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Investigation of the structural reorganization of micromycetes in hypomagnetic fields

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Abstract. Using the experimental setup that allows the Earth's magnetic field to be screened up to 1-100 nT, we found features of the microscopic fungi growth pattern, namely, the appearance of spiral growth instead of fractal. A hypothesis was put forward on the participation of a charged protein cluster - Spitzenkorper, located in the apical zone of cells, in the reorganization of fungal growth.

1. Introduction

The evolution of the biosphere occurred in the geomagnetic field. Many facts of the adaptation of organisms to the geomagnetic field and its use, for example, as a navigation signal by many animals and microoganisms, are known. At the same time, there is a growing interest in the effects of the super-weak magnetic fields, compared with the Earth's magnetic field (EMF), on biological objects [1,2]. This becomes especially relevant in the light of future interplanetary flights, when the humans will be subjected to long periods of exposure to the hypomagnetic field, which is thousands of times weaker than the EMF.

Despite the numerous magnetobiological effects described in the relevant literature, the physical and biological mechanisms of action of hypomagnetic fields are far from being understood. In this paper, the effect of the EMF shielding on the morphology and growth of some micromycetes and the search for possible mechanisms for the considered magnetobiological effects are investigated.

2. Experimental details

For shielding, an experimental setup was used, which is a five-layer cylindrical ferromagnetic screen with an internal solenoid to create a super-weak uniform magnetic field (see figure 1). The outer screen is made of an Armco-iron, the inner cylinders of the screen are made of 79HM permalloy with high magnetic permeability. The coefficient of longitudinal screening of external disturbances in the frequency band of 0–0.15 Hz was ~ 10^3, and of the transverse one - 10^4. Such a setup made it possible to carry out experiments in the range of super-weak magnetic fields 1–100 nT. The magnetic field was measured using a fluxgate magnetometer and Mz magnetometer on cesium vapor.

Figure 1. Experimental setup for shielding the geomagnetic field.

The experimental biological objects were filamentous fungi *Ulocladium consortiale* (Thüm.) Simmons, *Neurospora crassa* Shear et B. O. Dodge. Micromycetes were cultivated under super-weak magnetic field for 7-10 days on thin agar films and in Petri dishes using Czapek agar medium. Control samples of fungi were grown in the geomagnetic field (~ 48 μT), at the same temperature and light intensity. A color digital camera LEICA DC 300F (Leica, Germany) mounted on a H605T trinocular microscope (WPI, USA) was used to photograph the fungi growth process.

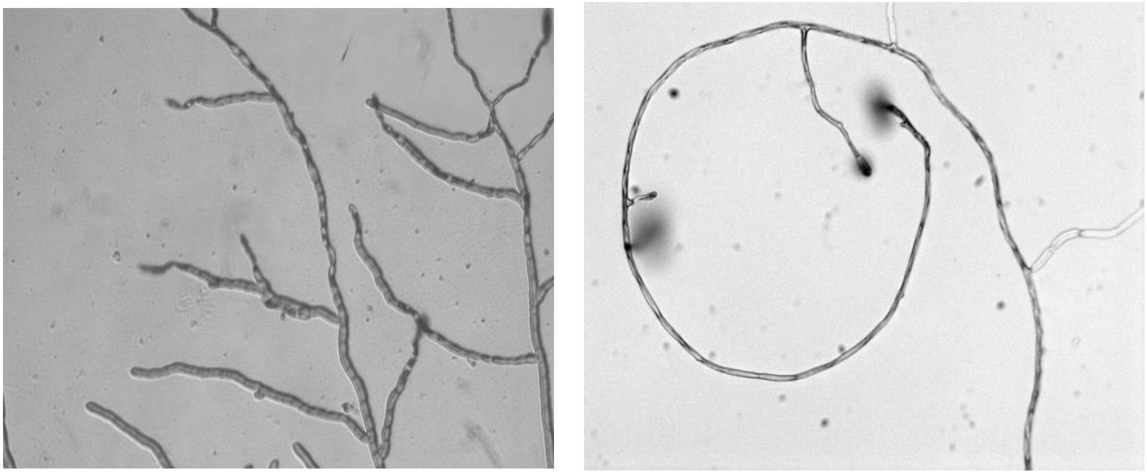
3. Results and discussion

Under standard conditions, the growth of the test species of filamentous fungi occurs in the form of branching hyphae (figure 2a), growing at the apical part, so called polar growth. We found that under shielding conditions of the EMF to values of 1-100 nT, filamentous cells of the fungal mycelium, instead of directed apical growth, show marked spiral growth (figure 2b and figure 3). A steady trend towards a similar type of mycelium growth was found in fungi of different taxonomic affiliation *U. consortiale, N. crassa*.

