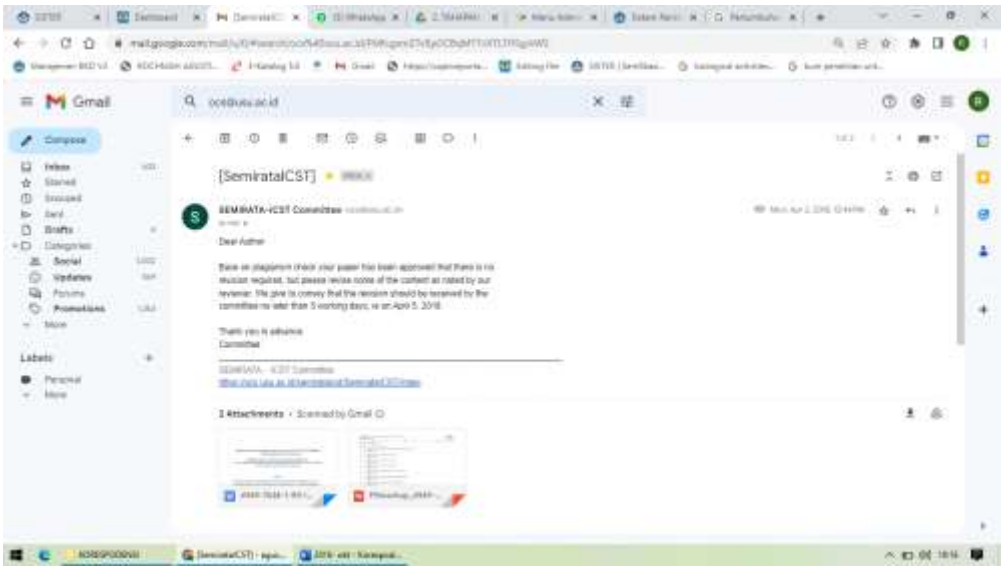


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# Tomato Generative Growth from the Seeds Exposed to 0,2 mT of Magnetic Field and Infected by *Fusarium* sp.

**Rochmah Agustrina, Endang Nurcahyani, Bambang Irawan**
**Jurusan Biologi Fakultas Matematik dan Ilmu Pengetahuan Alam Universitas Lampung**
***E-mail: rochmah.agustrina@fmipa.unila.ac.id**

## Abstrak

Penelitian sebelumnya membuktikan bahwa medan magnet dapat meningkatkan vigor dan pertumbuhan tanaman tomat yang tahan terhadap serangan *Fusarium* sp. Dalam penelitian ini dikaji apakah peningkatan vigor dan pertumbuhan tomat yang tahan trhadap serangan Fusarium sp diikuti dengan peningkatan pertumbuhan generatif. Penelitian dilaksanakan secara faktorial dalam rancangan strip split plot terdiri dari faktor paparan medan magnet 0,2 mT (M: kontrol; 7'48 "; 11'42" and 15'36 "); infeksi *Fusarium* sp. (F); dan perendaman biji (P: biji direndam dan tidak direndam selama 15' sebelum perlakuan medan magnet) dengan tiga ulangan. Parameter pertumbuhan generatif yang diamati adalah jumlah bunga, kecepatan berbuah, jumlah buah, dan berat segar total buah per tanaman.

Hasil analisis varians pada α = 1 s.d 5% menunjukkan bahwa perlakuan paparan medan magnet (M) dan kombinasi MxP mempengaruhi semua parameter yang diukur. Perlakuan infeksi *Fusarium* sp. (F) hanya mempengaruhi kecepatan pembentukan buah. Perlakuan P

dan kombinasi MxF, FxP, dan MxFxP tidak mempengaruhi semua parameter yang diukur. Paparan medan magnet selama 7'48 " menghasilkan tanaman dengan kecepatan pembentukan bunga tertinggi dan jumlah buah terbanyak. Jumlah bunga terbanyak dan kecepatan tertinggi diperoleh dari hasil paparan medan magnet selama 11'42". Infeksi Fusarium pada batang tanaman dari benih yang direndam dan ditanam pada tanah steril menghasilkan tanaman dengan kecepatan pembentukan buah terendah (F5). Paparan medan magnet selama 7'48 " pada benih yang direndam mengahsilkan jumlah buah terbanyak. Jumlah bunga tertinggi diperoleh dari perlakuan paparan medan magnet pada biji yang tidak direndam dan kecepatan berbuah tertinggi diperoleh dari perlakuan biji yang direndam tanpa paparan medan magnet.

