

Analysis of Extremely Low Frequency (ELF) Magnetic Field Effect to Oyster Mushroom Productivity

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Abstract— *Extremely Low Frequency magnetic field has frequency 0-300 Hz and included on non-ionizing radiation. The side effect of ELF magnetic field researched by many researcher on some sectors, such as on food sector and agriculture sector. In food sector, research of Sudarti (2016) shown that ELF magnetic field can use as alternative sterilization gado-gado food to decrease population of Salmonella. Oyster mushroom as alternative nutrition sources with many advantages for health, many people consume it and start cultivation it. ELF magnetic field can use as growth accelerator in agriculture sector, such as for oyster mushroom growth. This research aims to analyze of effect of ELF magnetic field to oyster mushroom productivity based on appearance of pin head and oyster mushroom wet weight. Result shown that exposure ELF magnetic field with intensity 500 μ T in 50 minutes influence appearance of pin head with average amount 20,2 and influence oyster mushroom wet weight amount 212,2 grams.*

Keywords—*ELF magnetic field, extremely low frequency, oyster mushroom*

I. INTRODUCTION

Everyday we always exposure by ELF magnetic field. Some electronic instruments around us are source of ELF magnetic field. Extremely Low Frequency (ELF) magnetic field is sub-class of electromagnetic waves spectrum with frequency 0-300 Hz. Radiation of ELF magnetic field is non-ionizing radiation and using electric energy to biologist object. Magnetic field has characteristic that can't blocked easily, able to penetrate on any material, no exception biologist materials. The capability of ELF magnetic field can penetrate biologist material, many researchers, researched about effect of ELF magnetic field on many sectors. Research result of Sudarti (2016) ELF magnetic field with intensity 646,7 μ T in 30 minutes can use as alternative for sterilization of gado-gado food to decrease Salmonella bacteria [1]. In addition can decrease Salmonella bacteria

population, ELF magnetic field can use as growth accelerator in plant. Research by Reza (2015) shown that exposure ELF magnetic field with intensity 300 μ T in 60 minutes give positive effect on ranti tomato growth. In addition as growth accelerator plant [11], research by Mardhika (2017) shown that ELF magnetic field with intensity 600 μ T in 70 minutes influence growth of *Auricularia auricular* [5].

In the study of Kristian et al. (2015) dose of ELF exposure of 500 μ T resulted in an increase of pH of 1.00 at 24 hours after fermentation and a decrease in bacterial count at 72 hours after fermentation of tape [14]. Study of Handoko et al. (2017), shown that exposure ELF magnetic field with intensity 300 μ T for 60 minutes and 90 minutes is capable of affecting to height of red chili plants and exposure ELF magnetic field with intensity 300 μ T for 60 minutes is capable influencing to the number of red chili leaves [15].

Based on the last research, shown that ELF magnetic field has different effect with different intensity and exposure duration. Oyster mushroom, as alternative nutrition source, many people starting to consume oyster mushroom. People start to consume oyster mushroom, because oyster mushroom has some benefits and nutrition to prohibit high blood pressure disease and heart disease as mushroom consumption. In addition, consume oyster mushroom can recover from anemia, as tumor resistant, and prohibit iron deficiency [9]. Oyster mushroom known as mushroom which contain lovastatin as blood cholesterol inhibitor [7].

Many people starting to consume oyster mushroom, oyster mushroom requirement is so high, so many people start to cultivate it. People cultivated it in big scale or in small scale. But, they still cultivate oyster mushroom with traditional cultivation. So, they still can't fill market requirement. So, researcher want to research about effect of ELF magnetic field which exposure to oyster mushroom.

ELF magnetic field is a sub-class of electromagnetic fields (EMF) having frequencies below the electromagnetic wave spectrum. ELF field radiation is a non-ionizing radiation that uses electrical energy to direct to biological media. Exposure ELF magnetic field radiation give results in a non-thermal effect on applied biological targets [16]. Electromagnetic waves are waves generated when there is a change of electric field and magnetic field at a time [17]. Electromagnetic fields are magnetic fields and electric fields generated by natural and electrically charged electronics. Humans as one of the biological systems among other biological systems, it is possible will always be emitted by electromagnetic fields [18].

Maxwell laid the foundations of the theory of electromagnetic waves by making Maxwell's equations based on the laws of Faraday, Gauss (Coulomb) and Ampere [19].

