Bull. Org. mond. Santé } 1970, **42**, 589-596
Bull. Wld Hlth Org. }

The Development of Snail Control Methods on an Irrigated Sugar-Cane Estate in Northern Tanzania*

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In an attempt to prevent the transmission of Schistosoma mansoni *on an irrigated sugar-cane estate, molluscicide experiments were carried out to find the optimum methods for controlling the intermediate-host snails,* Biomphalaria pfeifferi. *The ease of application of* N-*tritylmorpholine led to its adoption as the molluscicide of choice for the two separate irrigation systems on the estate. Experiments on the frequency and duration of molluscicide treatments were carried out, and from these it was concluded that 5-day applications of* N-*tritylmorpholine at 0.025 ppm every 7 weeks might lead to a break in transmission by control of the snails.*

In another set of trials, drainage ditches were treated alternately with N-*tritylmorpholine and niclosamide ethanolamine salt, and although the chemicals differed only slightly in their effect, the latter—being ovicidal—was chosen to be applied at approximately 4 ppm by knapsack sprayer every 8 weeks. Extra treatment of small pools with the same compound was carried out during the long rains when irrigation was unnecessary and most of the canals were dry.*

It is pointed out that the effect of the control methods on S. mansoni *transmission will need to be evaluated by studying the incidence of the disease in the population.*

Sugar has been produced at the Tanganyika Planting Company since 1936. The estate is now 3600 ha in area and is situated 15 miles (about 25 km) due south of Moshi, a town in the shadow of Kilimanjaro in the Northern Region of Tanzania. The rainfall is usually about 450 mm per annum and a further 2000 mm are added by irrigation with water taken from a river which runs off Kilimanjaro. Except during the rains in April, May and sometimes June about 100–120 ft^3/s (i.e., 2800–3400 l/s) are taken continually at the intakes, with water in excess of immediate requirements being stored in reservoirs overnight. Water is distributed in open canals by gravity and some parts of the estate require drainage ditches to remove excess water. The reservoirs and many kilometres of irrigation canals and drainage ditches form excellent habitats for aquatic snails; the 5 species found are listed in Table 1, where their medical and veterinary importance is also shown.

TABLE 1
SNAIL SPECIES PRESENT ON THE TANGANYIKA PLANTING CO. SUGAR ESTATE

Snail species in order of abundance	Relative frequency	Medical and veterinary importance
Biomphalaria pfeifferi	Abundant	Intermediate host of *S. mansoni*
Bulinus (B.) tropicus	Abundant	Nil; but related to the intermediate host of *S. haematobium*
Lymnaea natalensis	Very common	Intermediate host of *Fasciola gigantica*
Cleopatra ferruginea	Common	Nil
Melanoides tuberculata	Common	Nil

In the absence of chemical snail control, the 5 species thrive throughout the estate during the dry period from June to March. During the long rains the intakes from the river are closed as the rainfall is usually sufficient to maintain the sugar-cane growth. Most of the canals then dry out and the reservoirs are cleaned and weeds removed. Most

* The work reported was assisted by a grant from the World Health Organization.

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snails are killed by desiccation except in pools shaded from the heat of the sun by weeds or sugarcane. Other pockets of snails survive in concrete sumps where the canals are bridged by roads.

The aim of the experiments now reported was to determine the optimum methods of applying molluscicide to the snail habitats on the estate in order to achieve a level of snail control which might lead to a complete break in transmission of *Schistosoma mansoni*. To this end, molluscicide trials were carried out in the different types of canals—the irrigation systems and the drainage systems.

THE IRRIGATION SYSTEMS

The 3600 ha are irrigated by 2 separate irrigation systems—the New Area and the Old Area. Each has its own water intake from the river and its own reservoirs and each irrigates half the estate.

Crossland (1963) treated the New Area with niclosamide ethanolamine salt at a concentration of 8 ppm-h. The procedure involved draining the canals and reservoirs before applying the molluscicide from a motorized dispenser to the water as each reservoir in turn was refilled. The treatment took 6 days and required skilled water management and considerable manpower. Most of the New Area remained free of snails for 7 months and pretreatment levels were not reached until 12 months after treatment. A breakdown occurred in one small area, however, and *Biomphalaria pfeifferi* were found 8 weeks after the treatment. Despite focal spraying they reappeared in large numbers within a further 6 weeks.