**Kata Kunci: Medan magnet 0,2 mT; *Fusarium* sp.; perendaman benih; pertumbuhan generatif**

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## Abstract

Previous research has shown that magnetic fields can increase the vigor and growth of tomato plants resistant to *Fusarium* sp. In this study we investigated whether the increase of vigor and tomato growth of plants resistant to *Fusarium* sp. attack will continue with the resulting increase in generative growth. The research was conducted factorially using a split strip plot design consisting of 0.2 mT magnetic field exposure (M) as the main plot; infection of Fusarium sp. (F) as a sub plot; and seed soaking (S) for 15 'before the magnetic field treatment as strip plots. Each treatment unit was repeated 3 times. The generative growth parameters studied were the number of flowers, the rate of fruiting, the number of fruits, and the total fresh weight of the fruit per plant.

The results of the analysis of variance at $\alpha = 1$ and 5% indicate that the magnetic field exposure (M) treatment and combination of magnetic field exposure and seed soaking treatment (MxS) affect all parameters measured. Treatment of infection of Fusarium sp. (F) only affect the speed of fruit formation. The S treatment and treatment combinations of MxF, FxS, and MxFxS do not affect all parameters measured. Exposure to magnetic fields for 7'48 "produces plants with the highest rate of flower formation and the greatest number of fruits.

The highest number of flowers and the highest rate of fruiting was obtained from the treatment of magnetic field exposure for 11'42 ". Fusarium infection of plant stems from soaked seeds and grown on sterile soil produces plants with the lowest of fruiting rate (F5). Exposure of magnetic field for 7'48 "to the soaked seed yields the largest amount of fruit. The highest amount of flower was obtained from the treatment of magnetic field exposure on un-soaked seed while the highest rate of fruiting obtained from the treatment of the soaked beans without exposure to the magnetic field.

**Keywords: 0,2 mT of magnetic field; *Fusarium* sp.; seed soaking; generative growth.**

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## Introduction

Growth and development of plants is strongly influenced by various environmental factors that surround them including magnetic field (Majd and Shabrangi, 2011), because the earth is a source of natural magnetic field which then known the earth's magnetic field or geomagnetic field. However, since the energy emitted by the Earth's magnetic field is very low, 25 to 65 microtesla (Finlay et al., 2010), its presence and influence on plants is not widely recognized.

However, the last few decades it has known that the results of research that examines the prospect of the utilization of magnetic field energy to various types of plants began to appear. Although there are still many unexplained problems on how the reaction mechanism of energy generated by magnetic fields with plant cell systems (Belyavskaya et al., 2002), but the results of previous studies have proven that magnetic fields can improve the viability of seeds from tobacco ( Aladjadjiyan and Ylieve, 2003), corn (Florez and Martinez, 2007), soybeans (Agustrina and Handayani, 2008 and Atak et al., 2003), tomatoes (Agustrina et al., 2012 and De Souza et al., 2005), growth vegetation of various plants as indicated by the increase of dry weight (Agustrina et al., 2012), nutrient content (Esitken and Turan, 2004), chlorophyll content (Zdyrska et al., 2016; Radhakrishnan and Kumari, 2013; Racuciu et al. 2006, and Rochaska, 2005), and various plant carbohydrates (Small et al., 2012), as well as production of crops characterized by increased fruit quantities (De Souza, 2005), fruit weight (De Souza, 2005 and Esitken and Turan, 2004) produced.

The role of the magnetic field in improving vigor and crop production is heavily associated with the ability of the magnetic field to change the physical-chemical properties of water molecules. Cai et al. (2009) proves that the magnetic field lowers the surface tension and increases the viscosity of water. As a result water becomes more stable with lower molecular energies but higher activation energy. Morejon et al. (2007) proved that the treated water of magnetic field increases the percentage of seed germination of *Pinus Tropicalis* M. The hypothesis is that magnetic fields cause changes in the physics-chemical properties of water, among others: surface pressure, dissolving power, refractive index, and pH. As a result the water becomes more easily absorbed by the seed so that it can break the dormancy faster and shorten the latent period of the seed.

