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# ON SOME PROBLEMS OF THE BIOLOGICAL CONTROL OF HUMAN SCHISTOSOMES IN EGYPT

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**Abstract.** A survey is given of the results of investigations of parasites of watersnails from the area of Warak El Arab, and of competitive interactions between larval stages of trematodes of the family Echinostomatidae and Schistosomatidae in the intermediate host. The work has been performed by a joint Czechoslovak-Egyptian team in the years 1971—1973. The results obtained confirm earlier reports on predation of the rediae of echinostome flukes upon schistosome sporocysts, and the pathogenic effect of the developmental stages of these flukes, including the metacercariae, on the snail intermediate host. An analysis has been made of the possibilities to utilize the knowledge obtained in the practice for the biological control of human schistosomes in areas with a dense network of irrigation canals.

In recent years, antagonistic interaction between larval stages of various trematode species in the snail intermediate host in a so-called "double infection" has received increased attention in parasitological literature throughout the world (Basch and Lie 1966a, b; Lie 1967, 1969; Lie et al. 1965, 1967, 1968a, b, c; Heyneman et al. 1972). The authors proved on the grounds of experimental work that several trematode species, i.e. their larval stages, are capable to attack, damage and suppress larval stages of other trematode species within the course of their development in the shared intermediate host. Similar conclusions, although unconfirmed by experiments, but deduced from the results of frequency distribution in „double-" or „triple-" infected snails in the field have been suggested by earlier authors (Cort et al. 1937; Wesenberg-Lund 1934; Porter 1938; Fain 1953; Nasir 1962 and others).

In the years 1971—1973, during investigations of several ecological problems of schistosomiasis in the area of Warak El Arab (North of Cairo), carried out by the joint Czechoslovak-Egyptian working team, these antagonistic relationships were studied under experimental conditions. At the same time, the possibility was considered to utilize this phenomenon in the control of schistosomiasis in areas with a well-developed irrigation system (Ryšavý et al. 1973, 1974a, b; Moravec et al. 1974; Baruš et al. 1974).

All the authors referred to in the text, who studied antagonistic interaction between larval stages of several fluke species in experiments suggested that the principal factor involved was the predation of rediae of the more aggresive species (always members of the family Echinostomatidae) damaging mechanically and consuming sporocysts of the less aggressive species (mainly flukes of the family Schistosomatidae). The results of the Czechoslovak-Egyptian team drew attention to another important factor, i.e., that echinostome cercariae re-entering the body of the snail in order to encyst in its

organs and tissues, damage during this process not only the organs of the snail host, but also the sporocysts of schistosomes. In addition to interaction between the developmental stages of various fluke species in the intermediate host, it is necessary to consider also their effect on the intermediate host itself (the snail). Hence, there originates a complex of factors responsible for the inhibition, or suppression, of development of the less aggressive fluke species, and for increased mortality of the intermediate hosts. This leads, consequently, to a reduction of infective fluke stages (cercariae), and to a reduction in the number of intermediate hosts in the locality under consideration, a fact, which should not be overlooked in epidemiological studies.

The major purpose of the present paper was to summarize the knowledge obtained in our studies in the laboratory and the field under conditions of Warak El Arab, and to suggest several possibilities of utilizing the phenomenon of antagonism between developmental stages of flukes in the intermediate host, and their pathogenic effect on the snail host, in the control of schistosomes pathogenic to man.

