Simultaneously two bags of cacao of about 1 cwt. each were drawn from the same source. One of the bags was sterilized at 150°F. Both sterilized and unsterilized bags were transferred to the estate stores on July 1, 1936. On August 19, random samples were drawn from each of the three treatments; each sample consisted of 700 unfragmented beans and ½ oz. of fragmented beans. The results of the analysis of the three samples are given in Table II. The sample drawn from the drying-loft and protected from further infestation, showed no trace of *Ephestia* or *Araecerus*.

TABLE I

No. of Sample.	Sampling details.	Time from drying-floor in days.	Damage by* *Ephestia*	Presence of *Ephestia.*
1 ..	Drawn from drying-loft ..	0 ..	– – ..	Nil
2 ..	After 47 days in estate store ..	54 ..	+ (0·3%) ..	Nil
3 ..	On arrival in Colombo ..	59 ..	+ (0·3%) ..	Nil
4 ..	After 35 days in warehouse of estate agents ..	97 ..	+ (0·3%) ..	Nil
5 ..	After 37 days in warehouse of exporters ..	138 ..	+ (0·3%) ..	Nil
6 ..	After further 29 days in warehouse of exporters ..	167 ..	+ (0·3%) ..	Nil
	(Bag forwarded to London by estate agents after delay in shipment by exporters.)			
7 ..	On arrival in London ..	229 ..	+ (0·75%) ..	Live larvæ

* + Indicates damage, and – indicates absence of damage.

TABLE II.

Treatment	Number of beans damaged by		Number of *Ephestia*			Number of *Araecerus*		
	Ephestia	*Araecerus*	Larvae	Pupae	Adults	Larvae	Pupae	Adults.
1. Cacao drawn from drying loft and protected from further infestation	0 ..	0 ..	0 ..	0 ..	0 ..	0 ..	0 ..	0
2. Cacao drawn from drying loft and exposed to infestation in estate stores	13 ..	5 ..	3 ..	0 ..	0 ..	2 ..	0 ..	0
3. Cacao drawn from drying loft, sterilized and then exposed to infestation in estate stores ..	11 ..	2 ..	1 ..	0 ..	0 ..	1 ..	0 ..	1

Estate Series 2.—Details of this series are recorded below. The cacao was collected towards the end of the small spring crop :—

July 9, 1936.—One cwt. of cracked and broken beans was removed from a drying-loft of the factory on estate B. The age of beans was one month from the time of harvesting. A 7 lb. sample (series 2, sample 1) was withdrawn.

July 16.—The sterilized bag was deposited at the estate stores. The factory on estate B was a three-storeyed building, the two upper floors of which served as drying-lofts. A verandah on the topmost floor functioned as the store-room. The slatted wooden floor of the store-room differed from that of the adjacent drying-loft only in that it was not heated by hot air from the flue. The store-room was exceptionally clean, extremely well-lighted and ventilated, and had an average air temperature of 80°F.

August 28.—Sample 2 was withdrawn.

August 31.—The sterilized bag was despatched by rail to the estate agents in Colombo.

September 2.—The bag arrived in Colombo.

September 4.—Sample 3 was withdrawn.

September 7.—The sterilized bag was transferred to the warehouse by the estate agents.

October 12.— Sample 4 was withdrawn.

October 14.—The sterilized bag was transferred back to the warehouse of the estate agents.

October 24.—Sample 5 was withdrawn. The remainder of bag was left unsterilized on account of the short time available before despatch.

The results of the examination by the British Association of Research for the Cocoa, &c., Trades of this series of samples, are presented in Table III.

TABLE III.

No. of Sample.	Sampling details.	Time from drying-floor in days.	Damage by* *Ephestia.*	Presence of *Ephestia*
1	Drawn from drying-loft	0	—	Nil
2	After 43 days in estate store	50	—	Nil
3	On arrival in Colombo	57	—	Nil
4	After 35 days in warehouse of estate agents	95	+	Live larvæ and dead adults
5	After further 10 days in warehouse of estate agents and just prior to shipment	107	+	Live larvæ
6	On arrival in London	174	+ (1%)	None alive

* + Indicates damage, and – indicates absence of damage.

Small-holders' Series 1.—The details of this series are given below. The cacao was collected from the early part of the main autumn crop.

