THE RELATIONSHIP OF THE COTTON CROP TO PLAGUE, AND ITS ROLE AS A VEHICLE FOR RATS AND FLEAS IN EAST AFRICA

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(With 1 Graph in the Text)

Mombasa is the main port for the East African coast, handling all exports and imports for the two territories, Kenya and Uganda, which are incidentally the worst plague centres in the area. A fair amount of the Tanganyika and Belgian Congo produce also reaches this port. As Mombasa is the receiving centre for all the export trade of Kenya and Uganda, it might be expected that plague, if conveyable in any form or by any means, would appear regularly with the arrival of some of the main crops which are usually considered to be associated with the disease in the interior. Maize and cotton are generally supposed to be connected with the incidence of plague, and it is of particular interest to contrast briefly the figures for the incidence of the disease at the port within recent years and the periods of export of these crops.

During 1929 no human cases of plague were reported from Mombasa. One case occurred during the week ending June 21, 1930, one case in the last week of August 1930, and one case in the week ending September 1, 1930. From this date onwards the port has been free from the disease. The main export season for maize and cotton extends approximately over the period January to June, and two of the cases of plague occurring during this period were reported by the Health Office as immigrants to Mombasa. During the whole period, plague had not ceased to occur regularly at all the cotton-producing centres in Uganda and the maize-growing areas of Kenya. The plague incidence figures for the two colonies are as follows:

Year	Uganda (deaths)	Kenya (cases)
1929	5118	763
1930	2370	959
1931	2299	604
1932	990	281

Although the period of time with which we are dealing appears to be relatively small when considering such a disease as plague, the inference is obvious even over this small interval, when it is remembered that the two years 1929 and 1930 were epidemic years. From this evidence, it appears that plague-infected rats and fleas are either not carried in the main export rops in railway trucks or that they are killed off in the poorly ventilated

space before they reach the port. The latter idea is a very improbable occurrence, since no plague-infected or dead rats have ever been reported by the authorities from these trucks.

Kisumu, at the other end of the railway, which has been until quite recently the receiving port on Lake Victoria for most of the Uganda cotton crop, should also suffer heavily from plague, should this crop in transit act as a vehicle for rats and fleas from the plague-infected areas of Uganda. It has been the practice in the past to unload barges and transfer the bags of cotton seed to railway trucks at Kisumu, but the recent extension of the railway in 1932 allows the crop to be railed direct from the Uganda ginneries to Mombasa at the present time.

In 1929, two human cases of plague were reported from Kisumu, one at the end of August and one at the beginning of September. In 1930 one case occurred in the middle of March to be followed by eighteen more cases spread over a period up to the last week in July, and since then no further cases have been reported from the place. The township lies between two well-known endemic areas, North and South Kavirondo, and at the time of the above cases at Kisumu the Northern Kavirondo area was suffering from a severe epidemic. The proximity of the Northern Kavirondo area and the continuous interchange of human beings and merchandise between these areas possibly had some connection with the occurrence of cases at Kisumu.

The human cases at Mombasa in 1930 occurred at a time when the major portion of the maize and cotton crops had been exported. During 1929 and 1931 the town remained free from the disease, although cases were comparatively common in most of the crop-producing areas inland. No plague was present in any locality nearer Mombasa than Nairobi (over 300 miles distant) at the period when cases were actually being reported at Mombasa. Later, there was an outbreak in the old endemic centre at Voi, but these followed the Mombasa cases. With such a short train journey of only eighteen hours, it seems possible that the cases were contracted in Nairobi or district and the health authorities did indeed trace two out of the three cases definitely as very recent immigrants from Nairobi.

At certain seasons of the year, climatic conditions appear to be favourable to plague transmission at Mombasa, and it must be inferred that the disease is present and augmented periodically by immigrants. But it is only at certain periods, over long terms, that the disease has assumed serious proportions. Mombasa island ranges from 0 to 50 ft. above sea-level, with a mean temperature ranging from 66 to 90° F. and a relative humidity ranging between 70 to 85 per cent. The Table on p. 390 gives the average temperatures, humidity and saturation deficiency figures over a period of ten years.

The India Plague Commission concluded that a plague epidemic is checked when the mean daily temperature passes above 80° F. and usually ends when the temperature reaches 85° F. The mean temperature works in association with a saturation deficiency figure which should not be over 0·3 mm. The

mean temperature for Mombasa is below 80° F. for at least an average of six months in the year.

