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# ENTOMOGENOUS FUNGI ASSOCIATED WITH THE TICK IXODES RICINUS (L.)

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**Abstract.** The ticks *Ixodes ricinus*, *Dermacentor marginatus* and *Dermacentor reticulatus* examined during a field experiment were found to be infected with 17 species of fungi belonging to the groups Deuteromycetes and Phycomycetes, namely obligate parasites (5), facultative parasites (5) and saprophytes (7). In the case of *Ixodes ricinus* the season, biotope and infestation in relation to the beginning of oviposition were considered. A morphological characteristic of parasitic species of fungi is given.

In the course of a long-term investigation of the life cycle of *Ixodes ricinus* (L.) in the region of southern Moravia many ticks were found to be infected with several species of fungi, belonging mostly to the group of Fungi Imperfecti (Deuteromycetes). After isolation and cultivation of the fungi, besides the saprophytic species commonly occurring in nature, also the obligate and facultative parasites were detected. Although the main goal of our investigation was the life cycle of ticks, the fungi were studied in detail and the results obtained are summarized in the present paper.

## MATERIAL AND METHODS

The long-term investigation of the life cycle of *Ixodes ricinus* in nature was carried out at the Valtice locality, the district of Břeclav in southern Moravia, in the years 1969—1972. The fungi infecting ticks were studied in the winter season 1971—1972 and in the summer period 1972 when mostly engorged adults of first daughter generation were investigated. The ticks were kept in cylindrical cages measuring 50 × 25 mm, formed by a wire frame covered with a fine silon fabric. If necessary the cages were exchanged for new ones in order to exclude a possible contamination. Each engorged female was kept in a separate cage, while the unengorged adults were kept together, several specimens in one cage. The cages were covered with the litter or shaded with grass and placed in three different types of biotopes: meadow (opened area covered with dense turfy grass), wood (thermophilic oak forest) and a biotope on the border of meadow and leafy wood, marked further as the edge of the wood. The microbiotopes under investigation were situated at the distance of some tens of meters from one another. The cages were checked regularly every month and the specimens infected with fungus were removed and stored. The isolated fungi were identified gradually in order to separate especially the entomogenous species which may play a role in natural reduction of tick population.

The experiments carried out in the winter season 1971—1972 started on 3rd November 1971 when the cages with ticks were inserted in soil 10—30 cm under the surface, some of them, however, were left on the surface and covered with litter or grass. The hibernation of ticks took place in the same biotopes as in the summer experiments. The summer season 1972 was opened on 5th April 1972 when cages were taken out from the soil and closed on 3rd November 1972 when the ticks that were alive were again prepared for overwintering.

During the winter experiment we investigated 111 males and 599 females of *Ixodes ricinus*, of which 420 overwintered as engorged and 179 as unengorged ones. In the summer experiment 552 females, of which 495 engorged and 57 unengorged, were observed. The males were not included in the results of summer experiment, because they were exposed in the field for a relatively short time and were excluded from the experiment after copulation with feeding females. For isolation and determination of fungi we obtained 329 specimens of *Ixodes ricinus* on which the infestation with fungi was visible macroscopically. We succeeded in isolating the fungus from 68 specimens.

Engorged females of *Dermacentor reticulatus* (Fabr.) and *Dermacentor marginatus* (Sulz.) served as controls. They were exposed in May 1972 and the specimens infected with fungi were collected for cultivation during July, August and September. We used a total of 68 engorged females of *D. marginatus* and 58 engorged females of *D. reticulatus*. The fungi for cultivation were taken also from engorged larvae of all three species and engorged nymphs of both species of the genus *Dermacentor* originating from the above-mentioned females.

The strains of fungi were obtained directly from the tick bodies. The infected specimen was placed in a sterile Petri dish with Sabouraud's agar and kept in a thermostat at 27 °C. After 3—5 days of cultivation the fungus was determined. All isolated species and strains of fungi are deposited as pure cultures at the Department of Insect Pathology of the Institute of Entomology for further use.

## RESULTS

Considering that the relationship between the fungi and ticks was markedly influenced by the season, the results of winter and summer experiments are given separately.

**Winter experiment.** During the winter experiment, i.e. in the resting period of development, the ticks died of fungal infection only occasionally (Table 1). Out of 290 unengorged

**Table 1.** Infection of overwintering males and females of *Ixodes ricinus* with the fungi

| | | Meadow | | Edge of wood | | Wood | | Total | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Unengorged | Engorged | Unengorged | Engorged | Unengorged | Engorged | Unengorged | Engorged | |
| Investigated | ♂ | — | — | 42 | — | 69 | — | 111 | — | 111 |
| | ♀ | 11 | 52 | 66 | 175 | 102 | 193 | 179 | 420 | 599 |
| Alive after overwintering | ♂ | — | — | 31 | — | 64 | — | 95 | — | 95 |
| | ♀ | 11 | 36 | 45 | 128 | 82 | 148 | 138 | 312 | 450 |
| Losts during overwintering | ♂ | — | — | 11 | — | 5 | — | 16 | — | 16 |
| | ♀ | 0 | 16 | 21 | 47 | 20 | 45 | 41 | 108 | 149 |
| Infected with fungus | ♂ | — | — | 8 | — | 0 | — | 8 | — | 8 |
| | ♀ | 0 | 5 | 10 | 5 | 0 | 9 | 10 | 19 | 29 |
| Positive cultivation | | 0 | 1 | 0 | 2 | 0 | 2 | 0 | 5 | 5 |