In a second large-scale trial in the New Area (Crossland, 1967), *N*-tritylmorpholine (Frescon) was applied as an emulsifiable concentrate (FX 28), at the headwater, using a drip-feed dispenser at 0.025 ppm continuously for 30 days. Adult *B. pfeifferi* were all killed in the first 6 days and the rest of the treatment was aimed at the snail eggs that this non-ovicidal chemical failed to kill.

The first live snails were found 2 months after the completion of the application but after 4½ months the population was still low compared with pretreatment levels.

In both the above trials the Old Area was left untreated as a control area.

After consideration of the details of the above 2 experiments, *N*-tritylmorpholine was chosen for use in the irrigation systems for two main reasons:

1. Ease of application. A treatment with *N*-tritylmorpholine required no complicated water management and the managers on the estate were not involved with emptying and refilling the system or an interruption to normal irrigation methods. One headman (supervisor) applied the chemical by reading the water flow from a weir, quickly calculating the volume of molluscicide required and then adding the chemical to the drums and topping up with water. This simplicity and ease of application is an important consideration in an estate of this type.

2. Safety margins. The application of molluscicide at regular intervals to the irrigation system would make the effect of missing a pocket of snails less dangerous than, say, biannual application of niclosamide ethanolamine salt. Any survivors would be subjected to another treatment within a matter of weeks with the anticipated regime of *N*-tritylmorpholine whereas it would be 6 months before those snails would be attacked with biannual treatments and in that time *Schistosoma* transmission could have been continued.

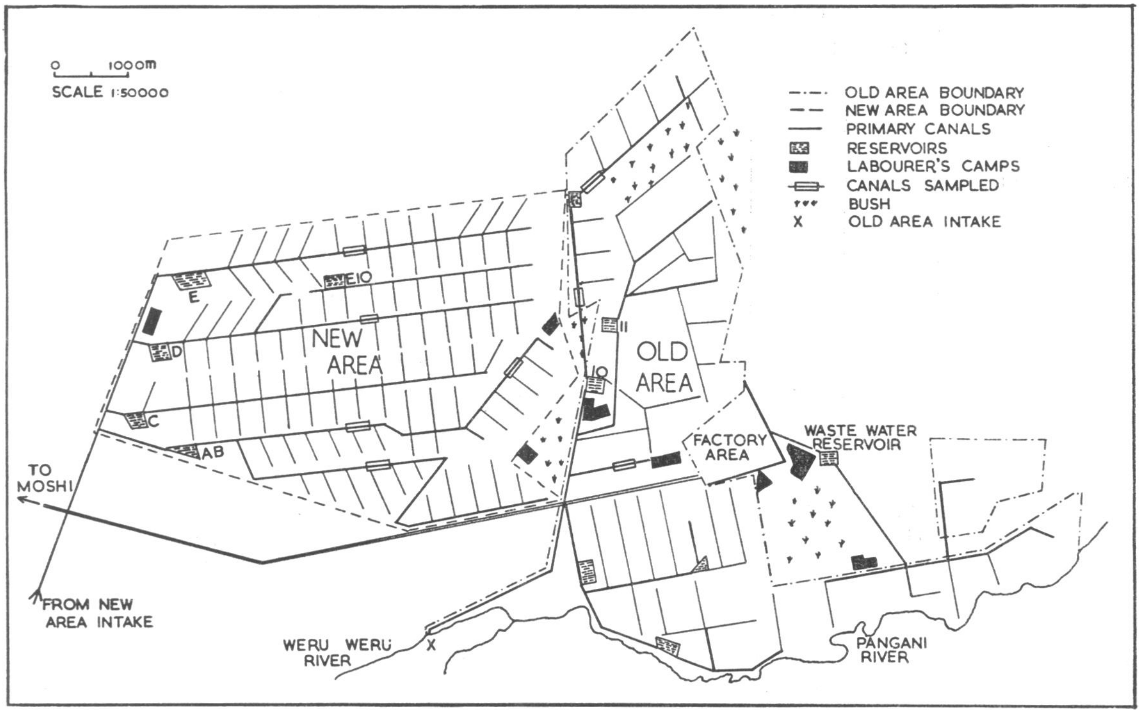
A series of experiments were designed (*a*) to determine the optimum number of days per treatment to kill all adult *Biomphalaria* snails in the canals and reservoirs, and (*b*) to study the frequency of treatments necessary to give effective control and hence break the transmission cycle.