The law of Gauss in the electric field can be expressed:

$$\nabla \cdot \mathbf{D} = \rho$$

The law of Gauss on a magnetic field can be written:

$$\nabla \cdot \mathbf{B} = 0$$

The law of Faraday can be written:

$$\nabla \times \mathbf{E} + \frac{\partial \mathbf{B}}{\partial t} = 0$$

The law of Ampere can be written:

$$\nabla \times \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t}$$

If using the assumption of propagation in a vacuum, with $\rho = 0$ and $\mathbf{J} = 0$, then Maxwell's equation has the following modification:

$$\nabla \cdot \mathbf{D} = \rho$$

$$\nabla \cdot (\epsilon \mathbf{E}) = \rho$$

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon}$$

$$\nabla \cdot \mathbf{E} = 0$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \times \mathbf{H} = \frac{\partial \mathbf{D}}{\partial t}$$

The propagation of electromagnetic waves in free space, Maxwell's equations are rearranged to be explained explicitly on time and coordinates.

$$\frac{1}{\mu} \nabla \times \mathbf{B} = \epsilon \frac{\partial \mathbf{E}}{\partial t}$$

$$\begin{aligned} \nabla \times (\nabla \times \mathbf{E}) &= \nabla \times \left(-\frac{\partial \mathbf{B}}{\partial t} \right) = -\frac{\partial}{\partial t} (\nabla \times \mathbf{B}) \\ &= -\frac{\partial}{\partial t} \left(\epsilon \mu \frac{\partial \mathbf{E}}{\partial t} \right) \end{aligned}$$

$$\nabla \times (\nabla \times \mathbf{E}) = -\epsilon \mu \frac{\partial^2 \mathbf{E}}{\partial t^2}$$

$$\nabla(\nabla \cdot \mathbf{E}) - \nabla^2 \mathbf{E} = -\epsilon \mu \frac{\partial^2 \mathbf{E}}{\partial t^2}$$

Because $\nabla \cdot \mathbf{E} = 0$,

$$\nabla^2 \mathbf{E} = \mu \epsilon \frac{\partial^2 \mathbf{E}}{\partial t^2}$$

$$\nabla^2 \mathbf{B} = \mu \epsilon \frac{\partial^2 \mathbf{B}}{\partial t^2}$$

This equation is a wave equation, with wave velocity

$$v = \frac{1}{\sqrt{\mu \epsilon}}$$

In a material, the speed of light is less than. Can be grouped into materials depicted by refraction index, the ratio of the speed of light in vacuum to velocity in a medium

$$n = \frac{c}{v} = \sqrt{\frac{\epsilon \mu}{\epsilon_0 \mu_0}}$$

The wave propagation around the strings that move the energy with the wave is proportional to the square of the wave amplitude. Electromagnetic theory explains that energy density (J / m³) is associated with electromagnetic waves as

$$U = \frac{(\mathbf{D} \cdot \mathbf{E} + \mathbf{B} \cdot \mathbf{H})}{2}$$

Using relation of $\mathbf{D} = \epsilon \mathbf{E}$ and $\mathbf{B} = \mu \mathbf{H}$ if applied in medium of propagation:

$$U = \frac{1}{2} \left(\epsilon E^2 + \frac{B^2}{\mu} \right) = \frac{1}{2} \left(\epsilon + \frac{1}{\mu c^2} \right) E^2$$

In vacuum place:

$$U = \epsilon_0 E^2 = \frac{B^2}{\mu_0}$$

In addition to propagating, the waves also carry energy. The change in energy density (energy per unit of sectional area, each time unit) transferred is represented by vector Poynting [20]. John Henry Poynting demonstrates that the presence of both electric fields and magnetic fields at the same time in place produces a flow in the energy field, called the Poynting theorem and the Poynting vector described

$$\mathbf{S} = \mathbf{E} \times \mathbf{H}$$

The unit of the Poynting vector is J/(m².sec) using the wave field to describe some portion of the vector. \mathbf{S} involves a quadratic relationship on \mathbf{E} , it is important to use the actual form of \mathbf{E}