October 23, 1936.—Nearly 1 cwt. of partially dried beans was secured in quantities ranging from 3 lb. to 33 lb. from drying-platforms of eight small-holders in Wattegama. The age of beans was about 3 days from the time of picking. The beans were thoroughly mixed and a 7 lb. sample (sample 1) was withdrawn. Sun-drying of the remainder was continued.

October 31.—Sun-drying of the cacao was completed. Sample 2 was withdrawn.

November 4.—The sterilized bag was deposited at the warehouse of a petty dealer in Wattegama. This type of dealer often buys imperfectly dried cacao from small-holders, and completes the drying operation himself.

December 12.—Sample 3 was withdrawn.

December 18.—The sterilized bag was deposited at the warehouse of a petty dealer in Kandy.

January 25, 1937.—Sample 4 was withdrawn. The sterilized bag was despatched to Colombo. Small-holders' cacao at this stage would normally have been transferred to the warehouse of a petty dealer in the Pettah, Colombo. Unfortunately, attempts at inducing petty dealers in the Pettah to handle this series failed.

February 2.—The bag reached the warehouse of the exporters. Sample 5 was withdrawn and the sterilized bag was placed in storage in the exporters' warehouse. A very large percentage of the cacao handled by this firm of exporters consisted of small-holders' cacao supplied by petty dealers in the Pettah. The quantity of cacao that passed through this firm was, however, relatively small. This firm dealt mainly in rubber and desiccated coconut, a considerable quantity of which was in storage in the warehouse at the time. The experimental bag was stored alongside cacao supplied by petty dealers in the Pettah. Some of this cacao was badly infested. On opening some of these bags *Ephestia* moths escaped. Many beans showed *Ephestia* damage. Illumination of the warehouse was poor.

March 8.—Sample 6 was withdrawn and the sterilized bag transferred back to the warehouse of the exporters.

March 22.—Sample 7 was withdrawn.

March 25.—The sterilized bag was transferred to the warehouse of another firm of exporters.

April 6.—The bag was shipped to London.

The results of the analysis of the above series of samples by the British Association of Research for the Cocoa, &c., Trades, is recorded in Table IV.

TABLE IV.

No. of Sample.	Sampling details.	Time from drying-floor in days.	Damage by* *Ephestia.*	Presence of *Ephestia.*
1†	Drawn from drying-floors	0	–	Nil
2	On completion of drying	8	–	Dead adults and pupae
3	After 38 days in warehouse of petty dealer in Wattegama	50	–	Nil
4	After 38 days in warehouse of petty dealer in Kandy	94	–	Nil
5	On arrival in Colombo	102	–	Nil
6	After 34 days in warehouse of exporters	136	+	Nil
7	After further 14 days in warehouse of exporters	150	+	Nil
8	On arrival in London	236	+	Nil

* + Indicates damage, and – indicates absence of damage.

† This sample was drawn before drying was complete and became mouldy during transit to London.

Small-holders' Series 2.—Details of this series are presented below. The cacao belonged to the latter part of the small spring crop.

August 29, 1937.—Nearly 1 cwt. of cracked and broken beans was collected from drying-platforms of small-holders in Ampitiya and Katugastota. The age of the beans was 3–5 days from the time of harvest. The beans were well mixed and a 7 lb. sample (Sample 1) was withdrawn. Sun-drying of the rest of the beans was continued.

September 6.—Sun-drying of the cacao was completed. Sample 2 was removed.

September 7.—The sterilized bag was deposited at the warehouse of a petty dealer in Katugastota.

October 15.—Sample 3 was withdrawn.

October 20.—The sterilized bag was deposited at the warehouse of another petty dealer in Katugastota.

November 27.—Sample 4 was withdrawn. The sterilized bag was despatched to Colombo.

December 2.—The bag arrived in Colombo. Sample 5 was withdrawn. The sterilized bag was transferred to warehouse of a petty dealer in the Pettah, Colombo.

January 11, 1938.—Sample 6 was withdrawn.

February 4.—The sterilized bag was shipped to London by a firm of exporters.

The results of the analysis of this series of samples by the British Association of Research for the Cocoa, &c., Trades, is given in Table V.

TABLE V.

