COTTON AND PLAGUE IN UGANDA

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With an appendix on post-mortem examinations of rats used in the experiments

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Introduction

Various authors have stated that the plague problem in Uganda is intimately connected with the cotton industry. Thornton sums up their statements: "as at present conducted the industry is a peril to other countries and to the peasants of Uganda themselves on account of plague". The evidence given in support of these statements is vague and unconvincing and Roberts has investigated the question and come to an entirely different conclusion.

The problem appears to resolve itself into the following questions, to which the present paper attempts to provide an answer:

(1) Is there a correlation between cotton and plague?

(2) Do rats utilize seed cotton and cotton seed, i.e. are these materials attractive to rats, as has been stated?

(3) Do fleas breed in seed cotton and cotton seed?

(4) Are rats and/or fleas more prevalent in cotton centres (ginneries or buying stores) than elsewhere? And do such places serve as distributing centres to neighbouring huts?

(5) Are rats and/or fleas transported in cotton and cotton seed?

(1) Is there a correlation between cotton and plague?

The statistics of cotton production and plague have been examined by Barrett and by Roberts. The former made a graph showing the figures for cotton production (reckoned as bales of lint exported) and plague incidence (as shown by the number of deaths reported to be due to plague) in Uganda from 1910 to 1930, and came to the conclusion that there was a positive correlation between cotton production and plague incidence. Roberts, using the same data, decided that there was no such correlation. Similar figures for the period 1910 to 1935 were submitted to Mr C. G. Hansford, who kindly made a statistical examination of them and states that there is actually a negative correlation ($-0{\cdot}4682$, $P < 0{\cdot}02$) between the two sets of figures.

The historical evidence is also against the positive correlation suggested by Barrett, since plague was rampant in Uganda (as in other parts of East Africa) long before cotton was introduced as a commercial crop.

There is little to be gained from an investigation into the statistics relating to the geographical distribution of plague and cotton. The figures for Uganda are given in Table I and no conclusions can be drawn from them. Two districts (Kigezi and Karamoja) are omitted from the table; they have no plague nor cotton.

Table I. *Statistics of cotton acreage, plague deaths and population in the various districts of Uganda. The figures of population are taken from the* 1931 *census, those for cotton and plague from the annual reports of the Agricultural and Medical Departments*

District	Population (1931 census)	Native population per square mile of land and swamp	Total deaths reported as due to plague	Plague deaths per 1000 of population	Average cotton acreage (unit 1000 acres)	Average cotton acreage per head of population
			1910–24			
Buganda	881,440	50·2	3669	4·2	52·2	0·06
Busoga	381,162	100·3	508	1·3	33·9	0·09
Bukedi: Budama, Bugwere, Bugishu	503,509	130·7	475	0·9	31·7	0·06
Lango	217,354	42·5	3945	18·2	18·3	0·08
Teso	271,431	69·6	4062	15·0	44·7	0·16
Bunyoro	114,700	23·8	154	1·4	2·2	0·02
Gulu	96,739	14·7	0	0	1·4	0·01
Chua	79,082	11·6	0	0	0·6	0·01
			1925–35			
Buganda:						
Mengo	362,666	61·7	7229	19·9	150	0·4
Entebbe	186,511	93·5	383	2·0	60	0·3
Masaka	174,406	42·0	110	0·6	29	0·2
Mubende	155,857	28·5	15	0·1	40	0·3
Eastern Province:						
Bugwere	176,794	145·3	3860	21·8	95	0·5
Teso	271,431	69·6	3169	11·7	111	0·4
Busoga	381,162	100·3	1471	3·9	149	0·4
Budama	148,460	147·3	1186	8·0	46	0·3
Bugishu	178,255	108·5	308	1·7	39	0·2
Northern Province:						
Lango	217,354	42·5	2205	10·1	69	0·3
Bunyoro	114,700	23·8	12	0·1	18	0·2
Gulu	96,739	14·7	0	0	18	0·2
Chua	79,082	11·6	0	0	13	0·2

Separate figures for districts are not always available prior to 1925 and Bugishu is probably included in Bugwere in the plague figures for 1925–29.

More detailed examination of the plague statistics to establish whether plague is connected with proximity to cotton centres would be futile. Cotton centres in Uganda are also centres of dense population, both Indian and African, and there are few areas where cotton is grown which are remote from such centres, the maximum distance being about 15 miles and the average probably in the neighbourhood of 10 miles. It is, therefore, impossible to exclude the possible influence of cotton centres.