What mechanism can cause such growth anomalies in fungi? Note, that micromycetes do not have specific magnetic field receptors like magnetosomes in magnetotactic bacteria that help microorganisms orient themselves along the magnetic field lines [3].

In the process of apical growth, the leading role is played by the position of Spitzenkörper, a structure localized in the hyphal apex, which directs the path of mycelium growth and is the center of organization of interaction between cytoskeleton elements [4]. The change in the position of the Spitzenkörper affects the direction of growth of the hyphae. This was proved experimentally: the Spitzenkörper was moved using laser tweezers, and as a result the direction of growth of the hyphae was changed.

From the physical point of view, Spitzenkörper can simply be represented as a charged spheroid cluster located near the apical cell wall, which will be affected by the Lorentz force during its movement in a magnetic field (figure 4).



(a) (b)

Figure 2. Typical picture of fungal growth in the geomagnetic field (a) and in the hypomagnetic field 10 nT (b).

In our case, the magnetic field in the experimental setup is provided with a longitudinal component. If the velocity vector of the particle is not perpendicular to the vector of magnetic induction, then the particle describes the trajectory in the form of a spiral.

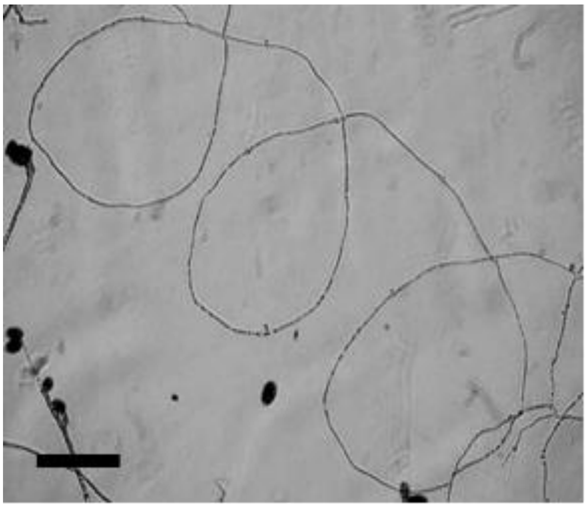


Figure 3. Photo of spiral-like trajectory of fungal growth. Scale bar is 25 μm.

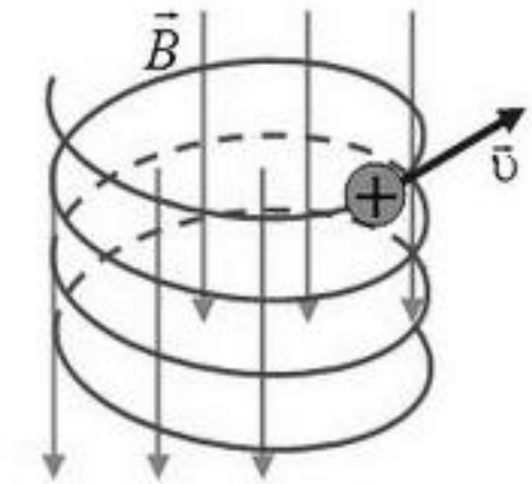


Figure 4. Schema of trajectory of a charged particle in a magnetic field.

4. Conclusion

Thus, it has been experimentally demonstrated that hypomagnetic fields affect the morphogenesis of some microscopic fungi. For a qualitative explanation of the experimental results obtained, a physical model was proposed, first described in [5]. In this paper, we hypothesize a nonspecific mechanism of spiral growth of hyphae under the influence of Lorentz force, with the Spitzenkorper being proposed for the role of the primary magnetic field receptor.

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