specimens (179 ♀♀ and 111 ♂♂) only 18 specimens (10 ♀♀ and 8 ♂♂), i.e. 6.2 %, died of fungal infection. All of them, however, were placed in one cage and overwintered in the depth of 20 cm under the soil surface. The cultivation was negative. Out of 420 engorged females, the fungus was isolated only from 19 of them, i.e. from 4.8 %. Eleven specimens overwintered on the surface, 3 in the depth of 10 cm and 5 in the depth of 20 cm under the surface. The presence of the fungus was confirmed by cultivation only in 5 cases (*Beauveria tenella* 1×, *Cephalosporium coccorum* 1×, *Scopulariopsis brevicaulis* 1× and *Fusarium graminearum* 2×); all these specimens overwintered on the surface.

**Summer experiment.** During the experiments performed in summer season, i.e. in the active period of tick development, we observed markedly higher percentage of ticks infected with fungi than in the winter. Table 2 based on macroscopical observation shows that there are no substantial differences in the percentage of infected engorged females in the different microbiotopes. The number of infected engorged females in the microbiotopes investigated ranges from 45.1 % to 57.3 % of the total number of the engorged females placed in the given microbiotope. The lowest infestation was on the edge of wood, the highest on the meadow area. However, these differences are not statistically significant ($\chi^2_{(2)} = 4.439$). Also the ratio of females infected before and after oviposition is almost the same in all the three microbiotopes (1 : 4—6) and the differences between the individual biotopes are statistically insignificant ($\chi^2_{(2)} = 0.951$) as well. A similar ratio was also found in the mortality of females which were not infected with fungi: 3—7.5 times less females died before oviposition than after it and the differences between the microbiotopes were statistically insignificant ($\chi^2_{(2)} = 3.356$).

In the meadow area and on the edge of wood about one half of females that died before oviposition was infected with fungi, while in the forest area the number of infected specimens reached nearly two thirds (Table 2). Although these ratios are not statistically significant, probably due to low operands, this fact should be taken into consideration. In the forest area the fungal infection is likely to decrease the number of females before oviposition.

A total of 16 fungal species have been isolated from the engorged females of *Ixodes ricinus*. Five of them may be ranged to parasites, 5 to facultative parasites and 6 to saprophytes (Table 3). Most abundant were *Beauveria tenella* (15×) and *Fusarium graminearum* (11×), less frequently were found the species *Aspergillus niger* (8×), *Mucor*

**Table 2.** Infection of the females of *Ixodes ricinus* with the fungi during 1972

| Ticks investigated / Biotope | Total number | Alive after season | Dead during the season: Infected with fungi: Before oviposition | After oviposition | Not infected with fungi: Before oviposition | After oviposition | Ratio of infected to not infected dead ticks |
|---|---|---|---|---|---|---|---|
| **Engorged ticks** | | | | | | | |
| Meadow | 89 | 0 | 8 | 43 | 9 | 29 | 1.3 : 1 |
| Edge of wood | 144 | 0 | 10 | 55 | 11 | 68 | 1 : 1.2 |
| Wood | 262 | 0 | 29 | 114 | 14 | 105 | 1.2 : 1 |
| **Unengorged ticks** | | | | | | | |
| Meadow | 10 | 10 | 0 | — | 0 | — | — |
| Edge of wood | 29 | 3 | 25 | — | 1 | — | 25 : 1 |
| Wood | 18 | 2 | 8 | — | 8 | — | 1 : 1 |

*spinosus* (8×) and *A. parasiticus* (5×). Other species were detected only sporadically. The parasitic species *Beauveria tenella* occurred most frequently in the forest area, less frequently on the edge of the wood and only in one case in the meadow area. Similarly also the saprophytic species *Mucor spinosus* was most abundant in the forest area, occasional findings were from the edge of the wood. On the other hand, *Fusarium graminearum* infected the ticks mostly in the meadow area, less frequently on the edge of wood and a single isolate originated from the forest area. Other species did not show any relation to the type of biotope.