Observations on water media for soybean germination under magnetic field treatment (Agustrina, 2008) show that the results are consistent with the above proofs and hypotheses where the magnetic field strength of 110 and 160 A/m can increase the water evaporation rate respectively by 15.87% and 41.47%, while the magnetic field strength of 275 A/m increases the media temperature by 2.5°C and the evaporation rate of 135.96%.

Other studies have shown that magnetic field treatment is also known to increase peroxide enzyme activity (Mousavizadeh, 2013, Radhakrishnan and Kumari, 2013; and Atak et al., 2007). Peroxidase is an enzyme that plays an important role in the formation of polysaccharides within cell walls such as phenol oxidation, suberation, and lignification that plants will use as defense against pathogens (Ray et al., 1998). *Fusarium* sp. is an important pathogenic fungus causes Fusarium wilt disease, and in tomatoes cultivation this fungus also often becomes as a major constraint (Novita, 2011 and Sussana et al., 2010).

This paper discusses the effect of 0.2 mT magnetic field exposure on the seeds of tomatoes infected by *Fusarium* sp on the number of flowers, the rate of fruiting, as well as the number and weight of the fruit.

**Methods**

The tomato seeds used are obtained from the farm shop with the germination percentage reaching 95%. Before the magnetic field is exposed, the seeds are soaked for 15 minutes (S1) and the un-soaked seeds ase the control for the immersion treatment (S0). The treatment exposures of 0.2 mT magnetic fields (M) given respectively are 7'48" (M1); 11'42" (M2), 15'36 "(M3), and control (M0) or without exposure to magnetic fields

Monospora Fusarium sp. which is used for seed infections is obtained from propagation of *Fusarium* sp. isolates from IPB Culture collection. *Fusarium* sp. infections are performed in two ways: first, by soaking the seeds exposed to the magnetic field in a monospore suspension with a density of 1x107 for 12 hours for 12 hours, and the second, injecting of 50 µl monospore suspension in to the stem of tomato plant when the age of the plant reaches 28 days after seeding. The notation for Fusarium sp. are as follows.

F0 = control, seeds not infected by Fusarium sp. and planted on sterile soil,
F1 = seeds not infected by Fusarium sp. and planted on non-sterile soil,
F2 = seed is infected by Fusarium sp. through soaking the seeds and planted on sterile soil
F3 = seed is infected by Fusarium sp. through soaking the seeds and planted on unsterile soil
F4 = seed infected by Fusarium sp. through the stem of the plant at 28 days after seedling and
planted on sterile soil
F5 = seed infected with Fusarium sp. through the stem of the plant at 28 days after seedling and
planted on unsterile soil.

This research was conducted factorially with a split-strip plot design. Exposure to magnetic field is as main plot (M), treatment of infection of Fusarium sp. (F) is as sub plot, and seed soaking (S) as sub-sub plot. All treatment units were repeated 3 times. The process of seeding, planting, and maintaining crops in the field follows a common way of tomato farmers. The generative growth parameters observed were the number of flowers, the rate of fruiting, the number of fruits, and the total fresh weight of the fruit. The data obtained were analyzed by variance at $\alpha = 1$ and / or 5% and continued with the test between treatments using the LSD Test at $\alpha = 5\%$

**Results and Discussion**

The results of variance analysis in this study can be seen in Table 1 below which shows the effect of soaking treatment (S0 and S1), exposure to magnetic fields (M0, M1, M2, and M3), and *Fusarium* sp. infection (F0, F1, F2, F3, F4, and F5) against the measured generative parameters.

Tablel 1. The results of variance analysis of the effect of 0.2 mT magnetic field exposure on tomato seeds infected by Fusarium sp.

| No | Generative Parameters | Treatments | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | S | M | F | M x F | M x S | F x S | M x F x S |
| 1 | Rate of flowering | ns | 1% | ns | ns | ns | ns | ns |
| 2 | Number of flower | ns | 1% | ns | ns | 5% | ns | ns |
| 3 | Rate of fruiting | ns | 1 % | 1% | ns | 5 % | ns | ns |
| 4 | Number of fruit | ns | 1 % | ns | ns | 1 % | ns | ns |

Note: S = seed soaking, M = magnetic field exposure, F = *Fusarium* sp. infectiom, ns = not significans, and the numbers in % show the level of α.