Methods

Snail sampling started in August 1966 and continued thereafter. Canals in the Old and New Areas were chosen to provide a representative sample of canals on the estate and to include those which, in previous experiments, were sites of early snail repopulation (Fig. 1). The method used was that of Crossland (1962), in which 3 mud plugs were taken every 10 yards (9 m) along a 500-yard (457-m) stretch of chosen canal. At each location the plugs were combined in a sieve, washed, and the live and dead snails counted. The values shown in the tables are the totals of 50 such combinations along each stretch of canal.

Treatment was effected at the river intakes of both areas. Two 44-UK-gal drums were connected in parallel to one exit pipe with a nozzle to give a flow of 280 ml/minute (88 UK-gal/24 h). A nozzle of size 9 was large enough to avoid clogging. The water flow in the main furrow was measured at a weir and 0.5 UK gal (2.3 l) *N*-tritylmorpholine

FIG. 1
SKETCH MAP OF EXPERIMENTAL AREA AT TANGANYIKA PLANTING CO.



placed in each drum per 12.5 ft^3/s (354 l/s) of flow. The drums were then topped up with water (sieved to prevent nozzle-blocking by grass etc.) and the chemical was allowed to flow out. A steady emission rate was maintained by using the constant-head principle. The drums were recharged every 24 hours for the duration of the treatment.

Results

The first trial was with 0.025 ppm for 3 days in the Old Area. The results in Table 2 show that snails in Camp 9 furrow and the inlet furrow to Reservoir 10 were killed but not those in 11E, 16B and the exit furrow from Reservoir 10 (see Fig. 1). The first 2 furrows (camp 9 and inlet Res. 10) were fed directly from the river intake but the other 3 (11E, 16B, exit Res. 10) were fed from a reservoir in which the dilution effect was apparently too great to allow the chemical to leave the reservoir at a lethal level. However, over 50% of *Biomphalaria* were killed, indicating that the dose was near the required concentration. Other snails, mostly *Bulinus tropicus*, were hardly affected by the treatment. The next treatment was of 4 days' duration at 0.025 ppm in the New Area, and when the snails had repopulated the canals a 5-day treatment was applied. The results of snail counts (*B. pfeifferi* and total snail count) in 6 canals plus 1 reservoir are shown in Table 3. From this table it can be seen that there was little difference in the snail-free period achieved, as *Biomphalaria* were in all canals 36–42 days after the treatments.

From the results it was decided to stick to 5-day rather than 4-day applications because, since the aim was to achieve a break in *Schistosoma* transmission, it would probably be better to have a 1-day safety margin to allow for complete coverage of the estate.

The next 4 treatments of the New Area were all of 5 days' duration to test the effect of changing the interval between treatments. All previous applications had been made after repopulation by adult snails but now 2 treatments of 5 days each were applied with an interval of 14 days between them.

TABLE 2

RESULTS [a] OF A 3-DAY TREATMENT OF THE OLD AREA WITH 0.025 ppm *N*-TRITYLMORPHOLINE

Time of sampling	Fed directly from the inlet				Buffered by a reservoir between furrow and inlet					
	Camp 9 furrow		Inlet Res. 10		11E furrow		16B furrow		Exit Res. 10	
	Biom.	Total	*Biom.*	Total	*Biom.*	Total	*Biom.*	Total	*Biom.*	Total
Pretreatment	68	203	75	189	276	932	741	2 202	503	1 181
Post-treatment:										
3 days	0	69	0	20	42	524	295	1 680	158	585
7 days	0	80	0	38	140	544	163	1 427	130	465
2nd week	7	128	0	27	154	537	73	828	108	488
3rd week	6	150	0	28						

[a] Expressed as numbers of live snails found in selected canals.