**Table 3.** Species of fungi isolated from the adult *Ixodes ricinus*

| Species of fungus | Type | Meadow | Edge of wood | Wood | Total number of isolated strains | | |
|---|---|---|---|---|---|---|---|
| | | | | | Before oviposition | After oviposition | Total |
| *Aspergillus parasiticus* | OP | 1 | 2 | 2 | 1 | 4 | 5 |
| *Beauveria bassiana* | OP | | 1 | | | 1 | 1 |
| *Beauveria tenella* | OP | 1 | 4 | 10 | 5 | 10 | 15 |
| *Cephalosporium coccorum* | OP | 1 | | | 1 | | 1 |
| *Paecilomyces fumosoroseus* | OP | | 1 | 1 | | 2 | 2 |
| Total number of obligate parasites | OP | 3 | 8 | 13 | 7 | 17 | 24 |
| *Aspergillus niger* | FP | 2 | 3 | 3 | 1 | 7 | 8 |
| *Fusarium solani* | FP | 2 | | | 1 | 1 | 2 |
| *Scopulariopsis brevicaulis* | FP | | 1 | 1 | | 2 | 2 |
| *Trichoderma koningii* | FP | 1 | | 1 | 1 | 1 | 2 |
| *Conidiobolus coronatus* | FP | | 1 | | | 1 | 1 |
| Total number of facultative parasites | FP | 5 | 5 | 5 | 3 | 12 | 15 |
| *Alternaria tenuissima* | S | | 2 | | 2 | | 2 |
| *Fusarium graminearum* | S | 7 | 3 | 1 | 4 | 7 | 11 |
| *Mortierella* sp. | S | | 1 | | | 1 | 1 |
| *Mucor spinosus* | S | | 2 | 6 | 2 | 6 | 8 |
| *Penicillium* sp. | S | | | 1 | | 1 | 1 |
| *Verticillium psaliotae* | S | 1 | | | | 1 | 1 |
| Total number of saprophytes | S | 8 | 8 | 8 | 8 | 16 | 24 |
| Total | | 16 | 21 | 26 | 18 | 45 | 63 |

OP — obligate parasite; FP — facultative parasite; S — saprophyte

The fungi most frequently encountered during the collections of infected insects in nature are those of saprophytic type. The typical saprophytes isolated in our experiments were the following species: *Fusarium graminearum* Schw., *Penicillium* sp., *Mucor spinosus* van Tiegh., *Alternaria tenuissima* (Fr.) Wiltsh., *Mortierella* sp., *Verticillium psaliotae* Tresch., and *Cladosporium* sp. All these fungi were isolated from adult specimens of *I. ricinus*, with the exception of *Cladosporium* sp. that was isolated from the larvae of *I. ricinus* and nymphs of *D. reticulatus* and *D. marginatus*.

Another group comprises saprophytic species which, under certain conditions, are able to change for parasitic ones. These are the so-called facultative parasites. In our investigation, we isolated the following species belonging to this group: *Scopulariopsis brevicaulis* (Sacc.) Bain, *Trichoderma koningii* Oud., *Fusarium solani* App. et Wr., *Aspergillus niger* van Tiegh. and *Conidiobolus coronatus* (Cost.) Kev. All of them have been described several times as causative agents of insect diseases or death.

Most important group as to the relationship between the fungus and the host are the obligate parasitic fungi, as e. g. those obtained by us from *I. ricinus*: *Beauveria bassiana* (Bals.) Vuill., *B. tenella* (Delacr.) Siem., *Aspergillus parasiticus* Speare, *Cephalosporium coccorum* Petch and *Paecilomyces fumosoroseus* (Wize) Vass. The finding of some of these fungi on the tick is of such an importance that we are giving here their concise characteristics. All species belong to the group of Fungi Imperfecti — Deuteromycetes, with the exception of *Conidiobolus coronatus* of the group Phycomycetes. The mentioned representatives of the group Deuteromycetes are mostly common parasites of insects. Most widely spread are two species of the genus *Beauveria* Vuill., namely *B. tenella* and *B. bassiana*. *B. tenella* is of a polyphagous type, but its preferred hosts are the beetles. It has cosmopolitan distribution. The fungus covers the host organism with white, at first filamentous, later powdery cover. Microscopic observations reveal flask-shaped phialides bearing characteristic oval conidia. They measure 2—6 × 1.5—3 μ and often occur in multitudinous groups. Typical for the genus *Beauveria* is the zigzag spore bearing filaments (Fig. 1).