Months	Average temp. ° F.	Average humidity %	Saturation deficiency mm.	Average rainfall over 34 years in.
Jan.	80·0	77·6	5·7	0·90
Feb.	81·9	74·0	7·2	0·72
Mar.	82·7	76·1	6·9	2·48
Apr.	81·0	79·5	5·5	7·87
May	78·6	84·1	4·0	12·47
June	76·9	83·0	4·0	4·32
July	75·4	83·1	3·8	3·86
Aug.	76·0	82·0	4·0	2·33
Sept.	77·3	81·0	4·5	2·50
Oct.	79·5	77·3	5·7	3·37
Nov.	81·2	79·7	5·5	4·06
Dec.	81·8	77·4	6·0	1·86
				46·74

Survey of Mombasa

A rat and flea survey at Mombasa was continued on similar lines to that carried out for several years (*vide* Symes and Hopkins, 1932) and was essentially connected with buildings, though a few traps were set in the open. Trapping was carried out over a period of eight months in 1930, with the following results:

Rattus rattus. 111 ♂♂ 128 ♀♀ = 239. 83 ♀♀ pregnant; percentage pregnancy = 65 per cent. No. of embryos = 614; average per female = 7·4. 225 ♂♂ 212 ♀♀ *Xenopsylla brasiliensis*; average per rat = 1·8. 105 ♂♂ 109 ♀♀ *X. cheopis*; average per rat = 0·9. Also 4 ♂♂ 8 ♀♀ *X. humilis*, 2 ♀♀ *D. lypusus*, 2 ♀♀ *C. cabirus*, 7 ♂♂ 243 ♀♀ *E. gallinaceus* and 1 ♀ *X. crinita*. 51·1 per cent. of the *R. rattus* trapped were obtained in dwellings and stores made of brick, stone or wood and iron and the remainder, 48·9 per cent., were taken from native dwellings.

Most native huts are built of coral blocks or mud and poles and the more permanent buildings comprise wharf sheds, Arab stone houses, wood and iron buildings, and more modern concrete structures. The trapping figures in the two types of sources distinguished above have almost been equal for the period, but the *X. brasiliensis* index has been twice as great as that for *X. cheopis*.

The dominance of *X. brasiliensis* at Mombasa dispels any doubt that may have existed that this flea is confined to the highlands of East Africa, and fails to establish itself in the hot coastal regions. In India at the present day, this species is reported absent from the Gangetic Plains, Burma and the lowlands of Madras, but there seems to be no reason to doubt that at some period they will invade the coastal regions of Kenya in a similar manner. This gradual numerical increase of *X. brasiliensis* has previously been observed in Mombasa by Symes and Hopkins (1932). They found that up to the end of 1927 its index lay between 1 and 2, and that of *X. cheopis* between 3 and 4,

but from 1928 onwards the position has been gradually reversed so that to-day *X. brasiliensis* is twice as numerous as *X. cheopis.*

It is of some interest to epidemiological studies in Kenya to watch the future of Mombasa in regard to plague, and whether such a factor as the dominance of *X. brasiliensis* can establish endemicity or an epidemic such as the port experienced in 1912. This outbreak was essentially similar to those experienced inland, where *X. brasiliensis* is the vector. The disease progressed very slowly and intermittently during 1912, and not until May and June 1913 did it assume epidemic proportions.

An important fact concerning the 1912 outbreak was the incidence of plague among the several racial communities inhabiting the island:

(1)	Memon and Badali	41 per 1000
(2)	Hindu	35 ,,
(3)	Arab and Shihiri	32 ,,
(4)	Bohora	23 ,,
(5)	Khoja	10 ,,
(6)	Baluch and Sikh	10 ,,
(7)	Goan	5 ,,
(8)	Swahili	3 ,,
(9)	European	Nil

These figures are quoted to indicate conditions even as far back as 1912 in townships, as the racial incidence of plague in other townships in Kenya is of considerable importance, particularly in initiating and perpetuating the disease.

The Medical Officer of Health for that period gave very pertinent reasons for the prevailing state of affairs:

"(1) The large number of immigrant natives of India is ousting the African native from quarters at one time purely African, and a compensatory number of huts are not being built in the new African quarters. This is largely due to poverty brought about by the increased cost of living and increased house rent, so that a vicious circle is formed.

"(2) The Indian immigrants are mostly of the petty trader or pedlar class and using their houses as places of business can afford to and do pay higher rents than the African who formerly had used the same house as a residence.

"(3) Huts, as a result of this process, instead of being occupied by one man and his dependants, are now let out, each room to a number of people at exorbitant rents.

"(4) These altered circumstances lead to most undesirable mixing of the races, so that the cleanly African has to live in close proximity to the constitutionally uncleanly Asiatic."

Present observations do not bear out many of the above statements. Conditions differ, but poverty is rife and the Indian trader has been hard hit by the prevailing world depression so that overcrowding still occurs, in spite of efforts at communal aid amongst the various castes or tribes. The main objection to the statements is that plague has not been known to occur when

a depression has set in. In East Africa plague is essentially a disease of prosperity, so that overcrowding and mixing of races will play but a small part in its incidence.