No. of Sample.	Sampling details.	Time from drying-floor in days	Damage by* *Ephestia.*	Presence of *Ephestia.*
1† ..	Drawn from drying floor ..	0 ..	– ..	Nil
2 ..	On completion of drying ..	8 ..	– ..	Nil
3 ..	After 38 days in warehouse of a petty dealer in Katugastota	47 ..	+ ..	Pieces of adult moths of *E. cautella.*
4 ..	After 38 days in warehouse of another dealer in Katugastota	90 ..	+ ..	Nil
5 ..	On arrival in Colombo ..	95 ..	+ ..	Nil
6 ..	After 40 days in warehouse of dealer in the Pettah, Colombo	135 ..	+ ..	Nil
7 ..	On arrival in London ..	211 ..	+ ..	Nil

* + Indicates damage, and – indicates absence of damage

† This sample was removed before completion of drying and turned mouldy during transit to London.

DISCUSSION

The unsatisfactory state of the classification of the genus *Ephestia* has resulted in considerable confusion regarding the relative importance of various species of this moth in cacao infestation. Characters used for separating *Ephestia* species are either unreliable or involve elaborate micro-dissection. It has become customary to place *Ephestia* moths associated with cacao spoilage in the species *elutella* on account of the popular name "cacao moth" assigned to the latter. Results of recent investigations by Nicol (1935) suggest that *E. cautella* may probably prove as damaging a pest of stored cacao as *E. elutella*. *E. cautella* had hitherto been considered an unimportant pest of Ceylon cacao (Hutson, 1932). In the course of the present survey both *E. elutella* and *E. cautella* have been identified on Ceylon cacao, and it is likely the *E. cautella* is not as innocuous as was formerly supposed.

The most consistent feature in the four series was the apparent freedom of the drying floors from *Ephestia* infestation. In the first estate series, slight invasion occurred in the estate stores; the percentage of damaged beans after 1½ months storage was 0·3 per cent. No further damage was apparent till the bag of cacao left the exporters' warehouse. In the second estate series, on the other hand, the bag of cacao arrived in Colombo free from insect damage and from traces of insect life. *Ephestia* damage became evident only after the bag had remained in storage at the warehouse of the estate agents for about a month. The percentage of damaged beans in the bags belonging to the first and second estate series on arrival in London, were 0·75 and 1 per cent. respectively. The relatively low percentages are, at least in part, due to intermittent sterilization, and should not be considered valid estimates of the extent of *Ephestia* damage in cacao of estate origin.

Comparable results were obtained with the two small-holders' series. The cacao drawn straight off the drying-floor was free from insect damage. In the first small-holders' series, the sample drawn on completion of drying at the hands of the local petty dealer contained adults and pupæ of *Ephestia*. Despite the absence of *Ephestia* damage in the sample, this dealer's warehouse should be considered a seat of infestation. The cacao reached Colombo undamaged by *Ephestia*, and it was only after about a month's storage at the exporters' warehouse that visible injury occurred. In the second small-holders' series, *Ephestia* damage was evident after about a month's storage in the warehouse of the first petty dealer.

Most authorities have considered drying floors potential seats of *Ephestia* infestation. Knapp (1921), Patterson (1928) and Munro and Thomson (1929) among others, have entertained the possibility of drying-floor infestation. Noyes (1930) stated that moths deposit their eggs at night on beans exposed on drying platforms. (In Ceylon, at least, cacao is not left exposed on drying-platforms at night). Granato (1909) even reported the attack of cacao pods by *E. elutella* in Brazil. The apparent freedom from *Ephestia* of drying-floors of both estates and small-holders in Ceylon is accordingly of considerable interest. The cleanliness of small-holders' drying-floors and of estate barbecues where dehydration is effected by insolation, may, at least in part, be explained by the pronounced negative phototropism of both the larva and the adult of *Ephestia*. The relatively high temperatures occurring in estate drying lofts may possibly inhibit *Ephestia* development or may deter oviposition by the females. Exposure to a temperature of 55°C. (131°F.) for 40 to 45 minutes is lethal to all stages of *Ephestia* (Noyes, 1930). Lower temperatures may destroy stages of *Ephestia* other than the egg. All stages in storage subsequent to the drying floor—including warehouses of petty dealers, estate agents and exporters—may legitimately be suspected of being seats of *Ephestia* infestation. There is no evidence that infestation occurs during the actual process of transference between stores. As warehouse infestation is intensified by long storage, transport of cacao should be speeded up all the way from the estate to the boat. The practice of keeping cacao in storage till the advent of satisfactory market conditions should be discouraged. The periodic bulking and grading of peasants' cacao create conditions ideal for the distribution of the insect population throughout the beans. Estate cacao is more fortunate and there is a particularly high probability of its escaping infestation if shipped directly abroad by the estate agents; under these circumstances, estate cacao would escape contact with peasants' cacao.