$$\begin{aligned}
 \mathbf{H} &= \frac{\mathbf{B}}{\mu} = \frac{\sqrt{\mu\epsilon}}{\mu k} \mathbf{k} \times \mathbf{E} \\
 \mathbf{E} &= \mathbf{E}_0 \cos(\omega t - \mathbf{k} \cdot \mathbf{r} + \phi) \\
 \mathbf{S} &= \frac{\sqrt{\mu\epsilon}}{\mu k} \mathbf{E}_0 \times (\mathbf{k} \times \mathbf{E}_0) \cos^2(\omega t - \mathbf{k} \cdot \mathbf{r} + \phi) \\
 &= \frac{n}{\mu k} |\mathbf{E}_0|^2 \frac{\mathbf{k}}{k} \cos^2(\omega t - \mathbf{k} \cdot \mathbf{r} + \phi) \\
 I = |\langle \mathbf{S} \rangle| &= \frac{1}{T} \int_{t_0}^{t_0+T} A \cos^2(\omega t - \mathbf{k} \cdot \mathbf{r} + \phi) dt
 \end{aligned}$$

[21]

The magnetic field on a transmittable carrier is written:

The law of Biot-Savart written as:

$$\begin{aligned}
 \mu_0 I &= \int_0^{2\pi a} B \cdot dl \\
 \mu_0 I &= B \cdot dl \Big|_0^{2\pi a} \\
 &= B(2\pi a) - B(0) \\
 \mu_0 I &= B(2\pi a) \\
 \frac{\mu_0 I}{2\pi a} &= B
 \end{aligned}$$

Utilizing ELF magnetic field in many sectors definitely has standard or limit that appropriate for accelerate growth oyster mushroom. Using ELF magnetic field with exact intensity, hope can increase oyster mushroom productivity. Utilizing ELF magnetic field hope can be innovation for oyster mushroom farmers who cultivate oyster mushroom in big scale or small scale. So, researcher want doing research about the influence ELF magnetic field to oyster mushroom productivity.

II. METHODS

Type of this research is true experiment, which is this research engaging experiment group (group which exposure by ELF magnetic field) and control group (group which not exposure by ELF magnetic field) that sample given with randomly. Sample of this research is using oyster mushroom (*Pleurotus ostreatus*) seeds total 35 seeds. Oyster mushroom seeds got from oyster mushroom farmer with same age, 40 days. The oyster mushroom seeds in 40 days already have mycelium around seed media and ready for exposure with ELF magnetic field. Details 5 seeds for control group, 15 seeds for experiment group that exposure by ELF magnetic field 300 μT and 15 seeds for experiment group that exposure by ELF magnetic field 500 μT . Experiment group that exposure by ELF magnetic field 300 μT in 30 minutes 5 seeds, in 50 minutes 5 seeds, and 70 minutes 5 seeds. Experiment group that exposure by ELF magnetic

field 500 μT in 30 minutes 5 seeds, in 50 minutes 5 seeds, and in 70 minutes 5 seeds.

Sample that used in this research is oyster mushroom in ready condition to harvest. mushroom that used in this research is oyster mushroom seeds that already pass from inoculation period and incubation, so oyster mushroom seeds already ready to exposure by ELF magnetic field with indication appear mycelium. Researcher choose oyster mushroom seeds to exposure with ELF magnetic field 40 days after inoculation period because in this period choose growth hormone in oyster mushroom is starting active, and to stimulate hormone in oyster mushroom given treatment with increasing room temperature. In addition, different with other group, experiment group given extra treatment with exposure ELF magnetic field.

Weight of oyster mushrooms seeds that used approximately 1000 grams, with a length of 30 cm. In the study used oyster mushroom seeds that have been aged 40 days, where oyster mushroom seeds are filled by mycelium to be exposed to ELF magnetic field. Seeds of oyster mushrooms obtained are in a state ready for harvest. Oyster mushroom seeds bought form obtained from oyster mushroom farmers in Lumajang District.

This research using randomized post-test only control group design. Where is control group and experiment group separate randomly, measuring in once, that is after treatment has been given to experiment group. In control group class, oyster mushroom seeds save on oyster mushroom house, and experiment group oyster mushroom seeds exposure with ELF magnetic field.

This research held in Physics Education Laboratory, Building 3, Faculty of Teacher Learning and Training, University of Jember, with consideration any device ELF magnetic sources, current transformer, and EMF tester. After exposure by ELF magnetic field, both of experiment class and control class treatment doing in mushroom home. This research held on February on academic year 2016/2017.