(2) DO RATS UTILIZE SEED COTTON AND COTTON SEED?

The normal procedure in Buganda Province with regard to the cotton crop is as follows: The seed cotton is picked, dried in the open, and stored in the owner's house, either in sacks or loose. When the crop is good, the hut is filled with cotton and the inhabitants abandon it and live in a temporary shelter. This period of storage varies from 6 weeks to 4 months. When sold the cotton is either taken direct to the ginnery or stored (for short periods only) at a buying store, usually a temporary building, either with mud-and-wattle walls and a corrugated iron roof or built entirely of corrugated iron. At the ginnery the cotton is placed in a permanent and nominally rat-proof store, where it may remain (either in sacks or loose) for at least 4 months; ginning proceeds throughout this period and a large part of the seed may be burnt as fuel for the engines. The lint is compressed under a pressure of about 2 tons per sq. in. and exported as bales. Of the remaining seed a part is exported in bags, sometimes after a month or so in store, a small part is kept for sowing and some for fuel for the following year; the remainder is heaped up in the open and more or less thoroughly burnt. The seed kept for sowing and for fuel is usually piled on the floor of the "rat-proof" store; it is not kept in native huts for more than a few weeks prior to sowing. The procedure in other provinces is similar, differing mainly in that in some provinces the cotton is stored in granaries and not in the dwelling huts. The buying stores and ginnery stores are supposed to be cleaned at the end of the season and all unwanted cotton seed destroyed, but this is seldom done thoroughly.

(*a*) *Observations*

Baker (1921) states: "There is no doubt that the spread of rats and plague has some connexion with the cotton industry. The recent slump in the cotton trade caused the natives to store their cotton in their houses for months in the hope of obtaining a rise in the market price and this cotton provided a great attraction to rats and possibly a food conducive to prolific breeding."

Vassalo states: "The more extensive cultivation of cotton in this district has provided the Nsolima (*Rattus rattus*) with undoubted facilities for thriving. Apart from the fact that the cotton offers a very good nest, the cotton seed provides excellent nourishment, and in Nsolima and other house-rat nests the cotton seed is very much in evidence, and examination of the cotton seed shows that all the nutritive centre is eaten, nothing but the shell remaining."

Natives report that *R. rattus* steals raw cotton during storage and takes it up into the thatch, where it utilizes it for nest-making and for food. They also state that *Arvicanthis abyssinicus* joins in the theft and makes nests of the cotton in its burrows outside the huts.

The *Annual Medical and Sanitary Report for Uganda* for 1930 (p. 31) affords

an unusual piece of confirmation of the consumption of cotton seed by rats: "Experiments have been carried out in the use of poisoned baits in Kampala. It appears that cotton seed treated with strychnine is readily consumed and poisoned wheat neglected."

I have recently examined over 500 nests of *Rattus rattus* from native huts in Uganda. Over 90 % of these were composed, wholly or in part, of raw cotton and I never failed to find evidence that the seed had been eaten out.

(*b*) *Feeding experiments*

Roberts, working with *R. rattus* in Kenya, found that they were very seriously affected by the consumption of cotton seed. In his first series of experiments, performed with rats from Nairobi township, twenty-one rats were fed on cotton seed and water and all died with symptoms of poisoning within a very short time, the average period of survival being 3·5 days and the maximum 9 days. The controls, on a general diet, remained healthy.

His next experiment was with rats from Mayanga, in a cotton-growing area near to the Uganda border. They were divided into groups of twenty-eight, which were fed on (*a*) cotton seed, (*b*) cotton seed and vegetables, (*c*) a general diet (grain of several kinds, vegetables and cotton seed); water was given in all cases. The experiment was carried on for 10 days. In group (*a*) fourteen had died within 10 days, the remaining fourteen survived. In group (*b*), although all the vegetables offered were consumed, only minute quantities of cotton seed were nibbled at; two rats died after 9 days and one after 10, the remaining twenty-five survived. In group (*c*) only one rat ate cotton seed and it survived; of the remainder, one died after 3 days.

