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Observations on the possible role of filth flies in the epizootiology of bovine cysticercosis in Kenya

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INTRODUCTION

A prevalent problem in beef-raising areas, particularly in the less developed countries, is that of bovine cysticercosis. In Kenya, a high incidence occurs both in European and African-owned stock (Kenya, 1954–59). The obvious reason for this state of affairs is the large number of Kenya Africans parasitized by the tapeworm *Taenia saginata* Goeze, 1782. In the rural areas, sanitation is primitive or almost non-existent. In the European farming areas, attempts at control have been directed at providing suitable latrines for farm workers with strict enforcement of their use; this has had only limited success since trespassers and labour on farms still deposit faeces indiscriminately.

The circumstances leading to infection of cattle by human faces containing ova of *T. saginata* is not denitely known. Chandler (1929) states that domestic animals, especially cattle, pigs and dogs, habitually devour human faeces, although Miller (1954) does not substantiate this statement with regard to cattle, nor does it seem a common finding according to local stockmen.

Götzsche (1951) suggested that sea-gulls might be responsible for dissemination of tapeworm eggs from sewerage outfalls. Both he and Silverman & Griffiths (1955) were able to produce cysticercosis in experimental animals by feeding droppings from sea-gulls fed with taeniid ova. Dissemination from sewerage and effluent can possibly play a large role in more advanced countries, but in countries such as Kenya with little water-borne sanitation, this can be but a minor factor. Nicoll (1911), who has reviewed fully the earlier literature on the dispersal of helminth ova by flies, corroborates previous findings that flies can carry ova both internally and externally. Shircore (1916), investigating outbreaks of illness due to intestinal parasites in African hospital patients in Mombasa, suspected flies as being the cause of infection. He examined 275 house-flies and found that 10 % harboured helminth ova; 2·9 % of the flies contained ova of *T. saginata* in their intestines. Unfortunately he does not state the species of house-flies examined. More recently, Harris & Down (1946), Heinz (1949) and Pipkin (1949) have confirmed that flies can transmit mechanically both protozoan parasites and helminth ova as large as Ascariid and hookworm. Harada (1954) demonstrated the transport of larvae of *Ancylostoma caninum* by *Calliphora* sp. and *Musca domestica*; he has shown that *Muscina* spp., *Calliphora* spp. and *Sarcophaga* spp. are 'fond of human excreta'. Patton (1931) found that in China *Chrysomyia megacephala* and *Sarcophaga fuscicauda* breed readily in human faeces.

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With special reference to hydatid disease, Schiller (1954) and Heinz & Brauns (1955) have demonstrated the dissemination of ova of *Echinococcus granulosus* by flies and the production of hydatid disease in experimental animals. Schiller's experiments—in which he used the fly *Phormia regina* Meigen—did not show whether eggs were carried internally or externally, although he thought that both methods probably operated. Heinz & Brauns (1955) infected rabbits by mouth with the crushed intestines of *Sarcophaga tibialis* (Macq.).

In Kenya, where filth flies occur in abundance, it would seem that conditions are extremely favourable for the dissemination and spread of ova of *T. saginata* from human faeces to pasture, by these flies.

MATERIALS AND METHODS

Breeding of flies

Three species of filth flies, *Chrysomyia albiceps* Wiedmann, *C. chloropyga* Wiedmann and a species of *Sarcophaga*, and the cockroach, *Blatta germanica* L. were used in the experiments.