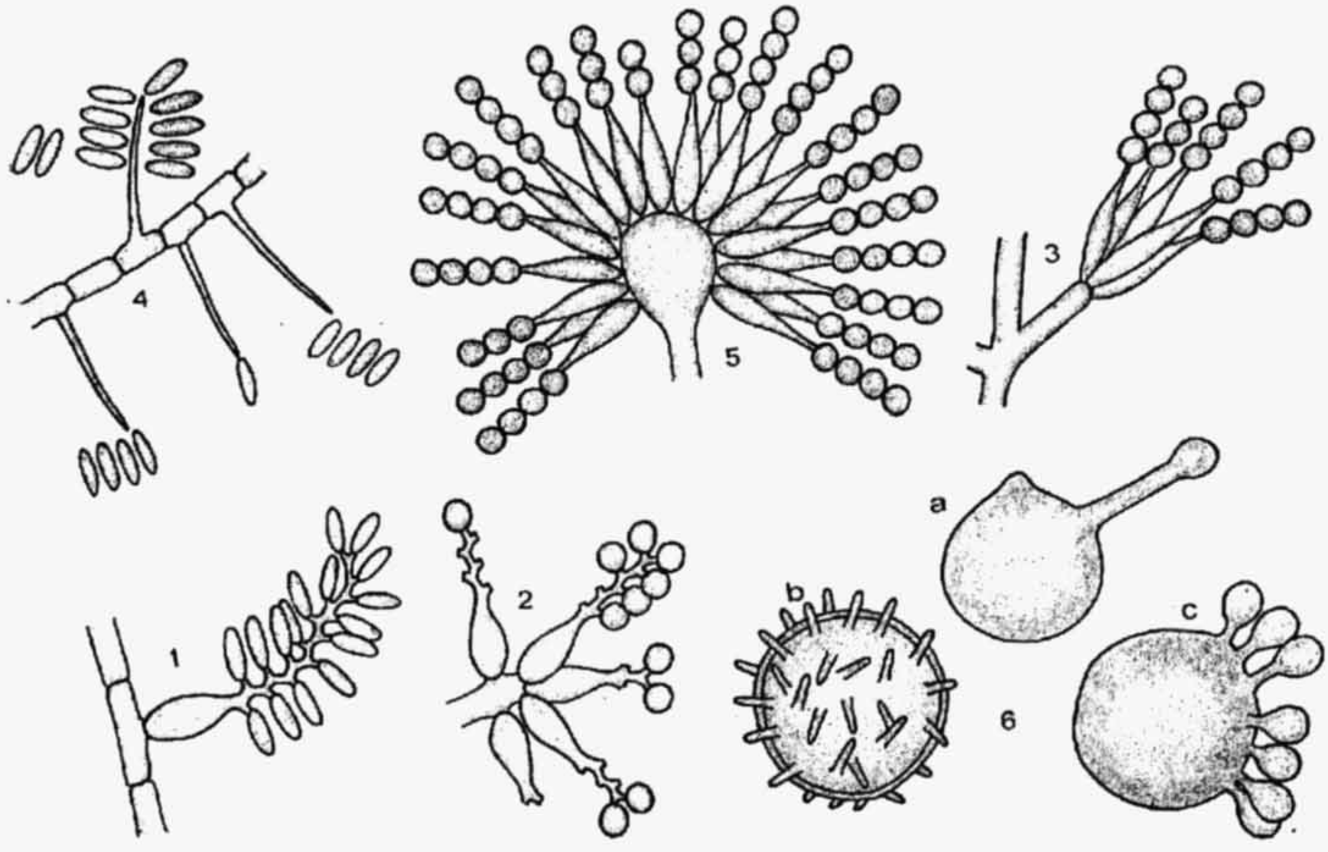


**Fig. 1.** 1 — *Beauveria tenella:* phialides with characteristic zigzag spore bearing conidiophore. 2 — *Beauveria bassiana:* cluster of phialides with conidia. 3 — *Paecilomyces fumosoroseus:* cluster of phialides with conidia in chains. 4 — *Cephalosporium coccorum:* conidiophores with oval conidia. 5 — *Aspergillus parasiticus:* apical part of conidiophore with typical bladder and a row of phialides with conidia in chains. 6 — *Conidiobolus coronatus:* a) microconidium germinating from primary conidium, b) echinulate conidia, c) primary conidium with formed microconidia.

*B. bassiana* is very similar to the above species if observed both macro- and microscopically. It differs in the shape of conidia, which are spherical and measure 1—4 μ (Fig. 2). It is a non-specialized species parasitizing insects of all groups all over the world.

*Paecilomyces fumosoroseus* was earlier placed in the genus *Spicaria* Harz. Its distribution is cosmopolitan, similarly as with the previous species, it is also a non-specific parasite, infecting mostly Lepidoptera and Diptera. It closely resembles the genus *Beauveria*, but the cultures are of light pink-brown colour. Characteristic of this species are the phialides which are more slender, tubular, with straight attenuated part (Plate I, Fig. 2). Conidia are broadly oval to spherical, measuring about 3 μ and connected in chains mostly in younger cultures (Fig. 3).

*Cephalosporium coccorum* parasitizes mostly scale insects in the tropical and subtropical regions. Also in our country it reduces sometimes their numbers in case of their mass occurrence. It forms a white cover on the insects. In comparison with the genus *Beauveria* it is more thin and less compact (Plate II, Fig. 1), the oval conidia, especially with younger cultures, remain connected by the slime in a head which disintegrates in older cultures. Conidiophores are slender, attenuated, growing separately on the mycelium. Conidia are elongated, sometimes slightly crescent-shaped, measuring 3—5×0.75—1.5 μ (Fig. 4).

*Aspergillus parasiticus* is also a cosmopolitan species parasitizing different forms of insects, especially scale insects. At first it forms light filamentous hyphae, later a typical yellow-green powderous cover. Its conidiophores are not divided, they are widened in a typical bladder mostly with one row of phialides (Plate II, Fig. 2) splitting off the chains of globular conidia measuring 3.3—6 μ (Fig. 5).

All above-mentioned fungi do not demand any special nutrient media, due to their polyphagous character and may be therefore easily grown in all sorts of agars, as well as on plant substrates, e.g. potatoes, carrot, corn etc.

