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The effect of a control programme against *Schistosoma mansoni* on the prevalence and intensity of infection on an irrigated sugar estate in northern Tanzania

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On an irrigated sugar estate in northern Tanzania a control programme against Schistosoma mansoni *was carried out during 1968–70. Through the routine use of molluscicides, the population of* Biomphalaria pfeifferi *snails was kept at a greatly reduced level. Concurrently a mass campaign was carried out to detect residents who were infected with* S. mansoni *so that they might be treated. The effect of these measures on the overall prevalence of the disease was measured by random studies before and after the mass diagnosis and treatment. The techniques used for mass diagnosis, for treatment, and for the prevalence studies are described, and the results of the control programme are presented and discussed. In the mass diagnosis campaign over 90 % of the population were examined and 2 286 courses of treatment were administered to 1 922 persons. The combination of chemotherapy and snail control led to a significant reduction in the number of* S. mansoni. *infections. In field workers the prevalence was reduced from 59 % in early 1969 to 31 % in late 1970. In nonfield workers the reduction was from 36 % to 15 % and in the wives of employees from 28 % to 14 %. The main reasons why the prevalence was not reduced further were considered to be the failure of the drugs used to effect a complete parasitological cure and the inability of the mass diagnosis campaign to detect light infections. It was estimated that the overall reduction in the number of eggs released into the community as a result of the control programme was about 85 %.*

The Tanganyika Planting Company's sugar estate is situated at Arusha Chini in northern Tanzania in an area of low annual rainfall. Two irrigation networks of open canals and reservoirs supply the sugarcane with the required water from a nearby river. The snail fauna in these water systems includes *Biomphalaria pfeifferi*, the intermediate host of *Schistosoma mansoni*, which is prevalent on the estate.

During the 1960s a series of molluscicide trials were carried out in the area (Crossland, 1963, 1967; Fenwick, 1970) and a dosage regime was evolved, which, it was believed, would reduce the transmission of *S. mansoni* by continuous control of the host snail (Fenwick, 1970, 1972). By 1968 the antischistosomal drug niridazole was recognized as perhaps the most useful of the drugs then available. When the snail control campaign was put into operation in that year it was also decided to embark on a mass diagnosis and treatment campaign. The programme was evaluated by means of pre- and postcontrol prevalence surveys, carried out in early 1969 and late 1970, respectively.

Prior to the 1969 survey there was little information about the prevalence of the disease or the intensity of infection on the estate, but what there was suggested a high infection rate. Crossland (1961) examined a single stool sample from each of 100 schoolchildren and found 33 % of them to be infected with *S. mansoni*. Considering the relative

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insensitivity of the method used, Foster (1967) suggested that, in fact, this probably represented a true infection rate of 76–100%. The latter author carried out a survey among field workers in 1962 and found an infection rate of 53%. However, about half of his subjects were recent arrivals on the estate and when the same subjects were reexamined 6–9 months later the prevalence of infection had risen to 80%.

POPULATION AND METHODS

The estate residents

Within the estate boundaries about 2 000 workers and their families (3 500) were housed in 9 residential areas. Four camps were situated in the new area of the estate and housed mainly field workers, while the other five camps were situated in the old area. Of the old area camps, two housed mainly field workers while the others were situated near the factory and housed both field and nonfield workers (factory labourers, messengers, drivers, etc.).

All the residents on the estate were well documented by the company. All workers and dependants possessed numbered identity cards, and the numbers formed the basis of a filing system during the present study.

Snail control

The snail control methods have been described previously (Fenwick, 1970, 1972). *N*-tritylmorpholine was used in the irrigation systems at a concentration of 0.025 mg/litre for 5 days every 7 weeks and the drainage ditches were sprayed from the banks with niclosamide whenever snails were found in them.

Stool examination

Stools were examined by the slow-speed centrifugation method of Foster (1964), with the difference that a finding of four negative stools on consecutive days was used as the criterion for classifying a subject as uninfected. This was done in order to save time and is justified by the fact that the fifth stool examination would be expected to find less than a further 5% of positive cases; when Foster tested the method he found no additional positive cases.

In a separate experiment, the Foster method was evaluated by comparing it with the quantitative method described by Bell (1963).[1] Stool samples from 382 subjects were examined by both methods and it was found that whenever the Bell count was over 110 eggs/g the infection was detected by the Foster method. At lower levels of infection the proportion of positive cases missed by the Foster method increased as the level of infection dropped. The Foster method detected only 50% of positive subjects when the Bell count was 35 eggs/g (Table 1).