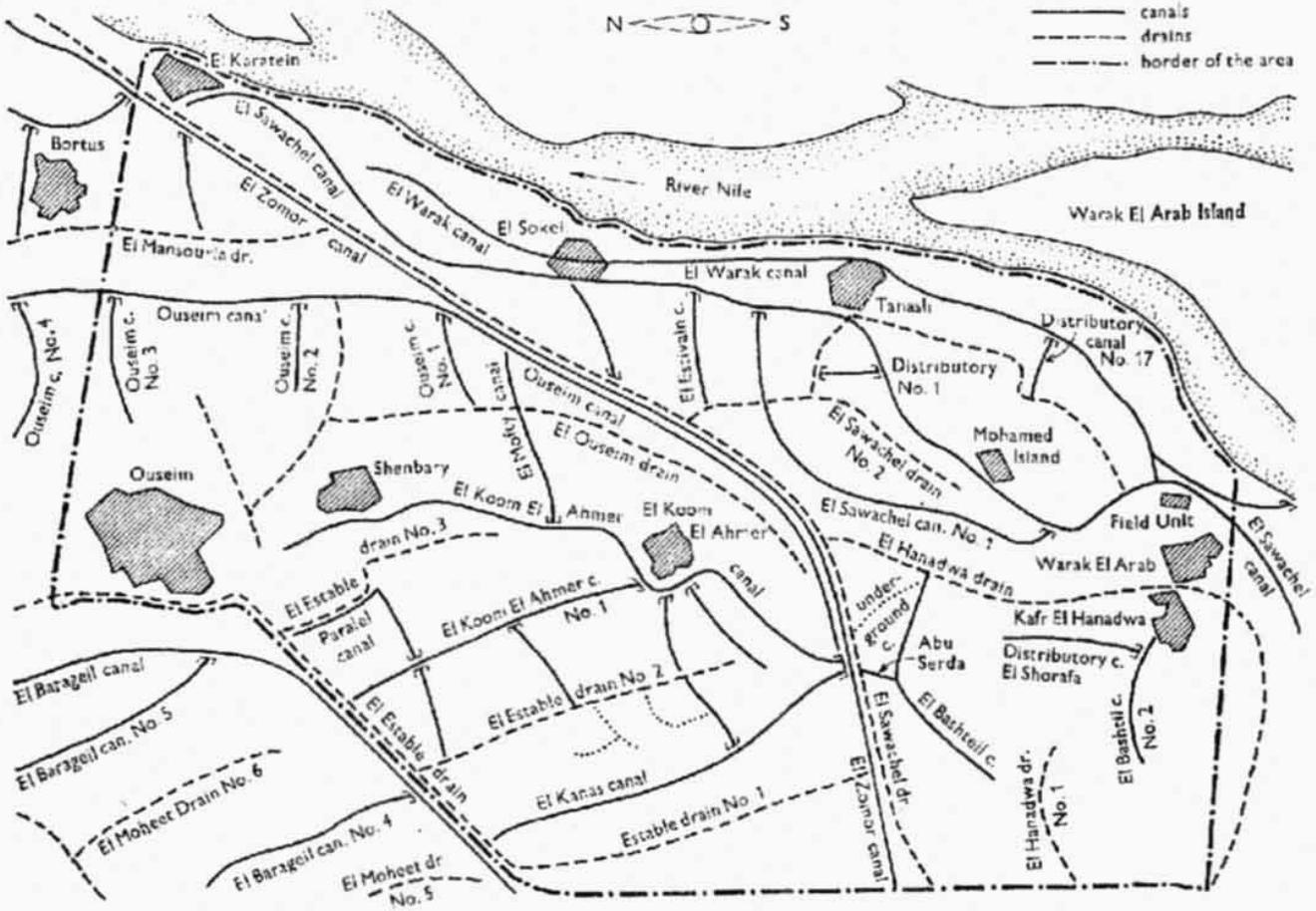


**Fig. 1.** Map of Warak El Arab area with a schema of irrigation system.

## OBSERVATIONS

Within the years 1971—1973, 7,200 watersnails belonging to 12 species, collected in the area of Warak El Arab, were examined for the presence of larval trematodes. Surveying results on the occurrence of all types of larval trematode stages based on examinations of 6,014 specimens of watersnails, are given in the paper by Ryšavý et al. (1974a). In this study attention has been paid mainly to trematode species which may be used as competitive species for the biological control of human schistosomes under conditions of the area under consideration.

The most frequent parasites of watersnails collected from the Nile and the irrigation canals in the area of Warak El Arab (Fig. 1) were developmental stages (sporocysts, rediae, cercariae, and for some species metacercariae) of trematodes of the family Echinostomatidae Poche, 1926, Plagiorchidae Ward, 1917, Lecithodendriidae Odhner, 1910, Dicrococliidae Odhner, 1911, Microphalidae Travassos, 1920 and Allocreadiidae Stossich, 1903 (see Ryšavý et. al. 1974a). The occurrence of snails shedding cercariae in the area of Warak El Arab differed in dependence on the season and locality (e.g., the incidence of *Echinoparyphium recurvatum* in the snail *Bulinus truncatus* from different localities ranged from 2.2 to 7.5 %; *Echinostoma revolutum* from *Biomphalaria alexandrina* 0.8 to 7 %, xiphidiocercariae from *Bithynia* sp. and *L. taillaudi* 0.8 to 7 %).