The flea population of Mombasa suffices to produce an outbreak (index 2·7 per rat for the transmitting species of *Xenopsylla*), and climatically, if the Indian figures are of possible application to Kenya, Mombasa offers the suitable medium. The only important difference between the port and inland endemic plague centres is that the rat density is low.

The fact that Indians use their houses as residences and business quarters is of equal importance to-day. The accumulating evidence for other townships, particularly inland, shows that the Indian community suffers most in premises which are used as homes and shops, particularly food shops, and it has been noted that outbreaks usually start there. There have been several outbreaks of plague among Indian traders in the smaller townships, whilst the surrounding population of Africans remained free. In all these cases the outbreak could be traced to the system of trading and the storage of maize and millet crops, which are brought in by the Africans and either bartered or sold for necessities, the storage of grain usually taking place under very insanitary conditions and in rat-ridden premises.

RATTUS NORVEGICUS. During the survey, 18 ♂♂ and 24 ♀♀ were caught, 24 of which were taken in African quarters, the remainder in buildings of a permanent type, mostly warehouses and dock sheds; 19 ♀♀ were pregnant (79·1 per cent.), with a total count of 144 embryos (average 7·5 per female).

Flea infested were 50 per cent. of *R. norvegicus* and 72 per cent. of *R. rattus* over the same period. 10 ♂♂ 13 ♀♀ *X. brasiliensis* were taken from 8 rats (average 0·5 per rat), whereas 25 ♂♂ 33 ♀♀ *X. cheopis* were taken from 10 rats (average 1·4 per rat). These figures agree with previous surveys when *R. norvegicus* was found to harbour more *X. cheopis* than *X. brasiliensis*. In addition, 2 ♂♂ 5 ♀♀ *D. lypusus* and 1 ♂ 34 ♀♀ *E. gallinaceus* were recorded.

TATERA MOMBASAE. 6 ♂♂ 4 ♀♀ were trapped, 8 from buildings and 2 in the open. Fleas taken: only 1 ♂ *X. humilis*, 2 ♂♂ 1 ♀ *X. brasiliensis*, 5 ♂♂ 4 ♀♀ *X. cheopis*.

CRICETOMYS GAMBIANUS. 1 ♂ 2 ♀♀ were trapped, one rat bore 3 ♂♂ 4 ♀♀ *X. cheopis*, 1 ♂ 1 ♀ *X. crinita* and 1 ♀ *Ct. felis strongylus*, and another bore 2 ♀♀ *Ct. felis*.

Of the total of 136 ♂♂ 158 ♀♀ rats trapped at Mombasa, five only were trapped in the open, and the following total of fleas recorded:

X. brasiliensis	237 ♂♂	226 ♀♀	Average per total rats 1·5
X. cheopis	138 ♂♂	150 ♀♀	Average per total rats 0·9
X. humilis	5 ♂♂	8 ♀♀	
X. crinita	1 ♂♂	10 ♀♀	
D. lypusus	2 ♂♂	7 ♀♀	
C. cabirus		2 ♀♀	
E. gallinaceus	8 ♂♂	277 ♀♀	
Ct. felis		3 ♀♀	
		1074 fleas	

Average of all species of fleas to total rats = 3·6.
The percentage infestation by fleas = 68 %.

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RATS AND FLEAS FROM COTTON SEED FROM UGANDA

An investigation carried out in June 1932 has proved that live rats and fleas can travel in closed railway trucks conveying cotton seed from Uganda. 101 trucks containing cotton seed, 12 trucks with baled lint and 2 trucks with hides were examined. 83 trucks came direct from Uganda stations and 18 contained seed transhipped at Kisumu. The following list gives the localities from whence the seed was railed, together with the average number of days taken by the trucks examined, to reach Mombasa:

Place of loading	No. of trucks examined		Average number of days in transit
Kampala	13		10·3
Namasagali	16		9·5
Nagongera	1		9·0
Namwenda	5		8·6
Nsinze	8		8·0
Kumi	6		9·0
Magodes	8		10·5
Kaliro	4		7·2
Kawolo	2		11·0
Mukono	4		11·0
Kamuli	4		10·0
Mbale	4		7·2
Kachumbala	2		7·5
Soroti	2		7·5
Myanga	1		7·0
Okungulo	1		6·0
Poala	1		11·0
Namaganda	1		8·0
Kisumu	18		6·4
	101	Average	8·6

Average number of bags of cotton seed per truck = 250 bags.
Approximate total of bags examined = 25,250 bags.
Number of rats caught or seen = 3 *R. rattus* from cotton seed.
Number of fleas = 4 ♂♂ 4 ♀♀ *X. brasiliensis* from cotton-seed trucks.