The table above shows that the *Fusarium* sp. infection only gives a significans effect on the rate of fruiting, while the magnetic field exposure treatment (M) affects all parameters measured. The combination of treatment between magnetic field exposure and soaking of seeds before magnetic field treatment (M x S) affects the number of fruits, the rate of flower, and the number of fruiting.

Figure 1. Flowers of tomato have begun to appear when the plants were 42 days after seedling (4 weeks after planting).

In this study, the plants start flowering between 3-4 weeks after planting. The rate of flowering is significantly influenced by magnetic field treatment. Exposure period to the magnetic field that yields the plant with the highest rate of flowering is for 7'48 "(M1) (Fig. 2).

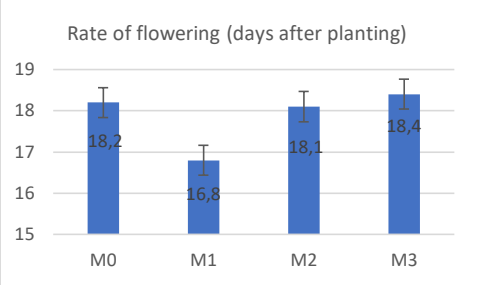


Figure 2. The effect of the exposure of magnetic field 0,2 mT (M) on the rate of flowering

The results of this study confirm the results of previous research De Souza (2005) which proved that the 120 mT magnetic field treatment for 10 minutes and 80 mT for 5 minutes can increase the rate of flowering of tomato plants compared to the control. Racuciu et al. (2006) proves that exposure to 10 mT magnetic fields for 1, 2 and 4 hours every day within 10 days can increase assimilation pigments and nucleic acids of corn and sweet pumpkin so as to increase the content of chlorophyll a and b. Increased chlorophyll content in response to exposure to magnetic fields is also found in sugar beets (Rochalska, 2005) and soybeans (Atak et al., 2007). Increased

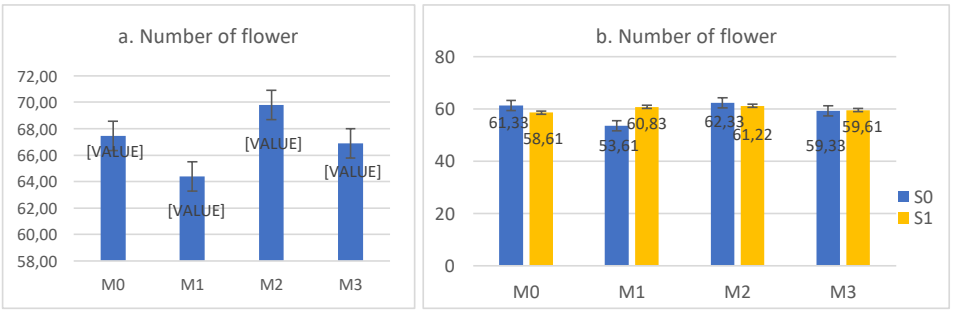


Figure 3. The effect of (a) the exposure of magnetic field 0,2 mT (M) and (b) the treatment combination between the exposure of magnetic field 0,2 mT and seed soaking (M x S) on the number of flower.

chlorophyll content will increase detectable photosynthetic rates by increasing carbohydrate and biomass contents (Small et al., 2012). According to (Agustrina et al., 2012) the increase in chlorophyll as a result of magnetic field treatment is thought to be closely related to the increase in dry weight of plants and may eventually increase other growth rate parameters, such as the rate of flowering.

The response of the rate of flowering (Fig. 2) and the number of flowers (Fig. 3a) to the rate of fruiting (Fig. 4b) and the number of fruits (Fig. 5a) does not show a positive relationship,

but the rate of the flowering (Fig. 2) in line with the response of the number of fruits (Figure 5a) to the magnetic field treatment. Treatment of 0.2 mT magnetic field exposure on the seeds for 7'48" (M1) produced the plant with the highest flowering rate (Figure 2), but the least number of flowers produced (Figure 3a) with the slowest fruiting rate (Fig. 4a), however, produces the largest number of fruits (Figure 5a). In contrast, for the treatment of 0.2 mT magnetic field exposure on the seeds for 11'36 "(M2) yielding plants with flowering rate significantly lower than the flowering rate of the plants of M1 treatment results (Fig. 1). The plants from M2 treatment yielded the highest number of flowers (Fig. 3a) and the fastest fruiting rate (Fig. 4a), and the number of fruits produced is quite large, the second most after the treatment of M1 (Fig. 5a).