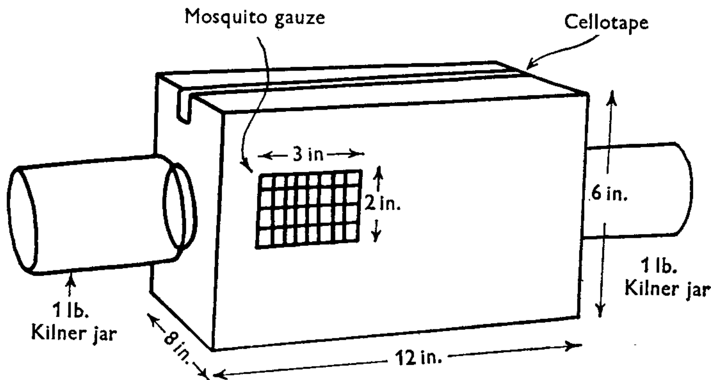

Fig. 1

The flies were bred in collapsible cardboard boxes, 12 in. × 8 in. × 6 in., the top and bottom being sealed with cellotape (Fig. 1). In each of the long sides (12 in. × 6 in.), a small rectangle, 3 in. × 2 in. was cut out and the hole covered with mosquito gauze, the gauze being affixed with cellotape. These windows, situated diametrically opposite each other, facilitated observations of the flies without disturbance. In each end a circular hole was cut of sufficient size to admit the threaded end of a 1 lb. Kilner jar. In practice, it was found that if the hole was cut accurately enough, the jar could be screwed into the hole and did not need any support. In one jar, a piece of raw meat was placed and in the the other, a pad of absorbent cotton-wool covered by muslin, the whole being soaked in a dilute sugar solution. The bottom of the box was covered with half an inch of sterile sand. Flies were introduced by the removal of one of the jars. The jar containing the meat was removed on the first day that eggs were deposited and then subsequently renewed each day. This was effected by covering with a thick cloth, both the box and the

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jar containing the meat, leaving the jar with the pad uncovered. An electric light was then placed close to the latter jar, the flies being thus induced to vacate the jar containing the meat and to move into the box and towards the source of light. At the same time, any dead flies on the bottom of the box were removed. The pad soaked in sugar solution was removed when apparent drying had taken place or when much contaminated with faecal spots. After the removal of the jar containing meat and eggs, its open end was secured by a piece of muslin and left at room temperature (20° C.). When necessary, more meat was added to the culture. As soon as the larvae began to migrate up the sides of the jar, the muslin cover was removed and the jar placed in a glass beaker containing sterile sand. The larvae migrated into the sand and pupated. After migration of larvae had ceased, the beaker was sealed with mosquito gauze and left at room temperature until the flies emerged. Only newly emerged flies were used in the experiments.

The original breeding stock were flies caught out of doors. To avoid any possible contamination with *T. saginata* ova, only the second and subsequent generations of flies were used in experiments.

The specimens of *Blatta germanica* were collected from laboratory food stores and outhouses and were washed before use.

Experimental technique

Flies were given access to ova of *T. saginata* on raw meat, in an emulsion of human faeces, or in dilute sugar solution. Under natural conditions, the number of ova in faeces available to flies is very variable, depending on the number of gravid segments present. In the experiments described here a final concentration of at least 1000 eggs per millilitre of base was used. After variable periods of time the flies were removed from the infective material, lightly anaesthetized with chloroform and washed by being placed in a jar containing water which was then vigorously shaken. The washing process was repeated several times. The flies were then dried on filter-paper and placed in tubes or small jars. This apparently rough treatment did not result in the death of many flies, provided that they were dried immediately after removal from the washing water. Nicoll (1911) has shown that flies very quickly free themselves of faecal material and helminth eggs adhering to the external parts of the body. In the present experiments, all flies examined after washing were free of external contamination. It is concluded that the chances of ova remaining on the external parts after washing are not very great.

The bottoms of the containers were covered by disks of filter paper moistened with a dilute sugar solution, the open ends being covered with mosquito gauze.

Examination of the faecal spots on the disks of filter paper was made by the method of Perez-Fontana (1954). Tests for viability of ova recovered and the criteria for viability were based on those of Silverman (1954).

In the case of the cockroach, *Blatta germanica*, the faecal pellets were emulsified with physiological saline, the emulsion being examined microscopically, drop by drop.

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RESULTS

The ingestion and excretion of ova of Taenia saginata *by cockroaches and flies*

(1) Blatta germanica

Two cockroaches were given access to ova which had been pipetted onto a muslin pad moistened with a dilute sugar solution. After 2 hr. they were removed, washed and transferred to a fresh jar. Faecal pellets were collected 24 hr. later, emulsified with physiological saline and examined microscopically. A total of 31 ova were observed of which nine showed slight signs of fragmentation.

(2) Sarcophaga *sp.*

Six flies were given access to ova in dilute sugar solution for a period of 2 hr. After this time they were removed, washed and transferred, two flies to a tube, in the bottom of which was placed a filter-paper disk moistened with sugar solution; 24 hr. later the disks were removed and examined by the method of Perez-Fontana (1954). In two tubes, five and three ova were observed, while in the third tube no ova were seen.