In this research, sample that ready to exposure is oyster mushroom sample which already pass incubation period and then exposure by ELF magnetic field with intensity 300 μT and 500 μT for experiment group. Control group not give the treatment for comparator, so they're just save in mushroom house. Exposure with ELF magnetic field in duration 30 minutes, 50 minutes, and 70 minutes for every experiment group. Treatment with ELF magnetic field doing in one day. After exposure procedure, oyster mushroom seeds saved in a room, called mushroom house with maximal temperature 35°C. If temperature in mushroom house increasing, can doing cooling with spread some water around oyster mushroom house or around the body seed.

When still in growth process, can do treatment process for avoid plant diseases. If there is plant diseases, can do spread pesticide. But, in this research, researcher don't doing any treatment procedure for avoid mushroom diseases. Oyster mushroom that saved on mushroom house can be harvest after 3 days from appear of mushroom pin head. Research procedure can be seeing on Figure 1. When oyster mushroom in harvest period, can doing harvest process and collecting data. After that, analyze the data. Data analyze that used is descriptive statistic analyze, where is data will be shown on table or graphic.

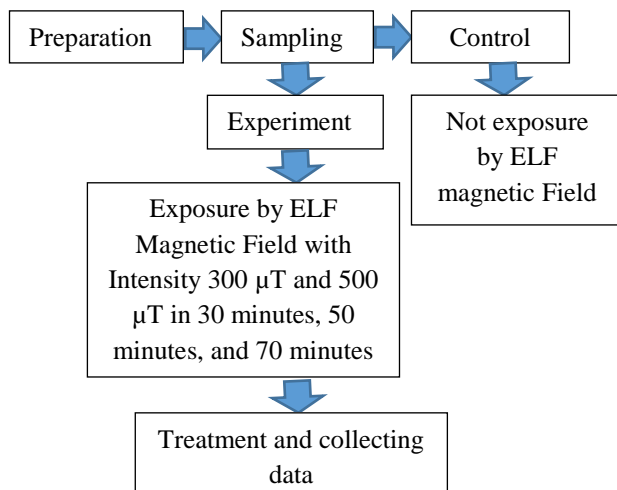


Fig.1: Research Procedure

III. RESULT AND DISCUSSION

1. Number of Oyster Mushroom Pin Head

This research aims to analyze the effect of ELF magnetic field to growth oyster mushroom (*Pleurotus ostreatus*). The process of exposure ELF magnetic field was carried out on May 6, 2017 at 06.00 AM. Oyster mushroom seeds for control class is not given treatment, so oyster mushroom seeds directly placed on mushroom house. The experimental group exposed to ELF magnetic field with intensity 300 μ T and 500 μ T with variation of exposure duration for 30 minutes, 50 minutes, and 70 minutes. After being exposed by ELF magnetic field, all experimental group of oyster mushrooms placed in the mushroom house same as the control group. During the treatment process, oyster mushrooms are preserved to be protected from mushroom disease that can damage oyster mushrooms.

This research was conducted from May 2017 until oyster mushroom seeds has reached the time of death, oyster mushroom seeds death about 4 month from breeding period with marked start to decompose planting medium which originally still white to brownish black color. Observation of oyster mushroom growth is done by

counting the number of pin head and wet weight of the oyster mushroom.

The results of this study include the observation of pin head and wet weight of oyster mushroom diameter that has been exposed to ELF magnetic field with variation of exposure duration and different intensity of exposure. Result of oyster mushroom pin head shown on Table 1.

Table.1: Average of Oyster Mushroom Pin Head

Group	Duration Exposure ELF Magnetic Field	Average of Pin Head
Control	-	12,2
Experiment 300 μ T	30 minutes	14
	50 minutes	9,2
	70 minutes	14,2
Experiment 500 μ T	30 minutes	15,4
	50 minutes	20,2
	70 minutes	14



Fig.2: Oyster Mushroom Pin Heads

Early growth of oyster mushrooms is characterized by the appearance of white oyster mushroom pin head. The indicator of the appearance of pin head on oyster mushrooms seeds is marked by the appearance of white pins on the seed medium. Then there will be a process of deference to form the rod and hood. The appearance of the first oyster mushroom pin heads occurs after 57 days after the ELF field exposure. While the control class pin head appeared on day-to-58. The oyster mushroom pin head appears first in the experimental class given exposure to a 500 μ T ELF magnetic field with 50 minutes exposure duration.