TABLE 3

COMBINED SNAIL COUNTS IN 6 CANALS AND 1 RESERVOIR IN THE NEW AREA FOLLOWING A 4-DAY AND THEN A 5-DAY TREATMENT WITH *N*-TRITYLMORPHOLINE AT 0.025 ppm

Time of sampling	*B. pfeifferi*	Total snails
Pretreatment	860	2 691
4-day treatment at 0.025 ppm		
Post-treatment:		
1 week	0	352
2 weeks	0	528
3 weeks	0	647
4 weeks	120	753
5 weeks	276	991
5-day treatment at 0.025 ppm		
1 week	0	367
2 weeks	0	389
3 weeks	4	481
4 weeks	29	520
5 weeks	70	626
6 weeks	253	1 176
7 weeks	375	1 628

The first treatment was aimed at the adult snail population, and the second at young snails hatched from the surviving egg masses. Most of the snail eggs in the area under study hatch within 11–17 days of laying so that if the hatchlings could all be destroyed before any snails reached maturity it was

TABLE 4

COMBINED SNAIL COUNTS IN 6 CANALS AND 1 RESERVOIR IN THE NEW AREA FOLLOWING 5-DAY TREATMENTS AT 14 DAYS' INTERVAL WITH *N*-TRITYLMORPHOLINE AT 0.025 ppm [a]

Time of sampling	*B. pfeifferi*	Total snails
Pretreatment	638	2 429
5-day treatment at 0.025 ppm		
Post-treatment:		
1 week	—	—
2 weeks	0	462
5-day treatment at 0.025 ppm		
3 weeks	2	664
4 weeks	0	445
5 weeks	0	562
6 weeks	0	595
7 weeks	0	654
8 weeks	0	912
9 weeks	0	812
10 weeks	0	1 459
11 weeks	—	—
12 weeks	52	1 363
13 weeks	93	1 392
14 weeks	175 [b]	1 459 [b]

[a] The dash (—) indicates that no sampling was carried out during the week shown, owing to redeployment of staff on drainage ditch treatments or to public holidays etc.

[b] Corrected figures; 2 canals were not sampled.

TABLE 5

COMBINED SNAIL COUNTS FOR 6 CANALS AND 1 RESERVOIR IN THE NEW AREA FOLLOWING 5-DAY TREATMENTS WITH *N*-TRITYLMORPHOLINE AT 0.025 ppm ON 2 OCCASIONS 66 DAYS APART

Time of sampling	*B. pfeifferi*	Total snails
Pretreatment	830	2 477
5-day treatment at 0.025 ppm		
Post-treatment:		
1 week	—	—
2 weeks	0	166
3 weeks	0	221
4 weeks	—	—
5 weeks	0 [b]	303 [b]
6 weeks	—	—
7 weeks	0	439
8 weeks	70	667
9 weeks	132	763
10 weeks	149	775
5-day treatment at 0.025 ppm during 10th week		
11 weeks	—	—
12 weeks	0	133
13 weeks	0	98
14 weeks	0	167
15 weeks	0	298
16 weeks	14	484
17 weeks	66	542
18 weeks	100	610
19 weeks	112	651

[a] The dash (—) indicates that no sampling was carried out during the week shown, owing to redeployment of staff on drainage ditch treatments or to public holidays etc.

[b] Corrected figures; 2 canals were not sampled.

TABLE 6

COMBINED SNAIL COUNTS FOR 4 CANALS AND 1 RESERVOIR IN THE OLD AREA FOLLOWING 5-DAY TREATMENTS WITH *N*-TRITYLMORPHOLINE AT 0.025 ppm ON 2 OCCASIONS 55 DAYS APART

Time of sampling	*B. pfeifferi*	Total snails
Pretreatment	235	847
5-day treatment at 0.025 ppm		
Post-treatment:		
1 week	0	186
2 weeks	0	206
3 weeks	0	271
4 weeks	0	288
5 weeks	0	348
6 weeks	43	418
7 weeks	95	546
8 weeks	211	690
5-day treatment at 0.025 ppm during 8th week		
9 weeks	0	63
10 weeks	0	69
11 weeks	0	116
12 weeks	0	139
13 weeks	0	139
14 weeks	0	159
15 weeks	30	397
16 weeks	86	557
17 weeks	73	531
18 weeks	102	615