Table 1

Group A. Removed after 1 hr. access to faeces			Group B. Removed after 18 hr. access to faeces		
No. of hours after removal from faeces	No. flies	No. eggs	No. of hours after removal from faeces	No. flies	No. eggs
18	14	115	—	—	—
42	14	30	22	12	91
66	14	8	46	12	22
90	14	4	70	9	12
114	12	8	94	8	4
138	11	3	118	6	1
162	11	6	142	6	0
186	11	4	166	5	19
210	9	0	190	5	3
234	9	1	214	5	0
258	5	1	238	5	0
282	5*	0	262	5*	0

* All flies died.

(3) Chrysomyia *spp.*

(*a*) Chrysomyia albiceps. Two flies were allowed to feed on raw meat on to which ova had been pipetted. After 2 hr. the flies were removed, washed and then placed in a tube with a small amount of water and allowed to 'paddle' for a further 2 hr. The washings were centrifuged and the deposit examined for ova. The first washing was negative and the second contained two ova. After 3 more hours, the flies were killed and their intestines removed and crushed. On examination, one fly contained two ova and the other twelve, of which one was damaged.

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(*b*) Chrysomyia chloropyga. Two groups of flies were allowed to feed on an emulsion of human faeces containing ova of *T. saginata*. Group A of fourteen flies was removed after 1 hr., washed and transferred to 3 in. × 1 in. glass tubes, three or four flies to each tube. In the bottom of each tube was placed a disk of filter-paper moistened with sugar solution. Group B consisting of twelve flies was removed after 18 hr. access to the faecal material and treated similarly. The flies were washed and transferred daily to clean tubes with fresh disks of filter-paper, The filter-paper disks were examined as previously. Group A continued to void ova in their faeces for 11 days after access to the infecting material, while group B showed ova in their faeces for 8 days following the infective feed. All ova observed appeared normal and unaffected by passage through the flies' intestines.

Viability of ova of Taenia saginata *after ingestion by* Chrysomyia albiceps *and* C. chloropyga

(1) Chrysomyia albiceps

A group of twelve *Chrysomyia albiceps* was fed on ova in dilute sugar solution. After 2 hr. they were washed and transferred to clean jars, each containing a filter-paper disk moistened with saline; 18 hr. later the jars and filter-papers were washed thoroughly and the washings centrifuged at 1000 r.p.m. for 2 min. The residue was tested for viability of the ova by the method of Silverman (1954). Of the eleven ova observed all were hatched, seven showing activation. On a control test with the same sample of ova, though not having been fed to flies, seventy-four out of seventy-five ova were hatched, thirty-nine of which were activated.

(2) Chrysomyia chloropyga

Thirty-three *Chrysomyia chloropyga* were given access to ova in human faeces for 4 hr. After washing, the flies were transferred to jars containing filter-paper moistened with a sugar solution. After the first and each subsequent 24 hr. period, the flies were transferred to clean jars. Used jars were washed, the washings centrifuged and tested for viability as before. The results are given in Table 2. After the third day, the number of ova were so few that no further tests were made.

Table 2

				Hatched					
					Viable				
Hours after feeding	No. of flies	Total of ova and onchospheres observed	Unhatched	Non-viable	On microscopic appearance	Activated	Motile	% total ova hatched	% activated motile of hatched ova
24	33	135	12	6	65	51	1	91·1	42·3
48	22	8	1	1	4	2	0	87·5	0
72	21	3	2	0	1	0	0	33·3	0