In the experimental class with 300 μ T exposure, based on Table 1, shows that the average number of oyster mushroom pin head the experimental class higher than the control class. In the control class, the average number of oyster mushroom pin head was 12,2, whereas in the

experimental class of exposure 300 μT , the average number of pin head was 14 with 30 minutes exposure, 9,2 with 50 minutes exposure time, and 14 ,2 with a 70 minute exposure time. The average number of lead pins in the exposure of 70 minutes.

In the experimental class with exposure ELF magnetic intensity 500 μT , based on Table 1, it appears that exposure to the ELF magnetic field of 500 μT has an effect on the appearance of oyster mushroom pin heads. It appears that the number of oyster mushroom head pin in the experimental class higher than the control class, where the average number of head pins appear is 15,4 in exposure for 30 minutes, 20,2 at 50 minutes, and 14 in 70 minutes. An increase in the number of head pins in the experimental class with exposure of 500 μT , occurred in oyster mushroom seeds exposed to ELF magnetic field for 50 minutes.

However, there is a decrease in the number of pin heads that appear on exposure for intensity 500 μT in 70 minutes. This proves that the exposure time or duration of the ELF magnetic field influence in number of appearance oyster mushroom pin heads.

2. Oyster Mushroom Wet Weight

The process of measuring the wet weight of oyster mushroom when the harvest time arrive. The oyster mushroom can harvest 2-3 days after the appearance of the oyster mushroom pin head. Harvesting oyster mushroom by removing all parts of the body of oyster mushrooms. After the harvesting process, wet oyster mushroom weighing should be done immediately to avoid the decrease in the water content in oyster mushrooms that can affect the wet weight of fresh oyster mushrooms. Measurement of wet weight of oyster mushrooms is done using a digital balance sheet. The results of wet oyster mushroom weight measurement can be seen in Table 2.

Table.2: Oyster Mushroom Wet Weight

Group	Duration Exposure ELF Magnetic Field	Average Wet Weight (grams)
Control	-	144,8
Experiment 300 μT	30 minutes	161
	50 minutes	156,8
	70 minutes	166,6
Experiment 500 μT	30 minutes	199,2
	50 minutes	212,2
	70 minutes	194,4



Fig.2: Process of Weighing Oyster Mushroom Wet weight

Based on Table 2, the wet weight of oyster mushrooms in the experimental group with exposure to the ELF magnetic field of 300 μT higher compared to the control group. At 30 minutes exposure obtained an average wet weight of 161 grams, 156,8 grams with exposure for 50 minutes, and 166,6 grams with exposure for 70 minutes. The experimental group with exposure ELF magnetic field intensity 500 μT has an increase compared to the control class. The average wet weight of oyster mushroom with 30 minutes exposure was obtained for 199,2 grams, wet weight of 212,2 grams with 50 minutes exposure time, and 194,4 grams with 70 minutes exposure time.

In the intensity 500 μT 70-minutes exposure, oyster mushroom weight decreased. However, the average wet weight obtained is still more than the control class. At 50 minutes exposure with intensity 300 μT , the wet weight of oyster mushroom also decreased compared to 30 minutes of exposure time. However, the oyster mushroom seeds exposed to ELF 300 μT magnetic field for 50 minutes still has a wet weight greater than the control class. Oyster mushrooms with 300 μT exposure for 70 minutes had the greatest wet weight compared to the control class as well as the experimental class with 30 minutes and 50 minutes exposure time. This result suggests that giving ELF magnetic field exposure with intensity 500 μT in 50 minutes influence to wet weight of oyster mushroom.

3. Discussion

Biological materials, such as oyster mushrooms, are better conductors than air. Due to the polarization effect of the electric field on the outermost surface of the body, the time variation of the electric field induces the surface of the body that produces current in the body, the magnitude corresponding to the surface charge density. In the sinusoidal electric field the value of the current in the body increases with the magnitude of the frequency [4].

ELF magnetic field has biological effects such as, inducing cell metabolism [3], altering chemical or enzyme processes (Agustrina, 2013: 405-412), and altering membrane surface properties [13]. The ability of the biological effects of the magnetic field to affect the permeability of the ion channels in the membrane can give the effect of ion transport into the cell and give changes to the organism [6]. Magnetic fields with frequencies less than 300 Hz are able to induce cells and tissues, primarily capable of affecting calcium in cells [10].