Roberts's experiments are of particular interest in showing a much greater degree of tolerance to cotton seed on the part of rats from a cotton-growing area than in those from an area where no cotton is grown. Of the rats from the cotton-growing area, fourteen out of twenty-eight survived a 10-day cotton-seed diet; he notes that they were transferred thereafter to a general diet and continued to survive.

Post-mortem examinations were carried out on all the rats from the first series of experiments and death was found to be due to poison, presumably from the food supplied.

In view of the difference between Roberts's results with rats from Nairobi and from Mayanga, and especially in view of the fact that (as noted above) cotton seed gnawed by rats had been observed frequently under natural conditions in Uganda, feeding experiments with local *R. rattus* were carried out in Kampala.

The diets used in the first experiments were (*a*) cotton seed, (*b*) cotton seed *plus* ground-nuts, and (*c*) ground-nuts alone; water was supplied in each case. The first experiment was with one rat, and the second with three rats, on each diet; all the rats were caught in a cotton ginnery and were full-grown or nearly so. All survived for a period of 8 weeks; one of those on diet (*a*) died on the last

day of the experiment, apparently from impaction of a tapeworm in the duodenum.[1]

The rats on diet (*b*) ate considerable quantities of cotton seed in spite of the fact that they had a generous ration of ground-nuts, which they never succeeded in wholly consuming. Both these and the rats on diet (*a*) showed a distinct loss of condition. Their faeces were bulky and often contained cotton lint which matted them into strings. There was also a tendency to constipation. In Roberts's experiments many of the rats developed diarrhoea prior to death, thus eliminating mechanical blockage of the intestine as the cause of death. This is somewhat at variance with the experiments detailed above.

At the end of 2 months the diets of the rats were changed as follows: batch (*a*) to mixed diet including green food, batch (*c*) to cotton seed; batch (*b*) was left on an unchanged diet as a control. The observations were continued for 4 weeks. During this period, of the rats transferred from ground-nuts to cotton seed one died after 20 days and another after 24, both were eaten by their comrades, so that the remaining rat was not on a pure diet for the whole period of the experiment. None of the rats on other diets died, and this is particularly worthy of note in the case of the three rats on a diet of cotton seed *plus* ground-nuts, which had now been on this diet for 3 months, during which they ate large quantities of cotton seed.

The faeces produced by the rats began to change almost immediately after the alterations in diet. The change in the droppings of those placed on a mixed diet after a cotton-seed diet was noted on the following day and was practically complete in 4 days. The change-over from the type of faeces characteristic of ground-nuts to that of cotton seed took longer and it was a week before much change was noted; this is to be expected, since both the diets were dry ones.

There was also a change in the general appearance of the rats. Those which had been on the cotton seed diet for 2 months had "staring" fur and were nervous; a week after the change their condition had much improved, their fur was more glossy and they were more active and less nervous. The rats transferred from ground-nuts to cotton seed lost condition and became thin and nervous.

A number of further experiments were performed with rats confined, several together, in cages. In almost every instance deaths occurred and the corpses were eaten. Post-mortem examinations were carried out on five of the rats on a diet of cotton seed which died in this series of experiments; in four rats (three confirmed by histological examination of sections of the intestine) no abnormality was to be found, in the fifth the intestine appeared atrophic and sections showed scattered areas of necrosis and sloughing in the mucosa, no other abnormality was noted. Cultures for pathogenic organisms were done in two instances, including that of the rat with atrophic changes in the intestine, and were negative.

[1] All post-mortem examinations were kindly performed for me by Dr R. S. Hennessey, Assistant Bacteriologist.

In view of the difficulty in obtaining autopsies and in keeping the rats to a strict diet if several were confined together, all subsequent experiments were done with isolated rats and the results of the experiments in which several rats were together have been discarded. Unfortunately this severely limited the number of rats which could be used, only a small number of cages being available. The rats used in these experiments were fed on (*a*) cotton seed (ginned but still retaining a small proportion of lint), (*b*) raw cotton (unginned and with all the lint attached), (*c*) a mixed diet including cotton seed, ground-nuts and sweet potatoes, and (*d*) ground-nuts (controls). Ground-nuts were chosen as the diet for the controls so as to eliminate any favourable influence of a moist or mixed diet; all the rats were kept supplied with water and the cages were cleaned out and fresh food supplied each day. The rats were obtained from Kampala, mostly from ginneries, but a small proportion from native huts and some from a store (on the Government Plantation), which did not contain any cotton. No difference was noted in the survival-rate of rats from the different sources and in practice the difference in source is more apparent than real, since few native huts are not used as cotton stores during the cotton season and the store was in close proximity to such huts. The period of all the experiments was 4 weeks.