The trucks were placed in a siding on the Kilindini docks in the late afternoon, and white rats and guinea-pigs released to wander over the bags inside the trucks. These animals were recaptured the following morning, during off-loading operations. No examination was possible inside the trucks as these were packed to the roof in many instances, several containing 300 bags and over.

Whilst off-loading was in progress, search was made for damage by rats or of faeces on the bags or floors of trucks. No signs were seen that rats had gnawed holes or that any seed had been eaten in the vicinity of holes caused by the hooks of the loaders. The mouths of the bags generally present an opening for rats to obtain seed and there is little need for them to gnaw through sacking, but there was no evidence that seed had been eaten even at this readily available source.

Rats and guinea-pigs were also released in the empty trucks after off-loading, but no fleas were obtained by this method, nor were faeces observed on the floors.

Only one live *R. rattus* was captured, and this had been nine days in transit from Kumi station, 1 ♀ *X. brasiliensis* being taken from it. Two other rats were seen, but escaped. No rats were captured in cage traps with green vegetable matter as bait when placed inside trucks. From enquiries made on the spot, it appears that live rats do travel down fairly regularly, sometimes one or two a day may be seen when trucks are off-loading.

From white rats and guinea-pigs released in trucks overnight, and captured during off-loading operations the following morning, the following fleas were obtained:

From Nsinze station,	8 days in transit	...	...	1 ♀	*brasiliensis*
From Nsinze station,	6 days in transit	...	...	3 ♂♂ 3 ♀♀	*brasiliensis*
From Kampala station,	11 days in transit	...	...	1 ♂	*brasiliensis*
				4 ♂♂ 4 ♀♀	

On June 7, four open trucks covered with tarpaulins arrived from Kisumu with cotton seed. A very thorough search was made in these trucks, as it has been generally imagined that cotton seed thus conveyed offers opportunities for the ingress of rats at various stopping places en route, and for many to escape should they so desire. No traces whatsoever of rats or faeces were seen.

The following averages were obtained for temperatures and relative humidity in trucks overnight at Mombasa: max. 87° F.; min. 79° F.; rel. hum. 59–76 per cent.

According to the port authorities, only in one season, 1923, has plague ever been suspected as having been carried in cotton seed from Uganda to Mombasa, when a localised outbreak occurred among rats in the docks where cotton seed and maize were being off-loaded.

Thus Mombasa is open to infestation with rats and fleas from up-country districts where plague is endemic, but only on one occasion has any suspicion been attached to the carriage of infected fleas or rats.

The influence of cotton seed on the reservoir and vector of plague

It is apparent from a further consideration of the evidence obtained, that the numbers of rats and fleas carried by such a large quantity of cotton seed from Uganda does not constitute the supposedly serious menace which we have been led to believe exists for Kenya and other countries to which this crop is exported. Plague is never absent from Uganda, but it occurs rarely at Mombasa, and at the particular period of the survey, the trucks examined had been loaded at some of the worst plague centres in Uganda, and it was to be expected that plague would be introduced to the port in some way. The period lapsing between on- and off-loading is longer than the incubation period for plague in rats, and should plague-infected rats be conveyed with cotton seed, they should be found dead on arrival of the trucks at the port.

Several people concerned in the handling of the Uganda cotton crop were interviewed and a search of the records of the Mombasa Health Office showed that there is not a single instance of dead or live plague-infected rats having arrived at the port.

As several eminent writers on the subject of plague affirm that cotton seed is an attractive and desirable food for rats, it is difficult to reconcile the finding of an infinitesimal number of rats or fleas either in trucks or sheds at Mombasa, as compared to the enormous quantity of cotton seed in transit, with hordes of rats both at loading centres and docks. There was also almost an entire absence of rodent faecal matter in the trucks, so that it may be assumed that only a small number of rats could have been present even at the commencement of the journey, allowing for a number to escape in transit, which is very improbable as the trucks are tightly sealed and no holes large enough for a rat to escape were seen. Further, no signs of damage by gnawing were observed on the bags, the greater part of which were new.

Several references are available in literature concerning the influence of the cotton trade on the incidence of plague in East Africa, most of the available information having been collected by Sir Edward Thornton in his report on an investigation into plague in the Protectorate of Uganda. In view of the importance of this trade to Kenya, and more especially Uganda, full quotations of three paragraphs from this report appear justifiable:

"Par. 52. Undoubtedly the spread of plague during the last twenty years has been closely associated with the ramifications of the cotton industry. In 1905 there was no ginnery in Uganda, and cotton was transhipped to the railhead at Kisumu, which was already plague infected.

"Par. 60. *Cotton seed is rat attracting....* With cotton seed it is otherwise, as it often has to be stored for lengthy periods prior to disposal. It is definitely rat-attracting, as it provides a desirable food and ample harbourage for rodents.