In attempts at cleaning up seats of infestation, the preference of moths for the dark and for still air, and the not too fastidious feeding habits of the larva should be borne in mind. Too much emphasis cannot be placed on the importance of scrupulous cleanliness and of satisfactory illumination and ventilation of cacao warehouses. Warehouse floors should be frequently swept, and walls and ceilings frequently whitewashed. The floors should be of cement ; wooden floors accumulate quantities of cacao débris between boards. The marked seasonal periodicity of the cacao crop facilitates off-season cleaning up of cacao warehouses.

It has been suggested that this periodic clean-up may be advantageously supplemented by fumigation of warehouse interiors with hydrogen cyanide or ethylene oxide. But fumigation is not likely to be profitable if facilities for making warehouses airtight do not exist or if warehouses contain numerous crevices. *Ephestia* larvæ lodged in crevices may escape damage even when lethal concentrations of the fumigant occur in the more exposed situations. A further disturbing factor is the occurrence of what is sometimes known as " protective stupefaction " : larvæ which succumb to the immediate application of a certain concentration of fumigant may, if previously subjected to sub-lethal doses, resist a subsequent application of that lethal concentration (Potter, 1937). A rather more efficient method of sterilizing warehouses is the spraying of warehouse interiors with a solution of pyrethrins in a white oil. The sprayed interiors are provided with a protective film of insecticide which possesses considerable residual properties and prevents re-infestation. Spraying should be done twice a week during periods of moth emergence (Potter, 1938).

In instances where complete extermination is not practicable, the survival level of *Ephestia* may be lowered by the use of moth-traps ; tea made up in the usual way with milk and sugar provides an efficient lure. The possibilities of biological control by the use of the small Braconid wasp, *Microbracon* (*Habrobracon*) *hebetor* Say., which is predacious on species of *Ephestia*, may be profitably explored. Numbers of limp *Ephestia* larvæ paralysed by this Braconid may sometimes be seen on sacks of cacao. The liberation of these parasites in cacao warehouses has been advocated as a measure of *Ephestia* control. The life cycle of the parasite is conveniently short, and a single parasite can destroy several *Ephestia* larvæ. The fact that the larvæ which is the only susceptible phase of *Ephestia*, spends most of its days inside the cacao bean in a situation inaccessible to the parasite, interferes with successful control. It is only when the larva emerges from the bean prior to pupation, that it is exposed to

attack by the Braconid. For effective control it is essential to ensure a high population of parasites at this particular time (Noyes, 1930). Another parasite which shows considerable promise is *Trichogramma minutum* Riley (Chaboussou, 1937).

The orientation of sacks in storage appears to affect the degree of infestation to some extent (Wadsworth, 1933). The upper end of a bag stood end on, has a relatively large air space suitable for pupation of the larvæ and mating of the moths. Sacks should be stacked on their sides.

In Ceylon, both estate cacao and small-holders' cacao undergo vigorous washing at the end of the sweating operations. This washing contributes to the attractive appearance of the final product, but makes the shell brittle and consequently liable to *Ephestia* invasion. The risk of prejudicing buyers abroad would, however, prevent Ceylon growers from dropping the practice. Besides, the danger of moulding is considerably reduced by washing. The fact that Criollo beans are more susceptible to *Ephestia* attack than Forastero beans is of some interest in view of the present change-over from Criollo to Forastero types in Ceylon plantations.

One of the most promising recent developments in *Ephestia* control is use of leaves of neem (*Melia azadirachta* L.) as an *Ephestia* repellent. Sacks of cacao beans lined with air-dried neem leaves have been maintained free from *Ephestia* in a heavily infested environment. The neem appears to discourage oviposition by the females or to repel young larvæ. The leaves should not be mixed with the beans in the sack as this would necessitate re-winnowing (Anon., 1938).

SUMMARY

1. The methods employed and the results obtained in an investigation undertaken by the British Association of Research for the Cocoa, Chocolate, Sugar Confectionery and Jam Trades, London, in collaboration with the Department of Agriculture, Ceylon, into the sources of *Ephestia* infestation of stored cacao, in Ceylon, are presented.

2. The freedom from *Ephestia* of cacao drying-floors of both estates and small-holders, is demonstrated.

3. Stages in storage subsequent to the drying-floor, including warehouses of petty dealers, estate agents and exporters, are shown to be seats of *Ephestia* infestation.

4. Methods of *Ephestia* control are indicated in outline.

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