During the course of the experiments the greater part of one complete batch of rats died from a bacterial infection; this batch was discarded. Other rats gave birth, ate their young, and were also discarded. In view of the undesirability of having rat-fleas, conceivably plague-infected, in the laboratory all rats were lightly chloroformed immediately before the experiment and the fleas removed. In a number of instances rats were found dead very soon after being placed in the cages; owing to the possibility that they had died from an overdose of chloroform all rats which did not survive at least 2 days are excluded from the results.[1] The results are shown in Table II. The numbers of rats fed on each diet are not very large, and too much reliance must not be placed on the figures, but the deleterious effect of an unmixed diet of raw cotton or cotton seed appears very marked, 39 % of the rats on these diets failing to survive 1 month. In considering these figures it must, however, be noted that 14–15 % of the controls also died, thus a certain number of the deaths are perhaps attributable to causes not connected with the diet. The figures for the mixed diet including cotton seed are particularly interesting since it would appear that the harmful effects of cotton seed are almost entirely eliminated if it is not given exclusively. The rats on this diet showed no objection to cotton seed in addition to their ration and were observed to retain their healthy appearance, in contrast to those on the unmixed diets of raw cotton and cotton seed.

A suggestion has been made (Roberts, p. 400) that the deleterious effects of cotton seed may be connected with its age, new cotton seed being more toxic

[1] On cotton seed seven died on 1st day, one on 2nd and three on 3rd. On raw cotton two died on 1st day, one on 2nd and two on 3rd. On mixed diet two died on 1st day. On ground-nuts three died on 1st day, one on 2nd, one on 3rd.

than old. This possibility has also been investigated by feeding experiments: twenty-two rats were fed on cotton seed which was not less than 6 months old, while some of it was a year old. Sixteen of these 22 rats died during the course of the experiment,[1] whereas of the twenty-one controls fed on a mixed diet only three died. It is particularly worthy of note that nine of the rats on a cotton seed diet died during the first 17 days of the experiment, during which the seed supplied was at least a year old; it is unfortunate that the amount of this seed available was so small that it could not be supplied throughout. In

Table II. Rattus rattus *fed on different diets for a period of* 1 *month.**

Diet	No. of rats used	No. died after 48 hr.	% died	Average survival-period of rats which died days
Ground-nuts	53	8	15	11½
Mixed diet without cotton seed	21	3	14	13
Mixed diet including cotton seed	35	4	11	6
Mixed diet including rotted cotton seed	5	0	0	—
Raw cotton	58	24	41	9
Cotton seed	68	25	34	10
Cotton seed 6 months old or older	22	16	73	14

* All rats which gave birth during the experiment are excluded, as also are a batch which died of a bacterial disease and all those which died less than 2 days from the beginning of the experiment.

this experiment the rats had been captured and chloroformed some weeks previously and then kept on a general diet; the possible effects of chloroform are, therefore, excluded and none died within the first 2 days of the experiment.

A further experiment was performed in order to find out if old decomposed cotton seed (such as is used for manure) is attractive to rats as a food. Five rats were fed on a mixed diet of sweet-potatoes (cooked and raw), ground-nuts, maize, green-stuff and cotton seed. The number of cotton seeds given to each rat was counted and checked when the cage was cleaned out. The seed supplied to the rats was taken from a supply which was being rotted for manure. The experiment lasted 6 weeks, during the whole of which period cotton seed was eaten by each of the rats. None died and none showed any reluctance to eat the seed. On the last day of the experiment each rat was given 25 g. of the seed (which now had been rotting for 6 weeks) and similar samples were retained to determine the loss of weight from drying. After allowing for loss by drying the rats were found to have eaten an average of 10·2 g. of the rotted seed, the minimum amount eaten being 5·3 g. At the end of the experiment the seed was so decomposed as to be unrecognizable as such.

[1] The survivors were kept on the diet for a few days longer and all died.

(3) Do fleas breed in seed cotton and cotton seed?