"Par. 73. *The weak points connected with the industry from the point of view of preventing plague.* The cotton industry is essential to the prosperity of Uganda, and every effort must necessarily be made to further it in every direction and to free it from all unnecessary and irksome restrictions. But it must also be recognised that as at present conducted the industry is a peril to other countries and to the peasants of Uganda themselves, on account of plague. Apart from the danger of infecting other countries it would be as well to consider the weak points in the position.

"(A) The long periods that often lapse between the issuing of the cotton seed and the actual planting of the cotton.

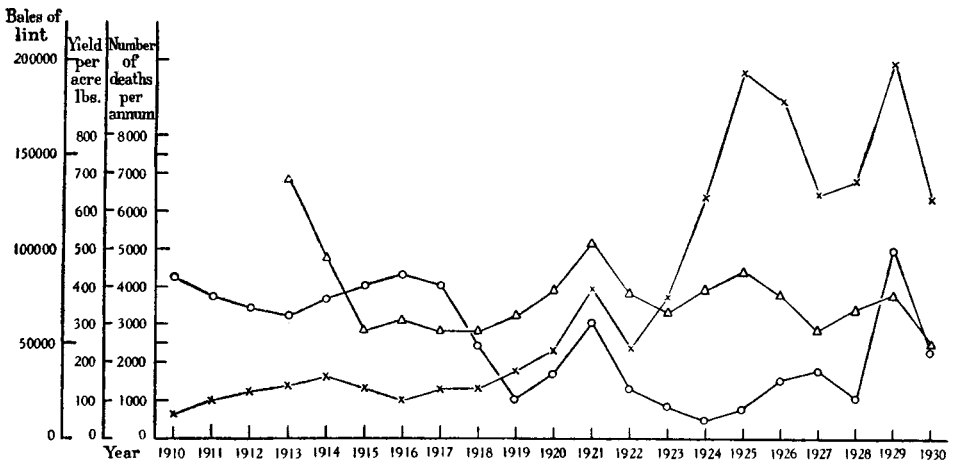
"(B) The storing of seed cotton in the huts after picking.

"(C) The unsatisfactory buying centres in Buganda (Prov. of Uganda)."

Considerable disagreement now exists over matters of particular and vital interest concerning plague in the East African territories arising out of work carried out in Kenya. Thornton states that the spread of plague during the

last twenty years has been closely associated with the ramifications of the cotton industry. He quoted historical data from Milne and Simpson's works and concluded that "Plague is an old standing disease in Uganda, introduced prior to British occupation". There are authentic records of plague being recognised in 1883–6, 1889–90, 1897–9. The first cases of plague during the present outbreak were reported to have occurred at Mbale, Uganda, in 1905. The following figures are taken from the reports of the Agricultural Department, showing the development of the cotton trade:

1902–3.	1 bale (400 lb.) of lint produced.	
1903–4.	2 bales (400 lb.) of lint produced.	
1904–5.	54 bales (400 lb.) of lint produced.	First cases of plague suspected.
1905–6.	248 bales (400 lb.) of lint produced.	Further cases suspected.
1906–7.	978 bales (400 lb.) of lint produced.	According to reports, plague definitely recognised.
1907–8.	3973 bales (400 lb.) of lint produced.	



Graph 1. Showing the relationship of the Uganda cotton crop to plague, 1911–1930.

o——o Number of deaths from plague.
×——× Number of bales of cotton lint.
△——△ Average number of pounds of seed cotton produced per acre.

We may note that it took the authorities of that period three years to recognise plague.

There appears to be but small relationship between these figures, showing the origin of the cotton trade and the onset of plague. The disease had been known to exist previously in districts considerable distances away from where it was first suspected in 1905, and where no cotton had been grown, and it is certainly very doubtful whether the production of a few bales of lint and some seed of an entirely new crop were sufficient to rekindle a disease which had previously existed, or to have had any influence on the 1905 outbreak. As to the further influence of the cotton trade on the incidence of plague, the above Graph is submitted with a view to showing any relationship which may have existed. During years when bumper crops of cotton have been

reaped, it would be expected that such an occurrence would be reflected in a greater number of cases of plague, or even should the acreage production show fluctuations above or below normal, there should be definite agreement over such a period of time.

It is apparent from the Graph that very little connection exists between the number of bales of lint produced, or the yield per acre and the number of plague cases reported.

It is to be regretted that figures are not available to show the relationship between cereals and plague in Uganda. It is roughly estimated by officers of the Uganda Agricultural Department that, normally, an acre of land produces about 1000 lb. of *mtama*, and between 1500 and 2000 lb. of *wimbi*. The acreage for mtama has remained fairly steady over a number of years, but the wimbi acreage has increased almost annually. It can only be conjectured what enormous stocks of these cereals are held in reserve in Uganda, and the approximate total for 1930 is given to show this availability:

1930: 675,000 acres at 1750 lb. per acre produced 527,344 tons wimbi.
240,000 acres at 2000 lb. per acre produced 214,286 tons mtama.