*Conidiobolus coronatus* is usually ranged to the saprophytes in the literature, mainly for its capability to grow on artificial media (Kevorkian 1937). The group Entomophthoraceae, to which it belongs, is characterized by a considerably reduced mycelium which is at first not divided, later divided, breaking up into one- and multinucleate segments, so-called hyphal bodies, typical of this group. They give rise to an asexual stage of the fungus — conidiophores bearing terminal conidia. In the species *C. coronatus* they measure 26—45 μ and are vehemently discharged from the conidiophore. On a suitable host the conidia germinate and produce either a hypha or a secondary conidium. In the species *C. coronatus* the primary conidia often form hair-like appendages mostly over the whole surface. These spores are named "echinulate conidia". Under favourable conditions these appendages give rise to globular microconidia (Fig. 6). Kevorkian (1937) reported this fungus from termites and performed a series of experiments with their artificial infection. He obtained 65 % mortality of termites and considers therefore this species to be parasitic for insects. The fungus occurs often in the tropical regions where it is responsible for serious diseases of face parts in man (Vanbreuseghem 1966); it is also abundant in our country, but mostly as a saprophyte. The finding of *C. coronatus* on *I. ricinus* is of great importance, because there is a possibility to transfer the spores on man and to cause a serious illness. Therefore we are giving a description of this fungus, although it cannot be placed in the obligate parasites of arthropods.

Table 4, which is based on the positive results of cultivation introduces new aspects in the study of this problem. As it follows from this table, most saprophytic species were found on the meadow area (ratio parasite:facultative parasite:saprophyte = 1 : 1.7 : 2.7), whereas in the forest area the parasitic species prevailed (2.6 : 1 : 1.6).

**Table 4.** Positive cultivations from engorged females of *Ixodes ricinus*

| Finding | | Biotope | Meadow | | Edge of wood | | Wood | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Number | % | Number | % | Number | % | Number | % |
| Positive cultivations | Obligate parasite | Before oviposition | 1 | 2.0 | 1 | 1.5 | 5 | 3.5 | 7 | 2.7 |
| | | After oviposition | 2 | 3.9 | 8 | 12.3 | 8 | 5.6 | 18 | 7.0 |
| | | Total | 3 | 5.9 | 9 | 13.8 | 13 | 9.1 | 25 | 9.7 |
| | Facultative parasite | Before oviposition | 1 | 2.0 | — | — | 2 | 1.4 | 3 | 1.1 |
| | | After oviposition | 4 | 7.8 | 4 | 6.2 | 3 | 2.1 | 11 | 4.2 |
| | | Total | 5 | 9.8 | 4 | 6.2 | 5 | 3.5 | 14 | 5.3 |
| | Saprophyte | Before oviposition | 3 | 5.9 | 3 | 4.6 | 2 | 1.4 | 8 | 3.1 |
| | | After oviposition | 5 | 9.8 | 5 | 7.7 | 6 | 4.2 | 16 | 6.2 |
| | | Total | 8 | 15.7 | 8 | 12.3 | 8 | 5.6 | 24 | 9.3 |
| Positive cultivations | | | 16 | 31.4 | 21 | 32.3 | 26 | 18.2 | 63 | 24.3 |
| Negative cultivations | | | 35 | 68.6 | 44 | 67.7 | 117 | 81.8 | 196 | 75.7 |
| Positive macroscopical examination | | | 51 | 100 | 65 | 100 | 143 | 100 | 259 | 100 |

On the edge of wood the ratio of parasites and saprophytes is almost the same, while the facultative parasites are less numerous (2.25 : 1 : 2).

The ratio of positive cultivation from engorged females of *I. ricinus* before oviposition and after it is approximately 1 : 2 for both parasitic and saprophytic fungi, while for facultative parasites it is roughly 1 : 4. These differences, however, are not statistically significant ($\chi^2_{(2)} = 0.769$), probably due to small number of specimens examined and are consistent with the total ratio of the engorged females dead before and after oviposition, as discussed above (Table 2).

The isolations from the unengorged females of *I. ricinus* were unsuccessful. Cultivation experiments were also carried out using engorged larvae of *I. ricinus* originating from 10 cages placed on meadow area and from 29 cages from forest area. From this material only 4 cultivations gave positive result s(*Aspergillus parasiticus*, *Beauveria tenella*, *Mucor spinosus* and *Cladosporium* sp.). It was also observed that the fungi may contaminate, and in fact do contaminate, the eggs so that after removal of the infected female the fungus keeps growing and often causes the destruction of all eggs. In this way the fungi may considerably influence the whole production of ticks.

The study of fungi associated with *D. reticulatus* and *D. marginatus* gave similar results as in the case of *I. ricinus*. The ratio of healthy and infected engorged females is nearly the same for both species and, like in females of *I. ricinus*, most of them are infected with the fungus only after oviposition (Table 5). All species of fungi isolated from these ticks are identical with those from *I. ricinus*. A great part of dead engorged

**Table 5.** Infection of engorged females of *Dermacentor reticulatus* and *D. marginatus* with the fungi during 1972

| Investigated ticks / Biotope | Total number | Alive after season | Dead during the season | | | | Ratio of infected and not infected dead ticks |
|---|---|---|---|---|---|---|---|
| | | | Infected with fungi | | Not infected with fungi | | |
| | | | Before oviposition | After oviposition | Before oviposition | After oviposition | |
| | | | *Dermacentor reticulatus* | | | | |
| Meadow | 30 | 0 | — | 12 | 1 | 17 | 1 : 1.5 |
| Wood | 28 | 0 | 1 | 12 | — | 15 | 1 : 1.1 |
| | | | *Dermacentor marginatus* | | | | |
| Meadow | 35 | 0 | — | 17 | 2 | 16 | 1 : 1 |
| Wood | 33 | 0 | — | 14 | 2 | 17 | 1 : 1.4 |

nymphs of these species was infected with fungi of parasitic (*Beauveria tenella* 9×), and of saprophytic (*Cladosporium* sp. 6×, *Mucor spinosus* 5×) type. Other species of fungi were found only occasionally (*Aspergillus parasiticus* 1×, *Beauveria bassiana* 2×, *Cephalosporium coccorum* 1×). No positive results were obtained when cultivating the fungi from the larvae of both these species.