The incidence of metacercariae in the watersnails was considerably higher. Echinostome metacercariae (*E. revolutum* and *E. recurvatum*) were present in 40.3 % of watersnails from the bank of the Nile between the villages of Warak El Arab and El Karatein. In canals and drains, the average incidence of echinostome metacercariae was 29 %. Xiphidio-metacercariae (at an average of 84 %) were present in watersnails from the banks of the Nile; their average incidence in snails from the remaining localities of Warak El Arab was 71 %. Larval stages of the remaining trematode species occurred in 2.1 % in the area of Warak El Arab (including the Nile shore).

In view of the natural occurrence of various trematode species in this area, the species (or their larval stages) to be used as possible competitors for the biological control of human schistosomes in snail intermediate hosts, might be flukes of the families Echinostomatidae, Plagiorchidae, Allocreadiidae, Lecithodendriidae, Dicrocoeliidae and Microphalidae.

Following suggestions by different authors (see Introduction) a suitable object for studying the phenomenon of competition and the possibility of practical application in the area under consideration appear to be trematodes of the family Echinostomatidae. Trematodes of the remaining families seem to be less suitable for these purposes for the following reasons:

a) Aggressiveness of larval trematodes of these families against sporocysts of human schistosomes in the snail intermediate host is evidently lower than that displayed by echinostomes.

b) The pathogenic effect of larval stages (particularly rediae) of these flukes on the organism of the snails is evidently lower than that of rediae of the family Echinostomatidae.

c) Xi phidio-metacercariae of these species are located mainly in the musculature of the foot of the intermediate host, while echinostome metacercariae damage vital organs of the snails (kidney, pericardiac sac). Also the pathogenic effect of cercariae during their re-entrance of the snail intermediate host, and penetration of associate snails, appears to be lower, because the majority of these cercariae are smaller than those of the two selected species of the family Echinostomatidae.

By contrast, flukes of the family Echinostomatidae have a number of advantages in comparison with the remaining fluke species (members of different families) and are better applicable to the possible biological control of schistosomes.

a) The adults of the family Echinostomatidae have a wide range of hosts and can, therefore, parasitize a large number of hosts including laboratory animals (white mouse, white rat, hamster, rabbit) and fowls (chicken, duck, goose). In nature, they parasitize various species of waterbirds and various rat species including the Nile rat (*Arvicanthis niloticus*) from areas in the vicinity of the Nile and directly from its banks.

b) The aggresiveness of larval stages, particularly that of the rediae, was confirmed in experiments by a number of authors (see Introduction) to be considerably higher that that of other larval trematode species.

c) The pathogenic effect of rediae of these flukes on the organism of the intermediate host is very high; this is reflected in an increased rate of snail mortality.

d) Cercariae of trematodes of the family Echinostomatidae re-enter the snail intermediate hosts, and penetrate other snails, in order to encyst in various organs (pericardiac sac, kidney) which they damage and disturb. The rate of mortality of these snails is higher than that of unattacked snails.

While examining the area of Warak El Arab (Ryšavý et al. 1973) we observed that the occurrence of larval *Schistosoma haematobium* and *S. mansoni* in the snail inermediate hosts was limited practically, to the Nile shore, (El Karatein, El Sokeil) (Plate II Fig. 2), except for the occasional finding of *S. mansoni* in another site (e.g., Estable Drain III). However, even in snails from the Nile shore, we observed variation in the occurrence of larvae of human schistosomes, and the same applied to the percentage of infected snails in the various seasons of the year. Considerable differences were observed also among the individual localities of which some represented, evidently, a focus of infection.

Such a focus was, for example, the locality near the village of El Karatein (Plate I, Figs. 1, 2, Plate II, Fig. 1), 12 km North of Cairo (on the left bank of the Nile). A cultivated strip of land several tens of meters wide, separates the village from the river. The village itself is situated on a slight ground elevation. In view of the raised water column of the Nile during the winter, a small bay forms below the village which, when the water starts to recede, becomes completely cut off from the river, leaving a large, shallow pool covering several hundred sq. m.; continuous desiccation reduces this area to several sq.m. in the summer months.