Wimbi and mtama are known and have been proved to be highly desirable foodstuffs for rats, and, although immense acreages of maize are reported for Uganda, the bulk of this commodity is purchased from other countries, particularly Kenya. Should the cotton-crop figures be indicative of any relationship to plague, it is believed that such would be reflected in the greater purchasing power of the native cotton growers, and the consequent hoarding of greater quantities of the prized cereals following good seasons. There will also be greater wastage.

Judging from the figures available there are indications that good years for all food crops are followed by more plague cases. In regard to cotton, years of abundance either in the total amounts produced or in acreage production show disagreement with the rise of plague cases over long periods.

At the conclusion of the Mombasa survey in June 1932 concerning the carriage of rats and fleas in cotton seed, a quantity of the seed was taken back to Nairobi to test its attractiveness to various species of rodents in captivity. These experiments were in the nature of a preliminary test, and are reported as noted on that occasion.

A. 1. vii. 32. Two *R. rattus* (trapped at Nairobi) were fed on a diet of cotton seed and water.
5. vii. 32. One rat dead. Post-mortem signs suggested poisoning, very little food in stomach, and indications that very little of the cotton seed could have been eaten.
6. vii. 32. Second rat dead, with similar symptoms. In both cases a light-coloured faecal matter was present over the fur of rat and cage. Only a very few seeds had been nibbled at.

B. 6. vii. 32. Four *R. rattus* placed in large cage with large quantity of cotton seed and water. On the following day there was evidence that some of the seed had been nibbled at.

8. vii. 32. One rat dead. Diarrhoeal matter on floor of cage—dark coloured.
9. vii. 32. Two rats dead. Diarrhoeal matter on floor of cage—light coloured.
11. vii. 32. Remaining rat dead. Diarrhoeal matter on floor of cage—light coloured. Post-mortem signs very suggestive of poisoning; very little food present in stomachs, and comparatively little cotton seed had been eaten.

C. 7. vii. 32. Two *R. rattus* placed in cage with cotton seed and water.
9. vii. 32. One rat dead. Light-coloured faecal matter on floor of cage.
10. vii. 32. Second rat dead. Light-coloured faecal matter on floor of cage.

These experiments were continued with the following results, utilising rats captured daily from various parts of Nairobi township.

Date when rats segregated with cotton seed and water	Date of death	Number of days taken to die
11. vii. 32	14. vii. 32	3
12. vii. 32	14. vii. 32	2
13. vii. 32	16. vii. 32	3
13. vii. 32	16. vii. 32	3
14. vii. 32	17. vii. 32	3
18. vii. 32	19. vii. 32	1
18. vii. 32	19. vii. 32	1
14. vii. 32	20. vii. 32	6
12. vii. 32	21. vii. 32	9
16. vii. 32	21. vii. 32	5
19. vii. 32	21. vii. 32	2
19. vii. 32	22. vii. 32	3
20. vii. 32	25. vii. 32	5

Number of *R. rattus* fed on cotton seed and water = 21.
Average number of days taken by rats to die = 3·5.

All dead rats from the above experiments were submitted to Dr F. W. Vint, Pathologist to Kenya, who certified the deaths as being due, in each instance, to poison, probably caused by some toxic substance obtained with the food.

A large number of stock *R. rattus* were kept in the same building as the above during the progress of the experiments. They were kept on general diets, with liberal quantities of cereals and vegetables, and no deaths occurred among them. They were regarded as controls.

Judging by the above results, employing Nairobi *R. rattus* and cotton seed, it was apparent that such gratifying results would be objected to on the ground that rats obtained from districts where cotton was grown would show a taste and possibly a certain amount of tolerance to any toxic effect from eating cotton seed. A survey was therefore carried out in one of Kenya's cotton-growing centres in Kavirondo, in order to obtain live rats to repeat the above experiments and to learn something of the rat and flea conditions in such areas.

The locality chosen for the survey was Myanga, which is quite close to the Uganda border in Kavirondo country, and trapping was carried out both at the loading site for cotton on the railway and within villages, remote from the railway, in the vicinity of which cotton was grown annually. Many of the natives were questioned regarding their observations on the food preferences of house rats, and deaths among the rat population. They stated that there were deaths in 1926 and 1929 among the black rat population, and that both years were remarkable for the abundance of crops. They had observed that

rats preferred to eat potatoes, cassava roots, bananas, wimbi[1] and mtama[2] within the huts. Large quantities of wimbi are grown but little mtama. The stores for the bulk of the crops produced are separate from the living huts, and are generally filled with wimbi and mtama in large earthenware pots.