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DISCUSSION

The climate of Kenya is extremely suitable for the breeding of filth flies all the year round. A large proportion of Kenya Africans harbour the tapeworm *Taenia saginata* and in the rural areas faeces containing large numbers of ova of this parasite must be deposited on pasture, thus being readily available to flies. Although gravid segments of *T. saginata* are capable of performing limited movements, and as noted by Mazzotti (1944) eggs are extruded through rupture of the uterus when the segments are detached from the strobila, they are not able to move to any great distance. As it seems unlikely that cattle do ingest human excreta as readily as Chandler (1929) states, some form of widespread dispersal from human faeces to pasture must operate, Miller (1954) has shown that dung beetles, (Coleoptera–Scarabaeidae) will remove human faeces and bury them up to a distance of 20 ft. from the site of deposition. It is possible that some eggs would be spread on the ground during this process, but the great majority would probably be buried. Macfie (1922) has shown that the cockroach *Periplaneta americana* is capable of ingesting *T. saginata* ova and voiding them in an apparently unchanged state. In the present study it has been shown that *Blatta germanica* is able to do the same, but since both species are dwellers in and around human habitations, their role in the spread of ova would appear to be small and insignificant, nor would it be expected that they would feed readily on human faeces with so many other sources of food available to them.

It is possible that birds are capable of disseminating ova, although the work of Silverman & Griffiths (1955) suggests that birds with crops do not void viable ova or onchospheres. Nicoll (1911) has shown that *Musca domestica*, *Fannia canicularis* and *Calliphora erythrocephala* will ingest and pass out ova of *Taenia marginata* (*hydatigena*), *T. serrata* (*pisiformis*) and *T. solium* for over 2 days. In the present study, it has been demonstrated that species of *Chrysomyia* will pass ova for up to 11 days after ingestion, and it was possible to show viability of ova up to 3 days after an infective feed. The majority of ova were passed out in the first 3 days, after which the numbers fell off considerably. It was not possible to determine viability after 3 days, since by this time the numbers being passed were few and the process of recovery and testing resulted in the loss of ova. This difficulty did not arise with quantitative counts, since direct observations were made of the filter-papers. Due to the lack of a diagnostic test to detect freedom from cysticercosis of the living animal and the high degree of resistance of adult cattle in Kenya to artificial infection, Urquhart (1959), Froyd & Round (1960) the feeding of recovered ova to cattle was not practicable. Further, the numbers of cysts found after artificial infection are seemingly not corrollated with the numbers of ova fed. Attempts in this Laboratory to infect rabbits and mice, per *os*, subcutaneously and intramuscularly with ova of hatched onchospheres of *T. saginata* have not been successful.

Many workers have determined the viability of *T. saginata* ova under differing conditions. Thus Jepsen & Roth (1952) showed that ova may remain viable in liquid manure for 71 days, 16 days in city sewerage, 33 days in river water and 159 days on pasture. Seddon (1950) quotes various workers in Australia, who found

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that ova may remain alive on pasture in Australia for at least 8 weeks and on dry sunny pastures for $14\frac{1}{2}$ weeks. Chandler (1955) states that they will live on pasture under favourable conditions for 6 months. Duthy & van Someren (1948) have shown that ova of *T. saginata* probably remain viable for about one year on pastures in Kenya. These workers indicated the difficulty of ensuring that calves are free from bovine cysticercosis prior to their use in experiments. The work of Urquhart (1958, 1959), Froyd & Round (1960) has shown that a high proportion of calves in Kenya are found to be infected in the first few weeks of life, even when reared under experimental conditions. It is very likely that Duthy and van Someren used calves which were infected prior to being used in their experiments. Their calves were slaughtered too long after being grazed on the experimental plots for a distinction to be made between cysts due to a previous infection and those originating from ova remaining viable on these pastures and therefore there must be an element of doubt about the validity of their conclusions.

Silverman (1956) has studied the survival of eggs of *T. pisiformis* and *T. saginata* under laboratory conditions, and he has shown that 'irrespective of relative humidity, tapeworm eggs do not survive longer than 14 days in the absence of surface moisture'. When stored in physiological saline at 4° C., eggs of *T. saginata* could be activated after 335 days and at room temperatures they survive for about 60 days. Further, at least 10 min. of heat treatment at 59° C. is required to inactivate taeniid eggs.

During recent years, the dispersal habits of flies have been investigated by Lindquist, Yates & Hoffman (1951), Yates, Lindquist & Butts (1952), Schoof, Siverly & Jensen (1952) Schoof & Siverly (1954 *a*, *b*).

In the course of these investigations random dispersal was observed, showing that *Musca domestica* L. will disperse for 5–20 miles, though the mass fly population moves between 0·5 and 2 miles; *Phormia regina* Meig. for up to 8 miles and *Phaenicia* (*Lucilia*) *sericata* Meig. up to 4 miles.