When four consecutive stool examinations were made by the Foster method, instead of a single examination, the sensitivity of the procedure increased so that all infections with a Bell count over 50 eggs/g and 50% of subjects with 15 eggs/g were detected (Table 2).

In the control programme discussed here, four consecutive daily stools were always examined in the prevalence surveys. In the mass diagnosis campaign, however, only one stool per subject was examined in the camp surveys and two stools from each hospital inpatient because of the shortage of manpower. Although this enabled excellent coverage of the estate residents to be obtained it also meant that some light infections were missed. It was felt, however, that it was better to detect all of the more heavily infected subjects in this campaign than to spend time detecting the lighter infections and fail to cover the estate.

Mass diagnosis

The aim of the mass diagnosis campaign was to find as many infected residents as possible so that they could be treated. Diagnosis was carried out in the estate hospital and by means of camp surveys as described below.

Hospital inpatients. Between July 1968 and January 1971 two stools were collected from each resident (excluding infants) admitted to the hospital, regardless of the reason for his admittance. Between 150 and 250 patients per month were examined for *S. mansoni* and all the infections detected were treated.

Camp surveys. During late 1969 and 1970 each of the residential areas was visited in turn to collect one stool sample from each resident. All the cases of infection detected were treated.

New employees. All men applying for employment during 1969 and 1970 were screened on 4 consecutive days for *S. mansoni* infection prior to engagement. Those found to be infected were treated.

[1] Fenwick, A. (1970) Miscellaneous Report of the East African Tropical Pesticides Research Institute No. 713 (unpublished).

Table 1. The sensitivity of a single stool examination by the Foster method for detecting *S. mansoni* infections in samples already counted by the Bell method

Foster method	Eggs/g (Bell method)							
	0	1–10	11–15	16–20	21–50	51–75	76–150	150
no. examined	91	64	25	26	55	28	39	54
no. found positive	1	5	4	7	35	22	35	54
% positive	1.2	7.8	16.0	26.9	63.6	78.6	90.0	100
mean number of eggs/g	0	5.8	12.8	18.1	35.7	61.9	112	220

Treatment

Until November 1969 all infections were treated with niridazole (25 mg per kg of body weight given orally for 7 days). After an experimental evaluation, hycanthone (a single intramuscular injection) became the drug of choice in mid-1970, unless its use was contraindicated (Jorgensen et al., 1970). However, all lactating females and all persons with impaired liver function, as detected with a serum bilirubin test, were given niridazole, and the treatment of pregnant females was postponed until after delivery.

Evaluation

The effect of the snail control measures and the treatment programme on the frequency of *S. mansoni* was determined by comparing the results of a pre-control prevalence survey carried out early in 1969 with those of a survey carried out late in 1970 on the completion of the diagnosis and treatment campaign.

In each survey the criterion for infection was the finding of *S. mansoni* ova in one of four consecutive daily stools from each selected subject. The aim was o examine 10% of the field workers and wives on the estate, 15% of the nonfield workers, and 20–30 children born in each of the years 1961–70 inclusive. The subjects were randomly selected from the housing cards held by the clerks of each of the camps. For each household, the cards record the name, number, and job of each employee, and also details of his immediate family, including the birth date of each child. For the purposes of the survey all residents of the camp were given a number based on the household cards and the samples to be studied were chosen by means of a table of random numbers.

RESULTS

Snail control

The snail control surveys showed that the populations of *B. pfeifferi* were drastically reduced throughout the period of the study. In the canals, snails were never detected by the standard sampling technique and it was calculated that the population was only 0.1% of its precontrol level. Snails were found periodically in some of the drains, just prior to molluscicide treatment. Thus little or no transmission of *S. mansoni* would be expected (see Fenwick, 1972).

Table 2. The sensitivity of four stool examinations by the Foster method for detecting *S. mansoni* infection in samples already counted by the Bell method

Foster method	Eggs/g (Bell method)						
	0	0–10	11–15	16–20	21–50	51–75	76–150
no. examined	91	64	22	13	25	13	7
no. found positive	4	16	8	8	21	13	7
% positive	4.8	25.0	36.4	61.5	84.0	100	100
mean number of eggs/g	0	5.8	12.8	18.5	34.2	59.2	104

The mass diagnosis campaign

Hospital inpatients. Between August 1968 and January 1971, a total of 4 786 patients admitted to the hospital were examined for *S. mansoni* and 1 246 treatments were administered to the persons found to be infected.