The survey at Myanga was commenced at the station where there is a small trading store carrying the usual ware and a posho (crushed maize) store close by.

In three days, August 10–12, 11 ♂♂ and 7 ♀♀ *R. rattus* were trapped, 15 of which were caught at the posho store and the remainder in living quarters. The following fleas were obtained:

50 ♂♂ 26 ♀♀ *X. brasiliensis*, 8 ♂♂ 9 ♀♀ *X. cheopis*, 1 ♂ *D. lypusus*. The number of traps set was 79, 18 rats being caught, giving a trapping percentage of 21 per cent.

Trapping was carried out in the native reserve at various villages in the vicinity of which cotton was being grown, a total of 165 traps being set, yielding a catch of 88 rats, giving a percentage catch of 53 per cent., 37 ♂♂ 51 ♀♀ *R. rattus* being obtained. With the exception of 1 ♂ and 2 ♀♀ taken in an outside cereal store, the remainder of the rats were all obtained in living quarters, and yielded 126 ♂♂ 64 ♀♀ *X. brasiliensis*, 1 ♀ *D. lypusus*, 1 ♂ *L. segnis*.

An average of 2·2 fleas per rat was thus obtained as compared with 5·5 fleas per rat from those trapped at the station.

The three rats trapped in the outside store yielded 31 ♂♂ and 17 ♀♀ *X. brasiliensis*.

In connection with this small survey of a cotton-growing district, the following features are to be noted:

(*a*) Cotton seed was present on the station premises in readiness for transport to the port of Mombasa. The trapping figure was 21 per cent. and the rats obtained were captured in a "posho" store and living quarters, not a single rat being taken from the cotton-seed warehouse.

(*b*) *X. cheopis* was present on the station premises and absent from the native reserve. The smaller number of rats and greater number of fleas at the station, 21 and 5·5 per cent. respectively, as against the reserve figures, 53 and 2·2 per cent. respectively. Nearly all the rats obtained within the reserve were from living quarters and only three were trapped in stores where cotton seed and cereals were in cribs or earthenware pots.

The following experiments were conducted at Nairobi with live *Rattus* trapped at Myanga station and within the native reserve:

Group A. 28 *R. rattus* fed on cotton seed and water.

Group B. 28 *R. rattus* fed on cotton seed, vegetables and water.

Group C. 28 *R. rattus* fed on general diet, *e.g.* maize, mwele, mtama, wimbi, vegetables and cotton seed.

In group A, each rat was segregated with its food on August 27, 1932,

[1] *Wimbi*, finger millet (*Eleusine coracana*).

[2] *Mtama, Sorghum vulgare.*

and the following deaths recorded after some of the rats had eaten small portions of the cotton seed:

30. viii. 32, 2 dead; 1. ix. 32, 1 dead; 2. ix. 32, 4 dead; 3. ix. 32, 5 dead; 5. ix. 32, 2 dead. On September 5, 14 rats had died within the 10 days, 14 remaining alive. The remainder were then fed on a general diet and remained alive.

In group B, each rat was segregated on August 27 and fed on cotton seed, vegetables and water. All the vegetable matter offered was invariably consumed daily, but only minute quantities of cotton seed would be nibbled at during the course of the experiment.

5. ix. 32, 2 dead; 6. ix. 32, 1 dead. On 6. ix. 32, 25 rats remained alive, and were then put on general diet with no further deaths.

In group C, all types of food supplied. No cotton seed was eaten by 27 of these rats, although several seeds had tooth marks. One rat was found to consume quite an appreciable quantity of cotton seed, together with other foodstuffs, and remained alive.

31. viii. 32, 1 dead. 27 rats remained alive.

All the rats in the above experiments were caged singly.

Discussion

It is well known in agricultural circles that great care is necessary when feeding cotton-seed cake to sheep and calves, and particularly when used as an adulterant to linseed cake. When young animals are fed on cotton seed, it produces anaemia and cachexia, and if given in small repeated doses and death intervenes, changes in the kidneys are noted, with signs of nephritis. An animal eating large quantities of cotton seed suffers from gastro-enteritis as well as inflammation of the kidneys and death generally supervenes.

