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Effect of Magnetic Field Intensity and Exposure Time on the Mycelial Growth of *Pleurotus ostreatus* and *Pleurotus pulmonarius*

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Abstract: ***The effect of 4 different degrees of magnetic fields (2 mT, 25 mT, 50 mT and 100 mT) and 3 different exposure times (5, 15, 30 minutes) on the mycelial growth of two species of oyster mushroom (Pleurotus ostreatus and P. pulmonarius) were investigated in this study. The Potato Dextrose Agar (PDA) was used for the cultivation of these two mushroom species. PDA was sterilized in autoclave for half an hour at 121 °C and then poured into the petri dishes at a rate of approximately 30 ml per dish. The dishes were vaccinated with mycelium of fungi that loaded on wheat grain. One grain of wheat was placed in the center of each petri dish and then an adhesive parafilm tape was placed around the edge of each petri dish to prevent contamination. The experiment was carried out in sterile conditions with five replicates per treatment and a total of 130 dishes. The average diameter of the fungal colony was measured every two days for a period of 20 days to determine the effect of magnetic field intensity and exposure time on the mycelial growth. The results indicated that mycelial growth of P. ostreatus and P. pulmonarius was influenced by magnetic field intensity and interaction of two factors (magnetic field intensity X exposure time). The magnetic field exposure of 100 mT for 30 minutes promoted the mycelial growth of both mushrooms significantly. On the other hand, the slowest growth of the P. ostreatus and P. pulmonarius mycelium was observed at 2 mT x 30 minutes and 50 mT x 5 minutes, respectively.***

Keywords: *Pleurotus ostreatus*, *Pleurotus pulmonarius*, magnetic field, mycelium

1. Introduction

All living things in the world, including fungi, are exposed to the magnetic field effect of the earth. Ruzic et al. [1] indicated that each living being has a particular reaction to the electromagnetic field, which is one of the most important and complex energy resources. Shams et al. [2] pointed out that the effects of electromagnetic energy on living tissues are the reason why they are used for agricultural development. Influence of such energy on living things depend on type, seasonal life spans, field intensity, and exposure time [3].

In recent years, researchers have conducted many studies on the effects of magnetic field on plants focusing on seed germination, seed vigour, plant roots, plant growth and development, antioxidant systems, flowers and total production, elements composition, minerals content and chemical structure of plants and seeds [4-18]. Similarly, magnetic field effect studies have been done on bacteria and fungi focusing on changes in amino acid sequence in fungi, production of spores and the growth rates, growth and sporulation of phytopathogen microscopic fungi, growth and yield of edible mushrooms, contents of trace elements, mycelial growth, sporulation growth and metabolic activities [2, 19-26].

The aim of this research is to study the effect of magnetic field intensities with varying exposure times on the mycelial growth of *Pleurotus ostreatus* and *P. pulmonarius*. Mushrooms of *Pleurotus* spp. are commonly known as oyster mushrooms which occupy the second position, after button mushroom, among the most popular edible mushrooms worldwide due to their nutritional values [27, 28]. Oyster mushrooms grow in tropical and subtropical regions and are easily artificially cultivated [29]. Most of the world's supply of oyster mushrooms today comes from commercial mushroom growers [30].

2. Material and Methods

The experiment was carried out in March, 2017 at the Faculty of Forestry, Kastamonu University, Turkey to test the effect of different degrees of magnetic fields and different exposure times on the mycelium growth rates of the oyster mushrooms *P. ostreatus* and *P. pulmonarius.*

Two species of oyster mycelia and potato dextrose agar (PDA) (Commercial Medium Powder) medium for mycelial growth were used in this study. According to Al-Bony [31], 39 g of PDA was dissolved in 1 liter of distilled water with heating up to boiling and then autoclaved at 121 °C and 15 psi, for 15 minutes. After the temperature dropped to room temperature, it had been poured into a 9 cm diameter petri dishes with a rate of about 25 ml per dish and left until harden. A total number of 120 dishes were prepared.

The dishes prepared in the previous step were vaccinated with fungi mycelium which was loaded on wheat grains obtained from a commercial company in Turkey. The process of vaccination had been done in the sterilized conditions by placing a grain of wheat coated with mycelium in the center of each petri dish. Each petri dish had been enclosed with a tape of adhesive parafilm to reduce the contamination (Figure 1).

Figure 1: The mycelia of oyster mushroom cultures maintained on PDA medium.

Magnetic fields were produced using ferrite magnets with intensities of 2 mT, 25 mT,50 mT and 100 mT. A magnetic disc was placed on each dish for different exposure times of 5, 15 and 30 minutes [25]. Magnet-Phy FH 51 Dr. Steingroever GmbH, Art no:2000510 ve seri no:113592 CE gauss/teslametre was used to measure the magnetic field strength generated by the magnets. The experiment was carried out with five replicates per treatment. For the control group, no magnetic field application was performed. Then the dishes were left at the room temperature measuring the radius of the fungal colony in each dish once every two days for twenty days [26].

A two-way analysis of variance (ANOVA) followed by Tukey's HSD method was performed to analyze the effect of magnetic field intensity and exposure time on the growth of *P. ostreatus* and *P. pulmonarius* mycelia. A P-value of 0.05 or less was considered as statistically significant. All the analyses were carried out with SPSS (SPSS 22.0 for windows, SPSS Inc., Chicago, IL, USA.).