## DISCUSSION

There are only occasional reports on the findings of fungi on ticks. Kolomiec (1945) mentions that the spores of *Aspergillus fumigatus* Fress. may be distributed by *Dermacentor marginatus* and cause a lethal infection of the ticks. Samšiňáková (1957) recorded a finding of fully engorged female of the tick *Ixodes ricinus* infected with entomogenous fungus *Beauveria globulifera* (Speg.) Pic. (= *B. tenella*). After transfer to the laboratory the female did not lay eggs and died after two weeks. Later on, a white mycelium of *B. tenella* appeared near the mouth and the fungus grew through the cuticle on the whole ventral part of body (Plate I, Fig. 1). In view of the fact that the ticks do not accept other food than the blood of their host, the oral infection may be excluded. Therefore the tick must have been infected through the cuticle and the fungus prevented it from oviposition. Krylov (1972) isolated the fungi of the genus *Penicillium* Link and *Aspergillus* Mich. from the ticks *Argas persicus* (Oken).

In other groups of mites the findings of fungi are more frequent. They belong to different species and live as commensals, symbionts or parasites (Thaxter 1896, 1924, 1926). The mites were also reported to serve as distributors of fungal spores (Giard 1889). Some species of typical entomogenous fungi, e.g. of the family Entomophthoraceae, were found to be responsible for epizootic diseases of mite populations. In Czechoslovakia these findings were recorded by Weiser (1968) and Weiser and Daniel (1969) in the species *Tetranychus althaeae* Hanst, *Veigaia nemorensis* (Koch) and *Proctolaelaps pygmaeus* (Mül.).

During some period of their life cycle the ticks take shelter in the soil where the conditions, especially humidity, are very favourable for the development of fungus and the ticks are thus exposed to the infection. The results of our experiments revealed that the species *Ixodes ricinus*, *Dermacentor reticulatus* and *D. marginatus* are infested by almost the same species of fungi and also the ratio of infected to not infected engorged females is nearly the same. Similarly also most females are infected with fungi only after oviposition.

Two thirds of the fungi originating from the forest area belong to obligate or facultative parasites. Considering that the forest is a natural and characteristic biotope of *Ixodes ricinus*, this finding is of great importance. It gives evidence that the parasitic species of fungi (represented most often by *Beauveria tenella*), which commonly occur in the forest area, may actively infest also the tick *Ixodes ricinus*. This assumption is supported by the fact that black spots were found on the bodies of some specimens and gradually the ticks grew black completely. This may be a characteristic of fungal disease.

With regard to the fact that our experiments were performed under artificial conditions (the ticks were kept in cages) which need not be fully consistent with those in free nature, it still remains to be verified whether the ticks are a suitable substrate for the development of entomogenous fungi, if the fungi do kill the healthy living ticks or infect only the weakened and damaged ones and what is the frequency of infection in nature and the conditions most favourable to it. However, the imperfect fungi may already be regarded as one of the potential factors reducing the natural population of *Ixodes ricinus*. Nevertheless, the application of our results in the biological control of ticks should be verified by further experiments.

## CONCLUSIONS

The ticks *Ixodes ricinus*, *Dermacentor marginatus* and *D. reticulatus* were found to be infected with 17 species of fungi belonging to the groups Deuteromycetes and Phycomycetes.

During the resting period of the life cycle of *I. ricinus* in the winter season the ticks were infected only occasionally, irrespective of the fact if they were engorged or not. It may be explained by the stillness of the environment in which the ticks hibernate. In winter period the spores are not introduced in the cage and the development of fungi is slowed down or stopped at that time.

In summer season the fungi infect 45.1—57.3 % of engorged females of *I. ricinus*. Higher infection rate during the summer is due to the activity of ticks and more favourable conditions for the growth of fungi.

The number of infected ticks is almost the same in all three biotopes. In the forest area, however, the ticks are infected mostly with parasitic fungi, whereas in the meadow area with saprophytic species.

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## ЭНТОМОПАТОГЕННЫЕ ГРИБКИ У КЛЕЩА *IXODES RICINUS* (L.)

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**Резюме.** На клещах *Ixodes ricinus*, *Dermacentor marginatus* и *Dermacentor reticulatus*, содержанных непосредственно в природе, было найдено всего 17 видов грибков, входящих в группы *Deuteromycetes* и *Phycomycetes*, именно облигатно паразитические (5), факультативно паразитические (5) и сапрофитные (7) виды. У вида *Ixodes ricinus* была сделана оценка находок в зависимости от сезона, биотопа и поражения в отношении к началу яйцекладки. Дана морфологическая характеристика паразитических видов грибков.