Studies on dissemination of flies infected with ova of *T. saginata* under natural conditions were not possible in the present work. The habits of filth flies in the field suggest certain happenings. They are positively phototropic, preferring direct sunlight to shade. It can be presumed that after feeding or laying eggs on contaminated faeces, they move to more open ground where they can be observed to rest on grass. Although defaecation occurs at the time of feeding, further deposition of faeces takes place while the flies are resting. Flies will visit both human and cattle faeces. An infected fly feeding on cattle faeces would defaecate at the site, thus depositing ova of *T. saginata*. It is probable that higher concentrations of ova would be found around the sites of human and cattle faeces with diminishing concentrations farther away. Due to the fertilizing properties of the excrement, the flush of new grass around such sites would encourage cattle to feed there, with subsequent increase in the chances of ingesting viable ova of *T. saginata*.

Two factors are thus required for the dissemination of ova by filth flies. These are: a large filth fly population and human faeces contaminated with ova. In addition, the spread will be facilitated by the dispersal habits of the flies and the longevity of ova on pasture.

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SUMMARY

The literature on the dissemination of helminth ova by flies is reviewed. In experiments using various species of filth flies, it was shown that ova of *Taenia saginata* Goeze 1782 can be passed out for periods of up to 11 days after ingestion, and viability of such ova was demonstrated for three days after ingestion. The possible methods of dissemination of ova are discussed together with the longevity of ova on pasture and the dispersal habits of flies. It is suggested that in Kenya, filth flies may play an important role in the epizootiology of bovine cysticercosis.

Permission to publish this paper is given by the Director of Veterinary Services, Kenya.

REFERENCES

Chandler, A. C. (1929). *Hookworm Disease*, p. 161. London: Macmillan.

Chandler, A. C. (1955). *Introduction to Parasitology*, 9th edn. New York: John Wiley and Sons.

Duthy, B. L. & van Someren, V. D. (1948). The survival of *Taenia saginata* eggs on open pasture. *E. Afr. agric. J.* **13**, 147.

Froyd, G. & Round, M. C. (1960). The artificial infection of adult cattle with *Cysticercus bovis*. *Res. vet. Sci.* **1**, 275.

Götzsche, N. O. (1951). Bidrag til *Taenia saginata's* epidemiologi. *Nord. Vetmed.* **3**, 957. (Cited by Silverman, P. H. & Griffiths, R. B. (1955). *Ann. trop. Med. Parasit.* **49**, 436.)

Harada, F. (1954). Investigations of hookworm larvae. IV. On the fly as a carrier of infective larvae. *Yokohama med. Bull.* **5**, 282. (Abstr. in *Helminth. Abstr.* **23**, 239; abstr. no. 528*b*).

Harris, A. H. & Down, H. A. (1946). Studies on the dissemination of cysts and ova of human intestinal parasites by flies in various localities on Guam. *Amer. J. trop. Med.* **26**, 789.

Heinz, H. J. (1949). Methodik zur Untersuchung des Darminhaltes von Fliegen auf pathogene Darmprotozoen des Menschen. *Zbl. Bakt.* (1. *Abt. Orig.*), **153**, 106. (Cited by Heinz, H. J. & Brauns, W. (1955). *S. Afr. J. med. Sci.* **20**, 131.)

Heinz, H. J. & Brauns, W. (1955). The ability of flies to transmit ova of *Echinococcus granulosus* to human foods. *S. Afr. J. med. Sci.* **20**, 131.

Jepsen, A. & Roth, H. (1952). Epizootiology of *Cysticercus bovis*—resistance of the eggs of *Taenia saginata*. *Rep. 14th Int. Vet. Congr., Lond.*, 1949, **2**, p. 43. H.M.S.O.

Kenya (1954–59). *Vet. Dep. Ann. Reps.* 1954, 1955, 1956, 1957, 1958, 1959.

Lindquist, A. W., Yates, W. W. & Hoffman, R. A. (1951). Studies of the flight habits of three species of flies tagged with radio-active phosphorus. *J. econ. Ent.* **44**, 397.

Macfie, J. W. S. (1922). Observations on the role of cockroaches in disease. *Ann. trop. Med. Parasit.* **16**, 441.