Even in those rats collected from a cotton-growing area, which survived the 14 days' test on a diet of cotton seed, there was an evident loss of condition and their coats were "staring", but the animals quickly recovered when placed on a general diet. The 50 per cent. survival rate among *Rattus* from a cotton-growing area may possibly be due to greater tolerance to the poisonous "gossypol" in the seed, or that the 100 per cent. deaths among *Rattus* obtained from a non-cotton-growing area would be explained by non-tolerance. However, even the survivors show definite and well-marked symptoms of some derangement in their well-being through partaking of this substance, and the evidence indicates that possibly there may be some other factor besides tolerance. The cotton seed employed in the first tests on Nairobi rats was fresh, it was of that season's crop, and all the rats succumbed, whereas the Myanga rats were fed on cotton seed of unknown date from that area. This introduces a new conception of the whole problem, for should cotton seed lose its toxicity with ageing, then the stocks remaining in a country for the next season's planting, if eaten by rats, might serve as food without causing

apparent ill-effects. Thus it is important to consider the amount of cotton seed which would be available in a country for planting during the following season and the possibility of it acting as a food supply to hordes of rats, which is the first essential in an outbreak of plague.

To trace what happens to cotton seed, from the time of reaping, thus becomes an important factor in any attempts at estimating the influence of the cotton trade on plague, and distinguishing its possible effects on the *Rattus* population. When the cotton seed is reaped, it is stored by natives on their premises for short periods only, not more than a few weeks, then taken to the ginnery for ginning and baling of the lint. All this operation takes but a short time, at the most about six months, and the lint and seed cotton are then ready, the bulk being exported. It is important to remember that cotton seed ready for export was used in the first experiments which proved so highly toxic to rats. Only a very small part of the season's crop is kept behind for planting in the following season, the bulk of the unexported crop being burned in the open. The seed kept for the natives for the next planting is stored at ginneries under conditions which display attempts at rat-proofing methods, or at the stores of the Agricultural Department, and is not issued to natives until close on planting time. Thus, but a small amount of cotton seed is actually kept for a very short time on native premises.

As it takes about six months before the crop is ready for export, up to which time the seed has been proved to be highly toxic, it would appear as if cotton seed should lose its toxicity during the months that follow, before it is planted.

The amount of cotton seed reserved for next season's planting would thus appear to be the only factor in the suggested cotton-plague cycle which might possibly have any influence on the course of plague. But when it is considered that the two territories, Kenya and Uganda, only supply a small fraction of the world's production of cotton, it would be expected that those countries whence the bulk of this crop is derived would also suffer from plague, should there be any connection. At present there is a fair amount of cotton being produced in South Africa, but there is no sign of plague in their cotton-growing areas, the disease being confined to maize-growing districts of the Orange Free State, and in no other area of the world, where cotton is a major crop, has there ever been any suggested association between plague and cotton—Uganda excepted. India also produces large quantities of cotton, but judging from the literature, workers in India do not appear to associate the cotton trade with plague, except in the carriage of fleas, as recorded by Hirst (1933). "Evidently the trade in cotton favours the transference of rats and fleas, particularly *cheopis*. In fact it would appear that weight for weight raw cotton is an even more dangerous vehicle of *cheopis* than grain or any other kind of merchandise." East African experience appears to be at complete variance with Hirst's statement, as *X. cheopis* is strongly represented at cotton-loading centres and is being offered opportunities to travel with seed

cotton, but in the Mombasa survey only *X. brasiliensis* was found in infinitesimal number.

It is regrettable that no specific reasons have been given by various authors for regarding cotton as the most dangerous vehicle for *X. cheopis* or other fleas or that cotton seed is rat attracting. It would be of immense value to all cotton-exporting countries and of international importance to solve this question of the vehicle of fleas and plague, or of any association between the growing and storage of cotton and plague, particularly now in view of the divergences of opinion existing between different sets of workers in different parts of the world.

It may also be pointed out that from a historical point of view of the problem, the evidence is strongly against cotton having any association whatsoever with plague. Plague occurred in East Africa long before the introduction of cotton as a crop. Plague was well in evidence and causing anxiety in parts of the country where no cotton had ever been grown or is being grown to-day. The native populations of both Kenya and Uganda were suffering from a high plague mortality before they had commenced cultivating this crop, and to-day in Kenya plague is only endemic in areas where no cotton is being grown.

The small numbers of rats and fleas taken from a large quantity of cotton seed in transit under conditions which apparently could allow of their ready transference from various up-country stations in Kenya and Uganda to the port of Mombasa, and the fact that the current crop of cotton seed, when fed to rats, has been shown to possess a toxic substance causing death in rats, appear to justify the following conclusions.

Conclusions

1. Cotton seed is *not* a rat-attracting foodstuff, nor does it provide a desirable food.

2. Cotton seed up to the time of export, and for some time after, is toxic to the majority of *Rattus rattus*, and when fed solely or when rats are forced through hunger to nibble at small quantities, a large proportion of them is killed.

3. Cereals and vegetables, if present, are always eaten in preference to cotton seed.

4. The cotton-seed export from Kenya and Uganda can be regarded as guiltless in the carriage or dissemination of plague infection, either through the agency of fleas or rats.

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