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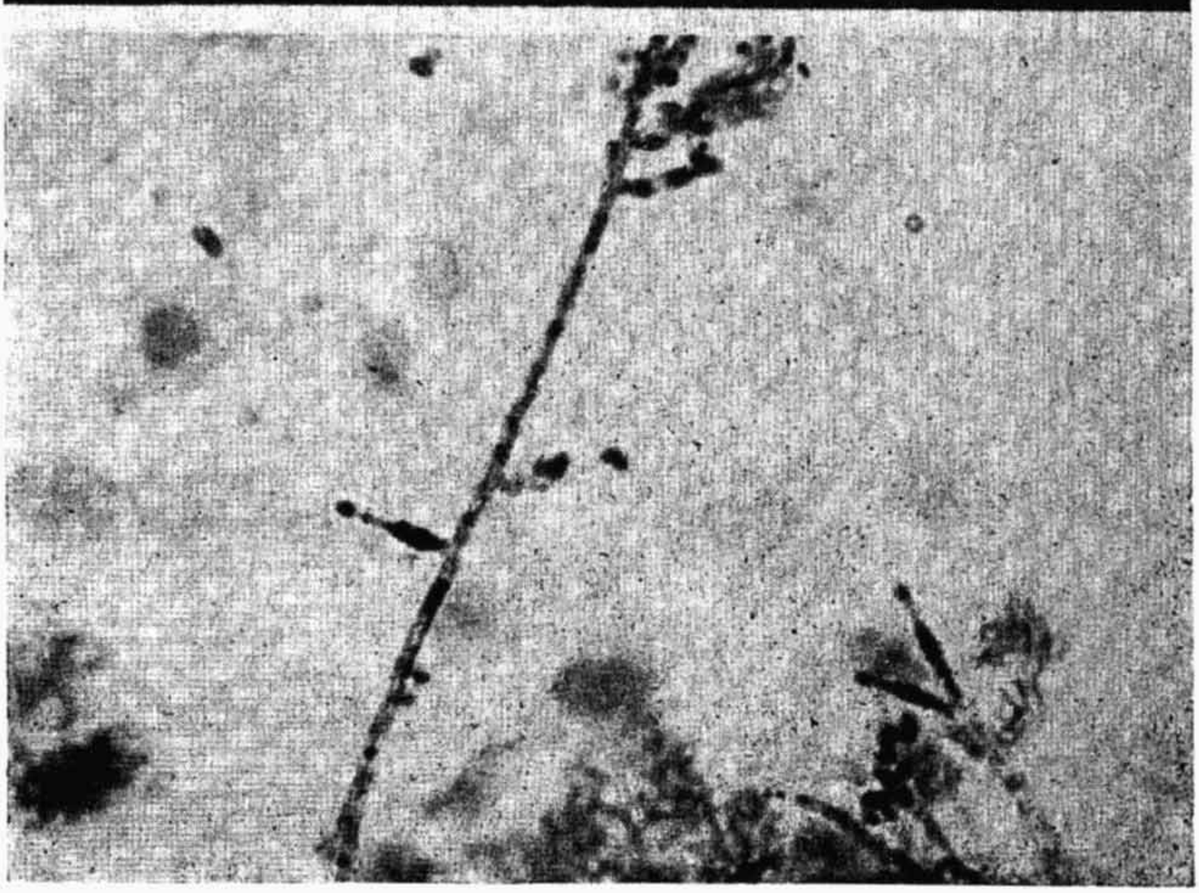
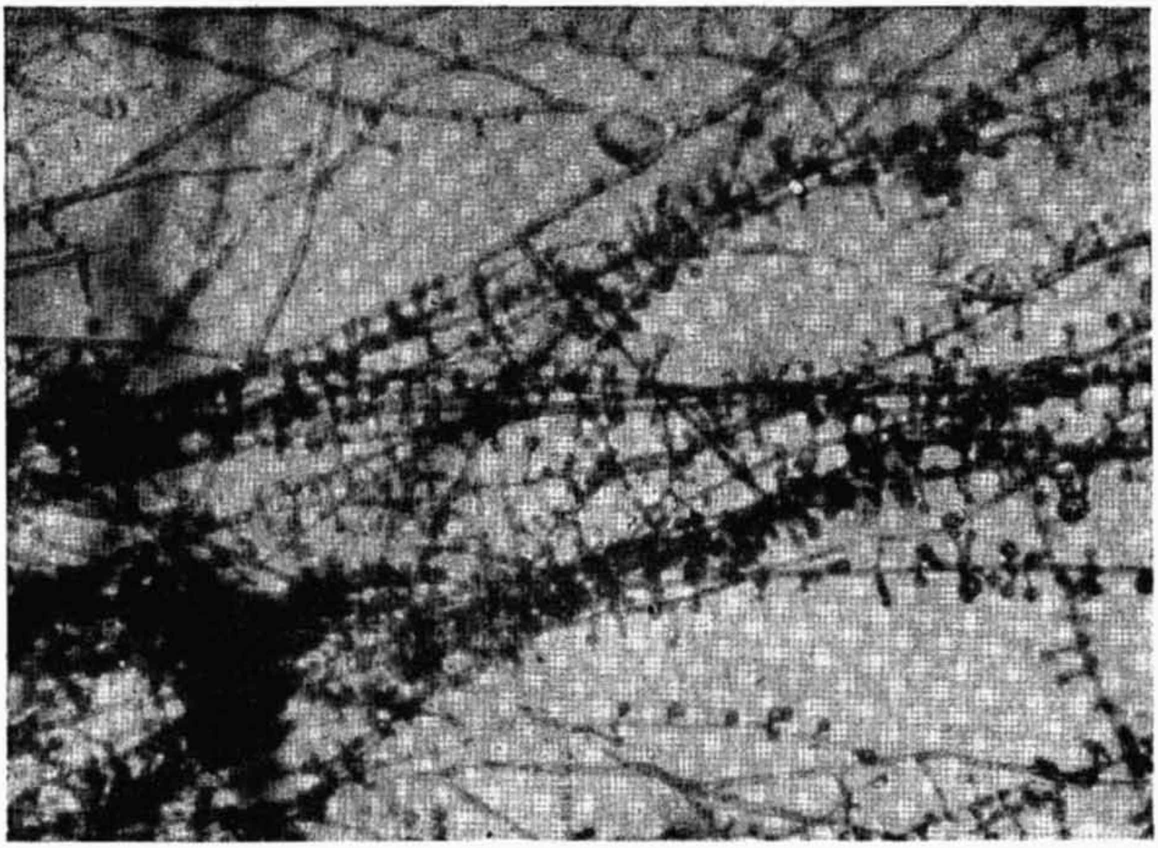