As has been noted, the bulk of the cotton seed is usually exported almost immediately after ginning. But at times seed may have to be kept for considerable periods, when the godowns become completely full of bags of seed and the surplus is stacked in the open under tarpaulins. The bags in the open are usually removed rapidly, but there is much more delay in the godowns, where new consignments are constantly being stored on top of the old sacks and are removed first, so that the lowest layers of bags are often left for a month or more before export. Seed for fuel and for sowing is stored for much longer periods. In the godowns, and also in cotton stores at ginneries, cleaning up at the end of the season is practically never really thorough; even in the cleaner stores we seldom failed to find seed (perhaps only half a pound) left over from the previous season.

At the times of congestion the mass of bags in the godowns form excellent harbourage for rats and in one such godown seventeen *R. rattus* were caught by hand among the bags. Rat-traces are abundant, the lower layers of bags are often gnawed by rats, and loose cotton seed, much of it rat-gnawed, is scattered on the floor.

In Kampala in February 1934 a number of sacks containing cotton seed from the 1933 crop (i.e. nearly a year old) were found in a corner of a cotton store heavily infested with *R. rattus*; they were piled on pieces of timber which kept them a few inches off the floor. Rats had gnawed holes in the sacks and on the floor underneath was a layer of cotton seed, much of which had been converted into dust by the activities of insects. Rat droppings were present in quantity among the seed. While examining the seed large numbers of fleas were found; the samples collected comprised *Xenopsylla cheopsis* and smaller numbers of *Ctenocephalides felis strongylus*.

This suggested the probability that the dust from old cotton seed is a suitable medium for the development of flea larvae. Further samples of dust and seed from other cotton stores were collected, lightly chloroformed, and searched for fleas. They were then stored in glass jars and kept in the laboratory for 1 month, when they were again chloroformed and a further search made for fleas. As fleas were found during the second search, and had therefore bred in the material, the first search was omitted in subsequent observations.

The results of searches of dusts and sweepings kept in jars for 1 month are shown in Table III. It must be noted that although weights are given in the table they give very little information as to the size of the sample. In many cases the sample was largely composed of such "extraneous matter" as small potatoes, onions, etc., and the proportion of dust was very low. No accurate comparison of cotton-seed samples with samples from other sources can be made, either by weight or by bulk.

The number of fleas in cotton seed appears to depend entirely on the amount of damage by insects, and hence on the degree to which the seed has

been reduced to dust. Samples undamaged by insects were invariably negative for fleas (a large number of such observations, all of which were negative, are omitted from the table as the weight of the samples was not recorded). Samples partially reduced to dust by insects often contained fleas and in one such sample, much damaged by insects and derived from a heavily rat-infested store, fleas (nearly all of the two species most concerned in the transmission

Table III. *Fleas found in various samples of dust and sweepings after retention for* 1 *month. The abbreviations B, C and F indicate* Xenopsylla brasiliensis, X. cheopsis *and* Ctenocephalides felis strongylus *respectively*

Nature of material	No. of samples	Total weight	Rat infestation	Insect damage	Fleas
Cotton seed					
New seed ready for export (two crops)	211	236 lb.	0	Nil	Nil
Current season's seed, mixed with previous season's	1	40 lb.	+ + +	+ + + +	452 (34 *B*, 417 *C*, 1 *F*)
Previous season's seed	14	27½ lb.	+	+ to + +	7 (in two samples; 1 *F*, 6 *B*)
Sweepings from stores and shops other than cotton stores					
From grain stores (chiefly flour and rice with some ground-nuts, beans, pulses, etc.)	6	10 lb.	+	0 to +	39 (in three samples; 38 *C*, 1 *F*)
From provision shops (varied, but mainly *millet*, peas, beans, maize, coffee and ground-nuts)	11	8½ lb.	+ to + +	0 to +	5 *C* (in three samples)
From coffee stores (coffee-beans and buni, not much dust)	7	8½ lb.	+ to + +	0 to +	Nil
From hide stores, dust and hairs mixed with much naphthalene	1	3 oz.	+ +	—	Nil
Similar but mixed with coffee (beans and buni) and without naphthalene	1	2 oz.	+ +	—	Nil

of plague in Uganda) occurred in very large numbers. From the results of these examinations it is clear that insect-damaged cotton seed can be a very prolific breeding-ground for rat-fleas.[1]

Examination of sweepings from shops and stores containing cereals showed that these also commonly breed rat-fleas and that the fleas may be present in considerable numbers—a fact already well known elsewhere.