Sometimes, it dries up completely in the autumn or winter. The pool is densely covered with vegetation and offers suitable living conditions for watersnails. The dominant snail species is *Biomphalaria alexandrina*, less abundant are *Physa acuta* and *Lymnaea taillaudi*, scarse are *Bulinus truncatus;* soon after the pool had been cut off from the Nile we observed also the presence of several other species in it. Since the pool is situated directly below the village it receives all the sewage; various garbage dumps, dung heaps etc. are closeby. These circumstances are sufficient to warrant a source of infection with eggs of human schistosomes. In addition, the Nile shore and the field below the village are frequently visited by the village people, and the banks of the pool covered with high stands of swamp plants (a special phytocoenological study will be published by Dr. S. Hejný, Botanical Institute, Czechoslovak Academy of Sciences) are greatly polluted with human excrements. Under these circumstances, the locality offers optimal conditions for the development of *Schistosoma mansoni* the larvae of which are abundant in *B. alexandrina* from this site; larvae of *S. haematobium* have not been found in the pool.

According to information obtained in this locality within the course of our investigation (1971—1973), the incidence of *S. mansoni* larvae in the snails showed a regular periodicity. During February and March, soon after the separation of the pool from the Nile, the percentage of infected snails was very low (0.6—3 %). This may be due to the fact that only few of the original *B. alexandrina* population survived unsatisfactory conditions in this locality persisting from the last months of the previous year till the end of January of the following year; it is probable that the majority of snails recorded in February and March had come to the pool at the time when the river and pool were connected. In the following months, together with the vehement development of snail populations and their continuous concentration in the gradually reducing area of the pool, the percentage of *B. alexandrina* shedding cercariae of *B. mansoni* increased speedily and attained approximately 50 % in the summer months. In September, October and November 1971, 70—90 % of snails were infected.

In December and January, when the pool was almost dry, snail populations decreased

considerably in this locality, and cercariae of *S. mansoni* were shed by 10—12 % of snails only. The reduction in the incidence of infection may, apparently, be ascribed to the high rate of mortality of infected snails. At the end of January and the beginning of February, following a rise of the water column of the Nile, the developmental cycle was renewed in this locality.

The source of the unusually high infestation of snails of this locality with larvae of *S. mansoni* were, apparently, not only *Schistosoma* eggs from human excrements; also rats, particularly the Nile rat (*Arvicanthis niloticus*), a frequent species in these parts and a very susceptible host of *S. mansoni* and partly also *S. haematobium* (Mansour 1973), evidently play an important role.

Similar foci of *S. mansoni* (and presumably also of *S. haematobium*) on a small area, are, evidently, not exceptional in Egypt (see also Heyneman et al. 1972); there can be hardly any doubt on their importance in the maintenance and transmission of schistosomiasis of man. Namely in these localities, the utilization of interspecific antagonism between the larvae of echinostome and schistosome trematodes in the shared snail intermediate host may be effective in the control of human schistosomes by biological measures.

The importance of introducing the breeding of domestic ducks (*Anas platyrhynchos* f. *domestica*), the definitive hosts of *E. revolutum* and *E. recurvatum*, in order to increase effectively the population density of these flukes in snails of selected biotopes (foci), has been suggested earlier by Ryšavý et al. (1973). The importance of these definitive hosts has been demonstrated by the following example showing the distribution of *E. recurvatum* in the vicinity of the village of Gezireh Muhammad. The village is crossed by the Sawachel Canal; at approximately 400 m upstream, a branch of this canal (Sawachel Branch no. 1) turns off from the main canal to the south and rejoins Sawachel Canal at a point between the villages of El Sokeil and Tanash. The length of Sawachel Branch no. 1 is approximately 3 km (Fig. 2). In 1971, a flock of ducks belonging to the village of Gezireh Muhammad, was observed regularly from May till July. The ducks living on the banks of the Sawachel Canal moved over an area extending from the village to the point at which Sawachel Branch no. 1 opened into the Sawachel Canal.