Various study shown that magnetic fields including the ELF magnetic field have an effect on cell membrane function, especially the transfer of Ca^{2+} ions through the membrane. Ca^{2+} ions are part of a variety of connections that signal the cells by involving protein kinases [8]. When magnetic field exposure, intracellular and extracellular mechanisms begin to activate. The magnetic field is able to penetrate the plasma and nuclear membrane of the cell, affecting cells and tissues. Ca^{2+} ion transport occurs continuously on the channel of the cell membrane [2].

The appearance of the first oyster mushroom pin head in the experimental class with 500 μT exposure for 50 min on the 57th day after the exposure process was performed. On the 58th day, the oyster mushroom pin appeared on the control class. This proves that exposure to the ELF magnetic field is capable of accelerating the appearance of oyster mushroom pin heads compared to the control class without exposure to the ELF magnetic field. In addition to affecting the appearance of the number of head pins, ELF magnetic field is able to influence the wet weight of oyster mushrooms when harvested. After oyster mushroom pin head appeared, there is a process of development from pin head to hood after 2-3 days from the appearance of pin head. After growing into a hood, oyster mushrooms can be done the process of harvesting. Harvesting is done by removing all parts of the body oyster mushrooms. Then performed the process of measuring the wet weight oyster mushrooms.

Dosage of ELF magnetic field exposure, able to influence the growth of oyster mushrooms. It appears that the ELF magnetic field is capable of affecting the appearance of the number of pin head oyster mushroom and wet weight oyster mushroom. When exposed to the ELF magnetic field, there is a process of changing the nature of oyster mushroom cell member resulting in changes in the transport of calcium ions in oyster mushrooms. Calcium itself, known as the carrier of responses to cells [12] and has various biological effects on living things. Exposure to the ELF magnetic field with the intensity and duration of certain exposure that can affect the transport speed of calcium ions in oyster mushroom cells that affect the

growth of oyster mushrooms. In addition, ELF magnetic field capable of affecting cell metabolism is also able to influence the growth of oyster mushroom.

It appears that exposure to a 500 μT ELF magnetic field for 50 minutes was able to increase the number of oyster mushroom pin heads and the wet weight of oyster mushrooms during harvest. However, the magnetic field exposure of 500 μT for 70 minutes indicates a decrease in the number of head pin and wet weight on oyster mushroom. This indicates the existence of the process of blocking the growth of oyster mushrooms as a result of massive calcium ion transport. The presence of excessive calcium ions in the cell makes the cell decrease or growth delay (Toshio et al., 2006: 597-602). As a result, the oyster mushroom is unable to grow to the maximum indicated by a decrease in the number of pin head and wet weight. This indicates that the long exposure of the ELF magnetic field has considerable influence.

Based on Table 1 and Table 2, both number of pin head oyster mushroom and wet weight oyster mushroom decreasing in intensity 300 μT in 50 minutes. This is happen because of the oyster mushroom medium nutrition factor. The nutrition in the oyster mushroom seed not spread evenly. So, it can be disturb growth process. The largest number of oyster mushroom pin head and wet weight, is on the exposure of a 500 μT ELF magnetic field for 50 minutes. Decreasing number of oyster mushroom pin head and wet weight in exposure 500 μT in 70 minutes shown that this exposure make some cells on oyster mushroom have too much calcium ions. So, the oyster mushroom cells can't growth well.

After the process of measuring of the oyster mushroom done, oyster mushroom seeds undergo a process of death characterized by the emergence of pathogens in oyster mushroom medium, pathogens that appear on oyster mushroom medium is greenish. Oyster mushrooms seed can't be reused after the age of 4 months from the nursery, because more than that, the nutritional content in the oyster mushroom seed has been decreased.

IV. CONCLUSION

Giving a proper dose of ELF magnetic field exposure, able to maximize the growth of oyster mushrooms. However, if excessive doses of exposure are given, making the transport of calcium ions in oyster mushroom cells becomes uncontrollable. In this research, exposure of ELF magnetic field influence to oyster mushroom growth at 500 μT exposure for 50 minutes, with growth parameters of pin head number and wet weight.

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