(4) ARE RATS AND/OR FLEAS MORE PREVALENT IN COTTON CENTRES THAN ELSEWHERE?

Thornton (par. 57) speaks of some cotton-buying centres in the Buganda Province as being "veritable rat-warrens". This is only part of the truth: the same remark applies with equal force to *any* badly constructed store.

A census of the rat population of huts close to and remote from cotton centres has been made and a rat-and-flea survey of ginneries as compared with other types of store has also been carried out.

[1] It is to be noted, however, that Symes & Hopkins record 365 fleas from one rat and that very large numbers of fleas sometimes occur in rat-nests. It is possible that a nest was included in the heavily infested sample.

(*a*) *Rat population of huts near to or remote from ginneries and cotton-buying stores*

Baker (1922) states of *Rattus rattus*: "The local natives said that this species was unknown to them five years ago and attributed its invasion to the erection of ginneries. It is curious that within a mile or so of the cotton ginneries the houses contained twice as many rats as elsewhere." He gives no figures in support of this statement and in any case a statement which was true at the time he wrote, when *R. rattus* is stated to have been comparatively newly introduced, may not be true to-day.

Since *R. rattus* occurs in the walls and floors of huts, as well as in the roof, it is desirable that counts should be done by destroying the hut entirely. This is impracticable for financial reasons, and is unimportant in investigations intended only for purposes of comparison. Investigations were, therefore, confined to removing the roofing of the hut and searching the thatch, the hut being first treated with "Cyanogas" to kill the rats. For the purpose of these observations huts were considered "near" ginneries and stores if within 1 mile and "remote" if 2 miles or more away from them. Huts between 1 and 2 miles away from a ginnery were not examined.

In the course of these investigations it was found that the rat population varied enormously, not only between hut and hut, necessitating the examination of much larger numbers of huts than it was at first thought would be required, but also between districts, even when adequate samples of huts had been examined in each district. For this reason, although huts elsewhere were examined, the results detailed below are those obtained in the Mengo district of Buganda Province. Considerable difficulty was experienced in obtaining sufficient huts for examination, money compensation proving unattractive. The difficulty was largely surmounted by making arrangements to have the hut rethatched immediately after examination.

In all, eighty-one huts near ginneries and forty-seven from ginneries were examined. Naked young in nests are not included in the figures. The following were found:

Rats and mice found	Huts near ginneries	Huts remote from ginneries
Rattus rattus spp.	135	117
Mastomys coucha ugandae	5	1
Average domestic rats per hut	1·7	2·5
Arvicanthis abyssinicus rubescens	2	9
Lemniscomys striatus massaicus	0	1
Grammomys discolor	32	11
Dendromus ruddi	1	6
Leggada bella	10	3
Average field-rats and mice per hut	0·5	0·6

The figures, admittedly inadequate, give absolutely no support to the belief that rats are more abundant in the neighbourhood of ginneries than elsewhere.

An indication that rats may be supplied to the ginnery by the huts, rather than vice versa, is afforded by the following observation: a series of six traps

were set at 10-yard intervals between a ginnery and its labour lines, about 100 yards away. Trap no. 1 was about 7 yards from the nearest hut. The observations only lasted 10 days because the huts were then pulled down. In this period twelve rats were caught, of which ten were caught by trap no. 1 (that nearest to the huts) and two in the trap next to it.

(b) Rat-and-flea survey of ginneries and other stores

The number of rats caught per trap set is sometimes used as an index of rat population. This index is subject to grave disturbance by extraneous factors, of which the most important is probably the amount of alternative food available. In places with much rat damage and quantities of rat droppings we have sometimes caught very few rats, this factor being the probable cause. In addition the rat-per-trap index can only be of significance if the number of traps used is very large. In the work done in Kampala neither staff nor traps were in any way adequate to give this figure any significance. The number of rats caught is, therefore, not further discussed beyond stating that it does not suggest any abnormal prevalence of rats in ginneries and seed stores.

The survey was carried out in Kampala or in its immediate environs: cage-traps were set in six ginneries (including their stores), seven grain stores or shops selling grain and flour, and five hide godowns. In addition the records of a very large number of rats caught in various stores (not including cotton stores) in previous years, and also those of a smaller number of rats caught in ginneries in previous years, have been utilized. The results are shown in Table IV.