The infection rate among the inpatients showed a steady decline after the first quarter of 1970 (Table 3). This decline was no doubt a result of the effective treatment given to so many patients, but it may not have been so obvious or so great if reinfection had not been prevented or greatly reduced by the snail control measures. Because of multiple admissions, and the admission to hospital of some of the persons found to be infected in the camp surveys, these figures give no measure of the success of the project.

Table 3. Results of hospital inpatient stool examinations (quarterly)

Quarter	Total no. examined	Total no. infected	% infected
3rd 1968 (August and Sept. only)	368	128	34.78
4th 1968	405	123	30.37
1st 1969	424	123	29.00
2nd 1969	555	162	29.18
3rd 1969	504	164	32.54
4th 1969	365	121	33.15
1st 1970	475	140	29.47
2nd 1970	434	98	22.63
3rd 1970	526	100	19.01
4th 1970	532	73	13.72
1st 1971 (January only)	195	14	7.07
total	4 786	1 246	26.0
field workers	1 409	519	36.84
nonfield workers	526	168	31.94
wives	2 114	423	20.01
children	737	136	18.45

Camp surveys. Each of the camps was visited in turn and a single stool sample was taken for examination from 5 444 of the residents (total number of residents about 5 600). The results in Table 4 show that 18.9% of these samples were infected and that the rate for field workers was higher (27.2%) than that for nonfield workers (17.6%) or wives (12.6%). Children over 7 years of age were more often infected (34.8%) than children aged 4–7 years (12.9%), while the infection rate in children under 4 years of age was only 1.13%.

The infection rate for all groups was lower than that found in the prevalence survey, but this was because only one stool sample was examined instead of four. All persons found to be infected were treated.

New workers. During 1969 and 1970, a total of 773 prospective employees were screened for infection with *S. mansoni* and 123 (15.9%) were found to be infected and were treated. One source of *S. mansoni* that was not blocked was the introduction of infection by the dependants of new workers.

Treatment

Details of the courses of treatment administered to estate residents during the period July 1968 to January 1971 are given in Table 5. Over half of the people treated (1 131) were employees but 407 wives and 384 children also received treatment.

Evaluation

The results of the 1969 (February–May) pre-control prevalence survey and the 1970 (September–

Table 4. Summary of the results of stool examinations carried out during visits to the residential areas during the mass diagnosis campaign

	Field workers	Non-field workers	Wives	Children			Total
				0–3 years	4–7 years	7 years	
total no. studied	1 589	450	1 079	793	736	797	5 444
total no. found infected	432	79	136	9	95	277	1 028
% infected	27.2	17.6	12.6	1.13	12.9	34.8	18.9

Table 5. Details of drug treatments administered against *S. mansoni*, July 1968 to January 1971

Subjects	Courses of treatment[a]									
	1N	1H	1N+1H	2N	2H	2N+1H	3N	3N+1H	4N	5N	Total
males	529	415	65	80	4	21	13	2	1	1	1 131
females	283	70	15	31	0	3	5	0	0	0	407
children	124	197	25	27	3	3	4	1	0	0	384
total	936	682	105	138	7	27	22	3	1	1	1 922

[a] N = Niridazole; H = hycanthone. 1N indicates 1 course of niridazole; 2H, 2 injections of hycanthone; 3N, 3 courses of niridazole, etc.

December) postcontrol prevalence survey are shown in Table 6. The data show a large decrease in prevalence of infection between the surveys.

The effect of the control measures on egg output

From the information in Table 7 it is possible to estimate the effect of the control programme on the intensity of the disease on the estate as measured by egg output.

Field workers. In 1969, 58.9% of the 1 700 field workers were infected with *S. mansoni*. If the mean egg output of those infected was E eggs/g and the mean stool weight was S g, then the total daily egg output from field workers in 1969 was:

$(58.9/100) \times 1\,700 \times E \times S$ eggs $= 1\,001.3 \times E \times S$ eggs.

At the end of 1970, 31.3% of the field workers were infected but this proportion was made up of 13.6% who were still infected after treatment, 12.5% who were lightly infected, having been examined but not diagnosed during the campaign, and the 5.2% who had not been examined during the control programme.