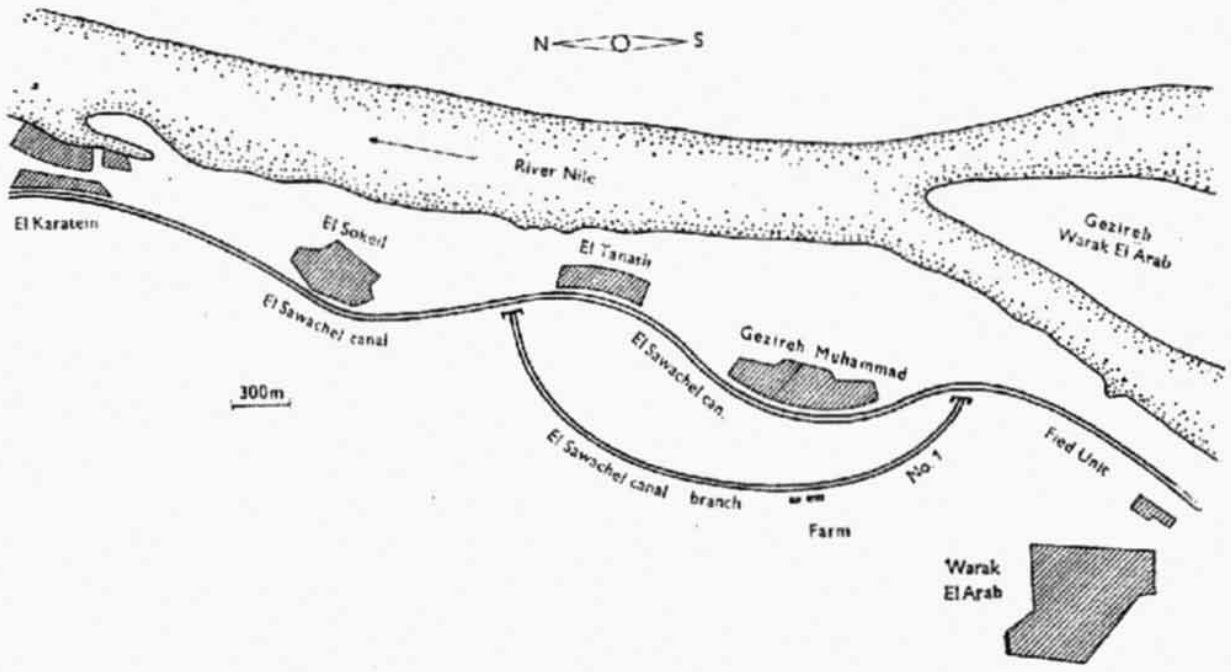


**Fig. 2.** Schema of Sawachel Canal branch No. 1.

In this area, we examined duck faeces coprologically and found in them numerous fluke eggs which resembled those of flukes of the family Echinostomatidae (both in size and structure). Examination of snails from Sawachel Canal Branch no. 1 disclosed that a permanently high percentage of *Bulinus truncatus* specimens released cercariae of *Echinoparyphium recurvatum;* the maximum of these positive intermediate hosts was found at the outlet of Sawachel Canal Branch no. 1. The number of infected snails decreased with the increasing distance from this point and, at a distance of approximately one km, it was down to zero. Also the percentage of snails harbouring metacercariae of this fluke decreased with the increasing distance, but metacercariae of *Echinoparyphium recurvatum* were found throughout the length of Sawachel Canal Branch No. 1 (Table 1).

**Table 1.** The incidence of cercariae of *Echinoparyphium recurvatum* in *Bulinus truncatus* and *Physa acuta* collected in Sawachel Canal Branch no. 1 from May till July 1971

| Distance from the outlet of Sawachel Canal Branch no. 1 | *Bulinus truncatus* | | *Physa acuta* |
|---|---|---|---|
| | Percentage of infection | | Percentage of infection |
| | Cercariae of *E. recurvatum* | Metacercariae of *E. recurvatum* | Metacercariae of *E. recurvatum* |
| 50 m | 6.8 | 72 % | 86 % |
| 100 m | 6.2 | 70 % | 85 % |
| 200 m | 4.3 | 68 % | 78 % |
| 300 m | 3.1 | 62 % | 72 % |
| 400 m | 2.5 | 52 % | 72 % |
| 500 m | 1.7 | 44 % | 68 % |
| 600 m | 1.8 | 46 % | 67 % |
| 700 m | 1.3 | 36 % | 62 % |
| 800 m | 0.9 | 27 % | 56 % |
| 900 m | 0.3 | 24 % | 47 % |
| 1000 m | — | 22 % | 42 % |
| 1100 m | — | 20 % | 39 % |
| 1200 m | — | 27 % | 37 % |
| 1300 m | — | 22 % | 35 % |
| 1400 m | — | 18 % | 33 % |
| 1800 m | — | 14 % | 30 % |
| 2000 m | — | 14 % | 29 % |