Table IV. *Showing the flea population on rats caught in various types of buildings in Kampala and on its outskirts*

	No. of rats caught	% infested	Fleas found		*X. brasiliensis*		*X. cheopis*		No. of fleas of other species
			No.	Index	No.	Index	No.	Index	
hops and stores, not including grain or cotton stores	1250	31	1871	1·5	124	0·1	1724	1·4	22
rain shops and stores	82	49	213	2·6	41	0·5	172	2·1	0
tore on outskirts of town (contents chiefly ground-nuts and beans)	52	77	516	9·9	472	9·1	39	0·7	5
Total (buildings other than ginneries)	1384	40	2600	1·9	637	0·5	1935	1·4	27
innery no. 1 (Kampala)	105	79	811	7·7	155	1·5	650	6·2	4
,, 2 (Kampala)	64	73	327	5·1	51	0·8	275	4·3	1
,, 3 (Kampala)	54	41	81	1·5	9	0·2	71	1·3	1
,, 4 (on outskirts)	148	42	345	2·3	177	1·2	159	1·1	4
,, 5 (on outskirts)	30	—	128	4·3	103	3·4	25	0·8	5
,, 6 (on outskirts)	11	—	17	1·5	8	0·7	4	0·3	0
Total (ginneries)	412	58	1709	4·1	503	1·2	1184	2·9	15

It is obvious that the percentage of infested rats and also the flea-index vary enormously, not only between different types of buildings but also between different ginneries. The table shows a somewhat higher infestation-rate and a much higher flea-index on rats from ginneries than on those from other sources. It is evident that these figures are prejudiced by the fact that many more rats were caught in some ginneries than in others, but even recalculated on the basis

of 100 rats per ginnery the flea-index becomes 3·2, which is still much higher than for all other buildings taken together, but not much higher than that for grain shops and stores and much lower than that for the single store containing ground-nuts and beans.

Summing up, the results cannot be considered conclusive, but they show that ginnery rats have a higher flea-index than those from miscellaneous sources and they direct attention to the rats from grain shops and stores, leaving undecided the question of whether these latter have a genuinely lower infestation-rate and flea-index than those from ginneries. A somewhat startling point which emerges is the extremely high infestation-rate and flea-index of the small number of rats caught in the store which contained ground-nuts and beans.

(5) Are rats and/or fleas transported in cotton and cotton seed?

Baker (1917) reports live rats seen among bags of seed cotton when it was being unloaded from carts at a ginnery. He notes that if rats will travel in carts they will also do so in lake steamers. This has received some confirmation from ginnery employees, several of whom state that they have occasionally seen rats leave bags of cotton which were being unloaded at the ginneries.

In the *Uganda Annual Medical and Sanitary Report* for 1919 (p. 30) there is a record of infected rats being brought ashore in a cargo of hides from a lake steamer and of a case of plague at Jinja, infection having been "almost certainly conveyed there" in a cargo of loose ginned cotton on the same trip. Ginned cotton is no longer carried loose in Uganda but the observation has a bearing on the question of carriage of rats and fleas in seed cotton.

Neilson writes: "Infection in the township outbreak...was brought...in old dirty seed cotton, brought in for ginning to a ginnery inside the town."

To-day the grower packs his bags by hand and as tightly as possible prior to taking them to the ginnery. Carriage by this method is, therefore, unlikely to be frequent.

African observers were stationed at three ginneries at the end of the 1934–35 buying-season, and at three ginneries and a store throughout the 1935–36 season. In the first season they watched 5389 bags being unloaded and in the second season 26,436. No rats were seen.

Carriage of rats to the ginnery in bags of cotton evidently occurs, but appears to be rare.

The pressure under which cotton is baled for export is such that no rat could survive in the bale nor enter subsequently; fleas might not be killed by the pressure but would certainly be unable to escape from the bale. It is, therefore, a reasonable assumption that baled lint can play little or no part in the carriage of rats or fleas. But the point has beeen investigated by Roberts, who examined twelve trucks of cotton lint from Uganda at Mombasa and found no rats nor fleas.

Cotton seed is a much more likely vehicle for rats and fleas. Garnham examined 1434 bags of cotton seed from Uganda and found an average of 11·5 fleas per 100 bags, comprising 9 *Xenopsylla brasiliensis*, 154 *X. cheopis* and single specimens of *Pulex irritans* and *Ctenocephalides felis strongylus*; his investigations were carried out at Kisumu, the lake-port for ships from Uganda to Kenya.