Thus the total daily egg output (T) from field workers in 1970 was:

$(13.6/100 \times 1\,700\,E_1 \times S) + (12.5/100 \times 1\,700\,E_2 \times S) + (5.2/100 \times 1\,700\,E \times S)$ eggs

where E_1 is the egg output of the treated workers and E_2 is the egg output of the workers missed in the diagnosis campaign. E_1 can be estimated at $E/10$ as it was shown that a reduction in egg count of about 90% can be expected following a treatment even though a cure may not be achieved. E_2 was estimated at 35 eggs/g because all the infections in that group were missed by

Table 6. Results of *S. mansoni* prevalence surveys carried out in 1969 early and late 1970

Subjects	1969 survey			1970 survey			χ^2	P
	No. examined	No. infected	% infected	No. examined	No. infected	% infected		
field workers	175	103	58.9	176	55	31.3	25.9	0.001
nonfield workers	87	31	35.6	88	13	14.8	9.04	0.01
wives	114	32	28.0	107	15	14.0	5.70	0.05
total adults	376	166	44.0	371	83	22.0		
children aged								
0–2 years	44	0	0	29	0	0		
2–4 years	36	1	2.8	64	0	0		
4–6 years	39	6	15.4	43	3	7.0	0.74	NS
6–8 years	38	20	52.6	35	6	17.1	8.52	0.01
> 8 years	—	—	—	60	14	23.3		

Table 7. Classification of subjects found to be infected at the time of the 1970 prevalence survey

Subjects	Treated but not cured	Examined but not diagnosed	Not previously examined	Total
field workers	24	22	9	55
wives	6	5	4	15
nonfield workers	2	6	5	13
children	10	12	1	23
total	42	45	19	106

a single stool examination by the Foster method and it was shown (Table 1) that 50% of infections or around 35 eggs/g were missed by a single examination by the Foster method. Thus

$$T = \{(0.136 \times 1\,700 \times E/10)\,S\} + \{0.125 \times 1\,700 \times 35 \times S\} + \{0.052 \times 1\,700 \times E \times S\}$$
$$= (23.12\,E + 7437.5 + 88.4\,E)\,S$$
$$= (7\,437.5 + 111.5\,E)\,S$$

Thus the percentage reduction from the 1969 level (R)
$= (1\,001.3\,E - 7\,437.5 - 111.5\,E)\ 100/1\,001.3\,E$

Now if E, the mean number of eggs/g, of infected workers in 1969 was 100 the percentage reduction was

$$R = (100\,130 - 7\,437.5 - 11\,150)\ 100/100\,130$$
$$= 81.4\%$$

If $E = 200$ then

$$R = (200\,260 - 7\,437.5 - 22\,300)\ 100/200\,260$$
$$= 85.2\%$$

Similar calculations show the egg reduction for an E value of 200 eggs/g to be 81.9% for wives, 80.1% for nonfield workers, 94.4% for 4–5-year-old children, and 92.6% for older children.

The mean eggs/g level in 260 infected patients used to compare the Bell and Foster methods was 206, suggesting that $E = 200$ is a reasonable figure for use.

DISCUSSION

The prevalence survey results indicate that the frequency of *S. mansoni* on the estate has been reduced overall by about 50%. This is considered a highly satisfactory achievement attributable to the control measures taken. However, it is of interest to consider why there was not an even greater reduction. Each of the persons found to be infected in the 1970 survey represented a shortcoming in one part of the programme or another and five possibilities should be considered.

(1) *Incomplete parasitological cures*

It has been shown that the overall cure rate was 59% with niridazole and 72% with hycanthone as measured by the same criterion of cure as was used to define " uninfected " in the final prevalence survey (Jorgensen et al., 1970). In fact, an examination of the medical histories of the 106 subjects found to be infected in the 1970 survey showed that 42 (39.6%) of them had received treatment for *S. mansoni* during the programme but were not cured (Table 7). Table 8 shows that in the total estate population 336 (8.7%) of the total adult population were still infected because the drugs did not effect a cure. This represented 39.8% of the total number of infections that remained among the adult population.

(2) *Failure of the diagnosis campaign to detect all infections*

Whereas four stool examinations were used in the final prevalence survey, only one was used in the

Table 8. Estimated number of adults still infected at the conclusion of the control programme

Subjects	No. of residents	Percentage infected 1970	Estimated no. infected			
			Total	Treated but not cured	Examined but not diagnosed	Residual infections
field workers	1 700	31.3	532	232	213	87
nonfield workers	573	14.8	85	13	39	33
wives	1 625	14.0	227	91	76	60
total	3 898	21.7	844	336	328	180

mass diagnosis campaign because time was limited, and probably some light infections were missed. The medical histories revealed that 45 (42.5%) of the 106 subjects found to be infected in the final survey had been examined during the campaign, but had not been recorded as infected. Table 8 shows that at the end of the control programme 328 (8.4%) of the adult population of the estate had an *S. mansoni* infection that was not discovered by the single stool examination during the mass diagnosis campaign. This represents 38.9% of the total number of infected cases still present on the estate.