Mazzotti, L. (1944). Observaciones en 10 individuos parasitados con *Taenia saginata*. *Rev. Inst. Salubr. Enferm. trop., Méx.*, **5**, 207. (Cited in *Veterinary Parasitology*, 1956, p. 298, by Lapaze, G. Edinburgh: Oliver and Boyd.)

Miller, A. (1954). Dung beetles (*Coleoptera, Scarabaeidae*) and other insects in relation to human faeces in a hookworm area of Southern Georgia. *Amer. J. trop. Med. Hyg.* **3**, 372.

Nicoll, W. (1911). *Report to the Local Government Board on Public Health and Medical Subjects.* (New series, no. 53.) *Further Reports* (no. 4) on Flies as Carriers of Infection. London: H.M.S.O.

Patton, W. S. (1931). *Insects, Ticks, Mites and venomous Animals of Medical and Veterinary Importance.* Pt II. Public Health, p. 624. Liverpool School of Tropical Medicine.

Perez-Fontana, V. (1954). Investigations on eggs of helminths with special reference to the epidemiology of Hydatid disease. *Amer. J. trop. Med. Hyg.* **3**, 762.

Pipkin, A. C. (1949). Experimental studies on the role of filth flies in the transmission of *Endamoeba histolytica*. *Amer. J. Hyg.* **49**, 255.

https://doi.org/10.1017/S0022172400039206 Published online by Cambridge University Press

SCHILLER, E. L. (1954). Studies on the helminth fauna of Alaska. XIX. An experimental study on blowfly (*Phormia regina*) transmission of hydatid disease. *Exp. Parasit.* **3**, 161.

SCHOOF, H. F., SIVERLY, R. E. & JENSEN, J. A. (1952). Housefly dispersion studies in metropolitan areas. *J. econ. Ent.* **45**, 675.

SCHOOF, H. F. & SIVERLY, R. E. (1954 *a*). Multiple release studies on the dispersion of *Musca domestica* at Phoenix, Arizona. *J. Econ. Ent.* **47**, 830.

SCHOOF, H. F. & SIVERLY, R. E. (1954*b*). Urban fly dispersion studies with special reference to movement pattern of *Musca domestica*. *Amer. J. trop. Med. Hyg.* **3**, 539.

SEDDON, H. R. (1950). *Disease of Animals in Australia*, Pt I. *Helminth Infestations*, Publication no. 5. *Commonwealth of Australia, Dep. of Health Service Publication* (*Division of Veterinary Hygiene*), no. 6. (Cited in Monnig's *Veterinary Helminthology and Entomology*, 4th ed. (ed. G. Lapage). London: Baillière, Tindall and Cox, 1956.)

SILVERMAN, P. H. (1954). Studies on the biology of some tapeworms of the genus *Taenia*. I. Factors affecting the hatching and activation of Taeniid ova, and some criteria of their viability. *Ann. trop. Med. Parasit.* **48**, 207.

SILVERMAN, P. H. (1956). The longevity of eggs of *Taenia pisiformis* and *T. saginata* under various conditions. *Trans. R. Soc. trop. Med. Hyg.* **50**, 8.

SILVERMAN, P. H. & GRIFFITHS, R. B. (1955). A review of methods of sewerage disposal in Great Britain with special reference to the epizootiology of *Cysticercus bovis*. *Ann. trop. Med. Parasit.* **49**, 436.

SHIRCORE, T. O. (1916). A note on some helminthic diseases with special reference to the housefly as the natural carrier of the ova. *Parasitology*, **8**, 239.

URQUHART, G. M. (1958). The production of experimental cysticercosis in calves in Kenya. *Bull epiz. Dis. Afr.* **6**, 385.

URQUHART, G. M. (1959). Cysticercosis in cattle and pigs in Africa. Paper presented at the IACED/IBED. *Helminthological Symposium, Nairobi, Kenya*, July 1959.

YATES, W. W., LINDQUIST, A. W. & BUTTS, J. S. (1952). Further studies of dispersion of flies tagged with radioactive phosphoric acid. *J. econ. Ent.* **45**, 547.

https://doi.org/10.1017/S0022172400039206 Published online by Cambridge University Press