The situation described indicates that domestic ducks on the Sawachel Canal were the actual source of infection of *B. truncatus* with the fluke *E. recurvatum* on Sawachel Canal Branch no. 1. Another source of infection to be considered are various rat species including the Nile rat (*Arvicanthis niloticus*), which are suitable definitive hosts of *E. recurvatum* in this locality (particularly in view of their synanthropy).

The confirmed presence of suitable hosts in the locality was reflected in the high incidence of *E. recurvatum* in the snail intermediate hosts and, simultaneously, in the high incidence of metacercariae of this fluke in the intermediate host and in associated snails. The decrease of the incidence of *E. recurvatum* in the snails in direction off the centre of the area inhabited by the definitive hosts demonstrates that the population density of *E. recurvatum* depends on the population density of the definitive hosts in the biotope. It confirms also that the roaming range of the definitive hosts distributing *E. recurvatum* infection in the snails, is limited by the structure of the irrigation system and by hydrological conditions.

Our example demonstrates that a situation favourable for a double infection of intermediate hosts of human schistosomes, may occur also under natural conditions. It follows from experimental work (Heyneman et al. 1972; Baruš et al. 1974; Moravec et al. 1974, etc.) that echinostome flukes are capable to suppress all larval stages of human schistosomes, and are also highly pathogenic to their snail intermediate hosts; this may contribute considerably to a reduction of snail populations in the individual biotopes. In order to obtain a positive effect which would be remarkable also from the epidemiological point of view, it is necessary to warrant a marked increase in the incidence of infection of the snails with echinostome flukes. This may be achieved by transferring a large number of echinostome eggs obtained in the laboratory from experimentally infected definitive hosts to selected foci. This, however, would be effective only in foci restricted to a small area outside the flow of the irrigation system. Under the conditions of Egypt, a more suitable and economically more effective way appears to be the introduction of duck breeds (the definitive hosts of *E. revolutum* and *E. recurvatum*) on free runs to localities marked as a focus of schistosomiasis (with the incidence of human schistosomes in the snails).

Since the participation of free-living birds (Bayer 1954) cannot be counted on as being remarkably effective in a landscape as greatly changed by man-made activities as that of Egypt, it will be necessary to introduce a new member to the systems of the individual biocoenoses with the aim to affect simultaneously both species of human schistosomes, i.e., *S. mansoni* and *S. haematobium*. In addition to the fact that ducks play an important role in the maintenance, distribution and increase of infection with echinostomes in the various localities, they also feed on snails and, in this way, may greatly contribute to a reduction of snail populations in selected localities.

It is, therefore, to be expected that the utilization of the phenomenon of direct and indirect antagonism between echinostomes and human schistosomes in the snail intermediate hosts for the biological control of schistosomiasis is one of the ways which may lead to a marked decrease in the incidence of infection with *S. mansoni* and *S. haematobium* in the human population. Moreover, this procedure might be used without chemical measures, unfavourably affecting the environment of man.

## К НЕКОТОРЫМ ВОПРОСАМ БИОЛОГИЧЕСКОЙ БОРЬБЫ С ШИСТОСОМАМИ ЧЕЛОВЕКА В ЕГИПЕТЕ

Б. Рышавы, В. Баруш, Ф. Моравец и Ф. Юсиф

**Резюме.** В статье дан обзор результатов исследований по паразитам водных моллюсков из района Варак эл Араб и по проявлениям антагонизма между личинками трематод из семейств *Echinostomatidae* и *Schistosomatidae* в промежуточном хозяине. Совместные исследовательские работы исполняли чехословацкие и египетские сотрудники в 1971—1973 гг. Полученные результаты подтвердили выявленную раньше аггрессивность редий эхиностом против спороцист шистосом и патогенное воздействие стадий развития этих трематод, включая метацеркарий, на промежуточного хозяина-моллюска. В работе проанализированы возможности практического использования полученных данных для биологической борьбы с шистосомами человека в областях с густой сетью ирригационных каналов.

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