(3) *Shortcomings in the coverage obtained during the mass diagnosis campaign*

The coverage obtained during the mass diagnosis campaign was not quite 100%, and because of this a few infections were missed. Some people refused to cooperate, some were transferred from a camp that had not been visited to a camp that had, and others were the dependants of new arrivals on the estate and were placed in a camp that had already been visited. In order to have missed detection these people must have been healthy enough to have avoided admission to hospital during the period of the programme, or they would have been examined there.

Of the 106 infected persons detected in the 1970 prevalence survey 19 (17.9%) had not previously been examined. This meant that of the total population on the estate by 1970 only 180 (4.6%) had untreated and unexamined infections, and that if the mass diagnosis campaign had detected all the infections in the stools examined, and had the drugs been 100% effective, the final prevalence on the estate would have been only 4.6% among the adults.

(4) *New infections contracted on the estate or on visits outside the estate*

It has been shown that despite the snail control measures the apparent incidence of *S. mansoni* infection on the estate has been about 10% per annum in workers, 5% in wives and 2% in children (Fenwick, 1971). Some of the infections in the 106 subjects found to be infected in the second survey could have been new infections but it is not known which, and they will have been classed in either section (1) or section (2) above; they will, however, be very few in number. In future surveys the proportion of new infections will be greater as the number of infected persons will grow year by year unless they are detected and treated.

(5) *New infections imported by newly arrived dependants*

No attempt was made to screen new dependants, but they are covered in section (3) above.

The calculations show that the overall egg output has been reduced by about 85% by the control measures. Both snail control and chemotherapy played their part in achieving these results. Without chemotherapy the prevalence probably would not have been significantly decreased, but without the reduction in transmission caused by snail control some of the persons who were uninfected in 1969 would probably have become infected by 1970 and some of the treated patients would probably have contracted new infections. It is considered that the control programme has reduced the prevalence and intensity of *S. mansoni* infections on the estate from an unacceptably high level to one that might be considered as acceptable considering the ideal conditions for transmission of the disease that existed in the area.

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RÉSUMÉ

INFLUENCE D'UN PROGRAMME DE LUTTE CONTRE *SCHISTOSOMA MANSONI* SUR LA PRÉVALENCE ET L'INTENSITÉ DE L'INFECTION DANS UNE PLANTATION DE CANNES À SUCRE POURVUE D'UN SYSTÈME D'IRRIGATION, DANS LE NORD DE LA TANZANIE

Au cours d'un programme de lutte contre la schistosomiase à *Schistosoma mansoni*, exécuté en 1968-70 dans une plantation de cannes à sucre en Tanzanie, on s'est efforcé de détruire systématiquement *Biomphalaria pfeifferi* afin d'atténuer la transmission de l'infection, tout en organisant simultanément une campagne de dépistage et de traitement de masse parmi les travailleurs de l'exploitation.

Le dépistage, assuré par un examen unique de selles, a fait découvrir 1028 infections (18,9%) sur 5444 personnes examinées. En outre, 1246 cas (26,0%) ont été diagnostiqués parmi 4786 malades hospitalisés. Au total, 2286 traitements par le niridazole ou l'hycanthone ont été administrés à 1922 patients.

Pour juger des résultats obtenus, on a effectué avant et après la campagne (au début de 1969 et à la fin de 1970) des enquêtes de prévalence à l'aide de sondages portant sur environ 10% des travailleurs de plantation et leurs femmes, 15% des autres travailleurs et un groupe d'environ 160 enfants. L'enquête de 1970 a fait ressortir une réduction importante de la prévalence de la schistosomiase par rapport à 1969. Elle était passée de 58,9 à 31,3% chez les travailleurs agricoles, de 35,6 à 14,8% chez les autres employés, de 28,0 à 14,0% chez les femmes et de 52,6 à 17,1% chez les enfants âgés de 6 à 8 ans.

Pour les auteurs, deux faits expliquent que la campagne n'ait pas amené un déclin plus accentué de la prévalence: le traitement médicamenteux n'a pas réussi à guérir tous les malades, et l'examen unique de selles n'a pas permis de déceler un certain nombre d'infections légères. Sur les 844 personnes encore atteintes de schistosomiase en 1970, 336 étaient considérées comme des cas rebelles au traitement et 328 comme des sujets porteurs d'infections légères ayant échappé au dépistage.

On estime que le programme de lutte a eu pour résultat de réduire l'intensité de la maladie (mesurée en termes de production d'œufs de *S. mansoni*) dans la proportion de 85% environ.

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