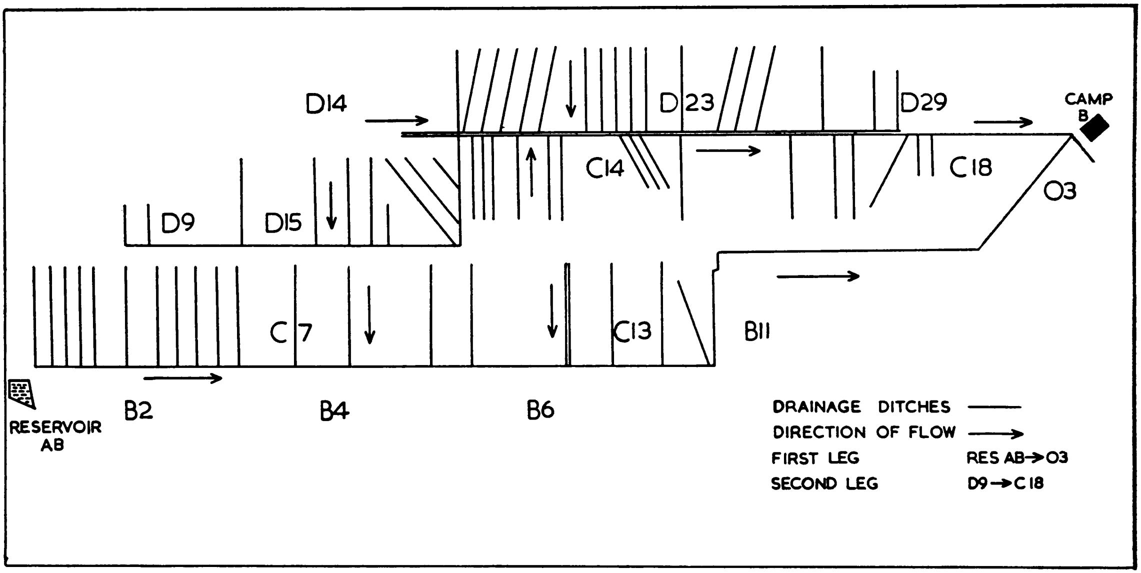
thought that the snail-free period might be extended. For direct comparison, single 5-day applications were made on 2 occasions 66 days apart in the New Area and on 2 occasions 55 days apart in the Old Area when conditions were suitable after the rains.

The results in Table 4 indicate that two 5-day applications 14 days apart w.ll give a snail-free period of 11 weeks. Over a year, then, 4 such double applications would be required to keep the canals snail-free. This would mean 40 treatment days per year.

From Table 5 it will be seen that single 5-day applications produced snail-free periods of 7 and 5 weeks, and from Table 6 that the same dosage in the Old Area resulted in 5-week and 6-week snail-free periods. Thus a treatment regime of 5 days of *N*-tritylmorpholine every 7 weeks might keep the estate snail-free for all except the 7–14 days prior to treatment, when a few *Biomphalaria pfeifferi* would be present. Over a full year 7–8 such treatments would be required (35–40 treatment-days) but, assuming normal long rains, this would be reduced to 6 treatments (30 treatment-days) given a 10-week irrigation-free period during April, May and June.

Therefore a single 5-day treatment every 7 weeks was adopted as standard procedure in preference to the double dosage of 5 days with a 14-day interval applied every 11–12 weeks. The annual cost of this

FIG. 2
DRAINAGE DITCHES IN "NEW AREA"



routine mollusciciding would be £1680 [1] at a maximum of £56 per treatment day for 30 days.

THE DRAINAGE DITCHES

In the areas of the estate liable to flooding, drains have been constructed into the fields to remove excess water due to irrigation or heavy rainfall.