3. Results and Discussion

Table 1 showed that while the effects of magnetic field intensity, exposure time and the interaction effect of them on the growth of *P. pulmonarius* mycelia were significant (P<0.05), magnetic field intensity and interaction of two factors were significant (P<0.05) for the growth of P. ostriatus mycelia. This study revealed that the magnetic field had a significant effect on mycelial growth of the oyster mushrooms. Our results are in accordance with the work of other researchers. It was reported that static and pulsed magnetic fields affected growth and enzymatic activity of fungi [32,33]. Ruzic et al. [1] found that the early germination phase was stimulated or inhibited depending on the magnetic field intensity.

Table 2 shows the effect of magnetic field intensity on both mushroom mycelial growths. The mycelial growth of both mushroom species with 100 mT magnetic field application was significantly greater than those with the control and other magnetic field applications. For both mushrooms, the lowest mycelial growth was observed in the control and 2 mT application.

Table 1: Summary of the effect of magnetic field intensity and exposure time on *Pleurotus ostreatus* and *Pleurotus pulmonarius* mycelial growth

Treatments	*P. ostreatus*			*P. pulmonarius.*		
	df	F	P	df	F	P
Magnetic field intensity	3	42.911	0.000	3	81,843	0,000
Exposure time	2	1.186	0.314	2	58,530	0,000
Interaction	6	5.513	0.000	6	4,223	0,002

*The mean difference is significant at the .05 level.

Table 2: Effect of magnetic field intensity on mycelial growth of *Pleurotus ostreatus* and *Pleurotus pulmonarius*

Dose (mT)	*P. ostreatus* (Mean±SD) (cm)	*P. pulmonarius* (Mean±SD) (cm)
0 (Control)	6,0540±0,12300a	7,1180±0,32011a
2	6,4893±0,26959a	7,3127±0,40893a
25	7,2773±0,77379b	8,3060±0,37144b
50	7,8987±0,80172c	7,6553±0,73590c
100	8,4320±0,45518d	8,7253±0,38892d

*Different letters after the means indicate a significant difference between the means (Tukey's HSD, p <0.05)

Table 1 showed that the exposure time of the magnetic field did not affect the mycelial growth of *P. ostreatus* significantly (P≥0.05), but it created significant differences (P <0.05) for *P. pulmonarius* mycelial growth. The most effective exposure time for *P. pulmonarius* mycelial growth is 30 minutes followed by 15 and 5 minutes (Table 3).

Table 3: Summary of the effects of exposure time on *Pleurotus pulmonarius* mycelial growth

Exposure time (minute) (I)		Mean Difference (I-J)	Std. Error	Sig.
5	0	.427*	0,136	0,017
	15	-.436*	0,086	0,000
	30	-.930*	0,086	0,000
15	0	.863*	0,136	0,000
	5	.436*	0,086	0,000
	30	-.494*	0,086	0,000
30	0	1.357*	0,136	0,000
	5	.930*	0,086	0,000
	15	.494*	0,086	0,000

*The mean difference is significant at the .05 level.

The interaction of the magnetic field density and exposure time significantly affected the both fungal growth (P <0.05) (Tablo 1, 4). The results showed that the mycelial growth increased in the magnetic field intensities of 2 mT, 25 mT, 50 mT and 100 mT. However, the rate of increase was different; with the 100 mT showing the greatest rate of increase across the study periods under the 30 minute-exposure to magnetic field. The slowest growth of the *P. ostriatus* and *P. pulmonarius* micellium was observed at 2 mT x 30 minutes and 50 mT x 5 minutes, respectively.

Table 4: Effect of magnetic field intensity and exposure time on the *Pleurotus ostreatus* and *Pleurotus pulmonaryarius* mycelial growth.

Exposure time (minute)	*Magnetic field dose (mT)*							
	P. ostreatus (Mean±SD) (cm)				*Pleurotus pulmonarius* (Mean±SD) (cm)			
	2	*25*	*50*	*100*	*2*	*25*	*50*	*100*
5	6,6280± 0,39815a	8,0860± 0,23554a	7,3360± 0,80906a	8,2780± 0,57330a	6,9480± 0,42228a	7,8800± 0,07906a	6,8660± 0,10968a	8,4840± 0,58735a
15	6,5120± 0,14114a	6,7320± 0,86823b	7,9560± 0,75610a	8,3440± 0,38292a	7,2840± 0,20816ab	8,3320± 0,18794b	7,5920± 0,36383b	8,7140± 0,15710a
30	6,3280± 0,13682a	7,0140± 0,10237b	8,4040± 0,55166a	8,6740± 0,37058a	7,7060± 0,05459b	8,7060± 0,11675c	8,5080± 0,24170c	8,9780± 0,08349a

*Different letters after the means indicate a significant difference between the means (Tukey's HSD, $p < 0.05$)

Magnetic field applications may provide positive or negative results for the growth of fungi and plants. Javanmardi et al.'s [34] study showed that the various magnetic field intensities positively affected the growth of *Pleurotus florida*. On the other hand, Gow [20] found a decrease in spore, hyphal and mycelial growth rates of *Culvaria inaequalis* and *Aspergillus puniceus* fungi exposed to different magnetic fields.

In conclusion, it is extremely important to determine the magnetic field intensity and exposure time correctly to obtain positive results from the magnetic field applications [26].

4. Conclusion

In this study, the mycelial growth of the oyster mushrooms *P. ostreatus* and *P. pulmonarius* was examined under the various magnetic field intensities (0 mT (control), 2 mT, 25 mT, 50 mT and 100 mT) and exposure times (0 minutes, 5 minutes, 15 minutes and 30 minutes). The results showed that the magnetic field exposure of 100 mT for 30 minutes promoted the mycelial growth of the both mushrooms significantly. On the other hand, the slowest growth of the *P. ostriatus* micellium was observed at 2 mT x 30 minutes and *P. pulmonarius* at 50 mT x 5 minutes.

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