Roberts (1935), working at Mombasa, examined 101 trucks (about 25,250 bags) of cotton seed from Uganda; he observed three specimens of *Rattus rattus* and eight of *Xenopsylla brasiliensis* in these trucks.

It is suggestive that no cases of plague have occurred in ships leaving Mombasa with cargoes of Uganda cotton and cotton seed.

CONCLUSIONS

From the observations and experiments detailed above it is possible to draw deductions which go far towards answering the questions outlined at the beginning of the paper:

(1) Statements as to the existence of a special correlation between the cotton crop and plague in Uganda appear to be unsupported by evidence. So far as the available sources of evidence can be examined they do not support the existence of any direct correlation.

(2) There is no doubt whatsoever that, in Uganda, rats utilize seed cotton and cotton seed to a considerable degree. The raw cotton is used very extensively for nesting material and the seed is habitually eaten, both in the field and in captivity. When placed on a mixed diet which includes seed cotton and cotton seed, *Rattus rattus* showed no aversion to eating the cotton seed, although ample quantities of the other foods were provided.

Cotton seed and raw cotton are not suitable as a pure diet for *R. rattus*, but some rats can survive at least 2 months on cotton seed alone or 3 months on cotton seed and ground-nuts. There is some evidence that provision of alternative foods largely or entirely eliminates the deleterious effects caused by a diet of cotton seed, although in such circumstances the seed is readily eaten.

The evidence suggests strongly that in Nairobi, where no cotton is grown, the effects of a diet of cotton seed are much more lethal than in cotton-growing areas, and that in Kampala *R. rattus* has acquired a considerable degree of immunity to the toxic effects of the diet.

(3) Fleas sometimes breed freely in cotton seed, but only when it is old and partly reduced to dust by insects.

(4) The observations do not support statements that rats are more prevalent in buildings associated with the cotton trade (ginneries and stores) than elsewhere, but there does seem to be a higher average flea population per rat in the case of rats captured in ginneries than in that of rats caught in similar buildings not connected with the cotton trade.

(5) The evidence shows that rats and fleas are not carried in baled lint. They

are sometimes carried among bags of cotton seed, but only in negligible numbers.

(6) The case against the cotton trade in Uganda as a special agency in the dissemination of plague is not proved and is probably false. The condition favouring plague in cotton centres is the same as in relation to other crops: dirt. The danger of dirty conditions does not apply more strongly to cotton centres than to any other similar class of buildings. Any building which is not kept thoroughly clean and in which suitable foods are available to rats is apt to be rat-ridden, to breed fleas in quantity, and to be a focus of plague.

The allegations made with regard to the danger to other countries of the export trade in cotton and cotton seed appear to be wholly groundless. Such danger as there may be is a local problem.

APPENDIX

Notes on post-mortem examinations of rats

By R. S. Hennessey, M.D., M.R.C.P.I.

Seventeen rats which had died while on diets of either cotton seed or raw cotton were examined. The results may be stated briefly as follows:

Cotton seed diet

Post-mortem result	No. of rats
Microscopic evidence of poisoning	7
Intestinal obstruction	1
Nil abnormal on macroscopic examination only	1

Raw cotton diet

Post-mortem result	No. of rats
Microscopic evidence of poisoning	7
Pneumonia	1

The post-mortem findings which were taken as evidence of poisoning were very similar in all rats examined, irrespective of the diet on which the animals had been kept before death. The organs appeared relatively normal on naked-eye examination, but the sections of the small intestine, liver, and kidney showed the following changes:

Intestine. Necrosis and desquamation of epithelium; congestion and (occasionally) haemorrhages into lumen; leucocytic infiltration of submucosa.

Liver. Congestion with focal haemorrhages; some cloudy swelling and early nuclear degeneration.

Kidney. Intense congestion with focal haemorrhages; marked degeneration of tubular epithelium; glomeruli congested, but otherwise normal.

The above changes were present in all the specimens which were sectioned. The general picture was suggestive of the action of a toxic substance causing degenerative changes in the intestinal mucosa and renal tubular epithelium; an acute haemorrhagic reaction had also occurred in these tissues and also in the liver, this phenomenon being most intense in the kidney.

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