These ditches are far fewer in number than the irrigation canals, and most of them are situated in the New Area. Two branches of the drainage systems were chosen for treatment (Fig. 2). The aim of the treatments was to compare the effectiveness of *N*-tritylmorpholine and of the ethanolamine salt of niclosamide (Bayluscide) in this type of habitat. To do this, each branch was treated alternately with the two chemicals.

Methods

In the drainage systems the water flows from the small ditches into the large main drains. Each branch of the drains had 1 main ditch which was treated by setting up a drip-feed apparatus at the source. Water flow at the source of this larger ditch was increased by diverting water into it at about 12 l/s from the nearest irrigation canal, and then *N*-tritylmorpholine (1 ppm) or niclosamide ethanolamine salt (4 ppm) was added for a period of 3 hours. While this was being applied, all of the smaller ditches were individually sprayed from the banks with knapsack sprayers at a similar concentration. The high concentrations were applied to compensate for the short period of snail–chemical contact.

Results

Selected stretches of the ditches were sampled for snails in the same way as for the irrigation canals. Two ditches from each branch were chosen and the results of various treatments with the 2 molluscicides are shown in Table 7.

This table shows the time taken for the sampling procedure to detect repopulation by *B. pfeifferi.* The periods varied widely—from 29 to 64 days with *N*-tritylmorpholine and from 43 to 71 days with niclosamide ethanolamine salt. The means of 46 days with the former and 54 days with the latter did not reflect the expected difference between the 2 chemicals. Niclosamide ethanolamine salt, being ovicidal, was expected to produce significantly longer snail-free periods than its competitor.

Both chemicals were applied by the same method of spraying from the banks and so in this type of habitat the liquid formulation of *N*-tritylmorpholine

[1] £1 = US\$2.4 approx.

TABLE 7
BIOMPHALARIA-FREE PERIODS IN DRAINAGE DITCHES AFTER TREATMENT WITH *N*-TRITYLMORPHOLINE AND NICLOSAMIDE ETHANOLAMINE SALT [a]

Location of drainage ditches	No. of days from treatment to repopulation	
	N-Tritylmorpholine	Niclosamide ethanolamine salt
O drains	36	43
	64	57
		50
B6/B7 drains	29	43
	64	50
		57
C 18 drains	36	57
	36	71
	43	
D 23 drains	29	50
	57	57
	64	64
Mean	46	54
Range	29–64	43–71

[a] Each entry represents a separate trial.

held no particular advantage. Both chemicals were applied at a high concentration because the contact period was short, the chemicals being quickly washed downstream after application. Niclosamide ethanolamine salt was chosen for routine use in the drains because of the possible advantages of its ovicidal properties.

Approximately 40 kg of niclosamide ethanolamine salt were required for one treatment of all the drains. With the treatment repeated every 8 weeks, the annual cost of the chemical plus the labour involved (108 man-days per year) was £500.

Additional treatments

During the 1967 long rains, no irrigation was carried out between April and July and in consequence the irrigation canals, reservoirs and to a lesser extent the drains dried up. In late July some of the driest areas were watered, and then full irrigation was resumed in early August.

During this period it appeared at first sight that no snails would survive. Closer observation, however, showed that in certain places there was standing water in which snails thrived; collections made there during June and July revealed infected snails.

These sites occurred in limited areas where ripe sugar-cane afforded shade or where the canals were exceptionally deep; for example, (*a*) at canal junctions, where deep concrete sumps were constructed to buffer the banks of the canal from the swirling water, and (*b*) where bridges over the canals gave shade to the water beneath.

For a more complete control of snails, a method of searching out these small snail habitats and destroying them was worked out in readiness for the 1968 rains. Two men in a 4-wheel-drive vehicle were posted to tour the estate, locate the pools and spray them with niclosamide ethanolamine salt. The cost of chemical used was small and the total expenses were roughly £100 per year.