**Fig. 1.** Female of *Ixodes ricinus* infected and covered with the fungus *Beauveria tenella*.

**Fig. 2.** *Paecilomyces fumosoroseus* — phialides with conidium.



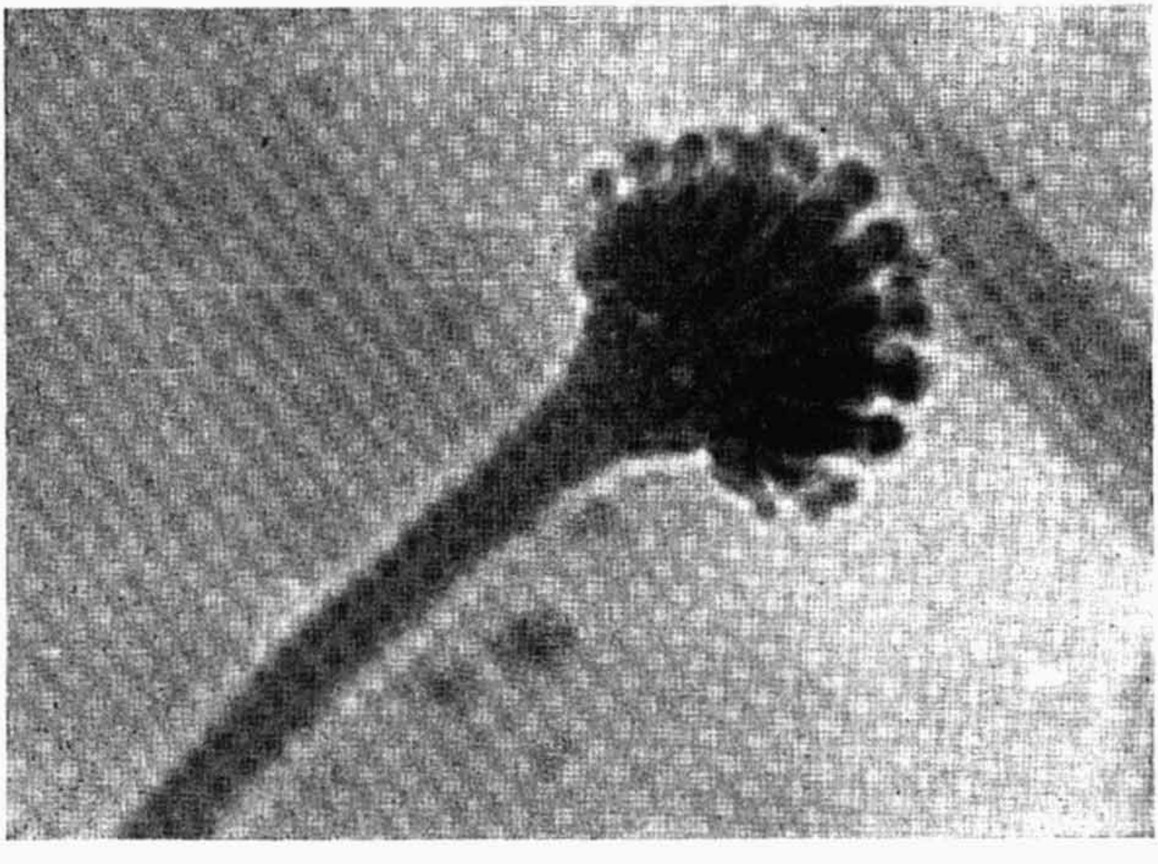


**Fig. 1.** Culture of entomogenous fungus *Cephalosporium coccorum.*
**Fig. 2.** *Aspergillus parasiticus* — conidiophore with one row of phialides bearing conidia.