DISCUSSION

The increasing number of schemes involving irrigation methods in Africa brings about an increase in the prevalence of schistosomiasis owing to the creation of suitable habitats for the intermediate-host snails. Sturrock (1965) outlined the position with regard to 9 irrigation systems in Tanzania and suggested several methods which could be implemented to halt or slow down the spread of the disease. McMullen et al. (1962) mentioned elimination of the parasite in the human population, elimination of snail habitats represented by waterbodies unnecessary for the irrigation scheme, control of host snails in the rest of the habitats and segregation of the human population from the habitats to interrupt the life-cycle of the parasite. Macdonald (1965) produced a mathematical model of the dynamics of schistosome infections and concluded from his theoretical studies that sanitation would be ineffective as a control measure against the disease. He observed that a break-point could be reached through a dual attack on the parasite, by reducing to one-fifth the longevity of the worm by treatment and concurrently reducing by at least one-half the exposure or the snail population.

At Arusha Chini an attempt is being made to control *S. mansoni* on the lines suggested above. This paper describes the steps leading to the first stage of the attack, snail control. The methods described for total snail control on the estate in the irrigation canals, drains and standing pools were adopted for routine use on 1 January 1968. The effect of this snail control upon *S. mansoni* transmission is being evaluated during the years 1969 and 1970 by parasitological means and is also being supported by a mass diagnosis and treatment campaign in an attempt to reduce the prevalence of the infection in the local population.

The transmission is studied by considering new workers on the estate. All new employees are being screened with 4 consecutive stool examinations, and those found negative form the subjects for study. These men are re-examined by the same method every 6 months to find out how many contract the disease during their stay on the estate.

The attack on prevalence—mass diagnosis and treatment plus snail control—will be evaluated by 2 prevalence surveys carried out before and after the treatment campaign.

ACKNOWLEDGEMENTS

Grateful acknowledgement is made to the management of the Tanganyika Planting Co. for their generosity, support and whole-hearted co-operation in this experiment. Mr W. M. Foster has supervised much of the day-to-day work at the company's estate and his staff have worked continually, sampling snails and using knapsack sprayers.

I thank Dr A. Smith for many helpful discussions during the work and for reviewing the manuscript in all its stages. I thank also J. S. S. Beesley, who worked with me for the first year of these trials and whose experience was invaluable, and Mr N. O. Crossland, who gave his permission for the extensive reproduction of his work and produced helpful criticisms of the first manuscript. The East African Community is thanked for supporting this work and for permission to publish.

RÉSUMÉ

MISE AU POINT DE MÉTHODES DE LUTTE CONTRE LES MOLLUSQUES DANS UNE PLANTATION DE CANNES À SUCRE POURVUE DE SYSTÈMES D'IRRIGATION EN TANZANIE SEPTENTRIONALE

On a recherché les meilleurs procédés de destruction des mollusques (*Biomphalaria pfeifferi*) dans les réseaux d'irrigation et de drainage d'une plantation de cannes à sucre en Tanzanie.

La *N*-tritylmorpholine, sous forme de concentré pour émulsion, a été choisie comme molluscicide pour le traitement du réseau d'irrigation en raison de ses avantages: simplicité et facilité d'emploi; marge de sécurité appréciable résultant de la répétition des applications. Après une série d'essais portant sur la durée et la fréquence optimales des traitements, on a adopté une technique standard d'opération: déversée pendant 5 jours consécutifs à raison de 280 ml/minute à l'origine du réseau, la *N*-tritylmorpholine à la concentration de 0,025 partie par million assure la destruction de *Biomphalaria pfeifferi* pendant une durée de 7 semaines environ. Le coût annuel des 7 à 8 traitements nécessaires au maintien de l'éradication est estimé à US $4000.

Dans le réseau de drainage, l'élimination des mollusques a été obtenue en recourant à des pulvérisations de sel d'éthalonamine de la niclosamide à la concentration de 4 parties par million. Les applications de ce produit, qui possède en outre des propriétés ovicides, sont répétées toutes les 8 semaines, le coût annuel des opérations étant de l'ordre de US $1200.

A cette lutte périodique par les produits chimiques, il convient d'associer la recherche et la destruction des habitats de mollusques qui persistent pendant la saison des pluies dans les canaux asséchés.

Ces procédés de lutte anti-mollusques, complétés par une campagne de dépistage et de traitement de masse de la schistosomiase, sont appliqués systématiquement depuis le début de 1968. Leurs effets sur la transmission de *Schistosoma mansoni* seront évalués au cours des années 1969 et 1970.

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