Figure 4a below hows that the treatment of *Fusarium* sp. affect the speed of fruit formation. In the results of the research team in our lab (Listiany, personal communication), it was found that the treatment of *Fusarium* sp. also affect the size of the fruit, especially on small fruits. The vegetative growth parameters did not show a significans response to the treatment of *Fusarium* sp. on the seeds exposed to magnetic field (Nastiti, personal communication). Thus the data on the results of this study are in line with the results of the study of Steinkellner et al. (2005) indicating that the symptoms of *Fusarium* sp. attack in early growth will cause plant death, but when the symptoms of Fusarium sp. seen after adult plants, plants can still grow but the production will decrease. This result led to the allegation that the treatment of 0.2 mT magnetic field exposure in the seeds prior to infection of *Fusarium* sp. able to maintain the vigor of tomato plants so as to escape the attack of *Fusarium* sp. especially for the treatment of Fusarium sp F2 and F3 wherein infections of the *Fusarium* monospora inoculates are administered by soaking the seeds. In this case means exposure to the magnetic field in the seed is able to prevent and cause the plant resistant to the spread of infection *Fusarium* sp. derived from infected seeds, so that the plant does not show symptoms of *Fusarium* wilt disease during the vegetative phase, however, it appears that the effects of *Fusarium* sp. is still there so affect the size of the fruit produced (Listiany, personal communication). This means that the magnetic field treatment is suspected to be able to increase the vigor of the plant originating from the seeds that escaped the *Fusarium* sp attack through soaking the seeds.

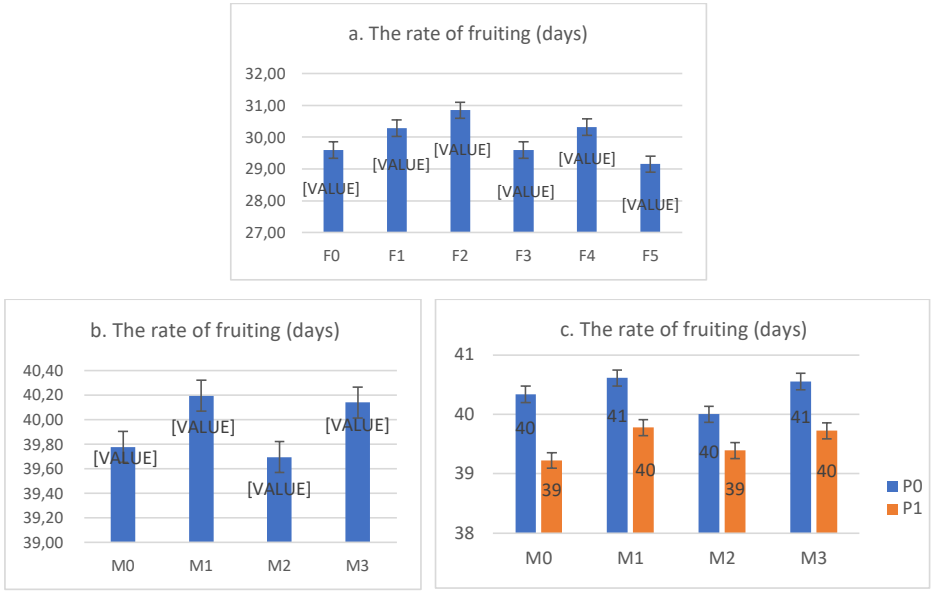


Figure 4. The effect of *Fusarium* sp. infection/F (a), 0,2 mT magnetic field exposure/M (b), and the combination treatment of magnetic field exposre and seed soaking/M x S (c)
on the rate of fruiting

Treatment of infection of *Fusarium* sp. F3 and F5, produce plants with a lowest fruiting rate (Fig. 4a) and yield a small average diameter of fruits (Listiany, personal communication) and this represents an opposite response to each other. The low size of the fruit diameter of the plants from the treatment of F4 and F5 which have high fruiting rate can not be explained yet how the interrelationship between each other. Whether the decrease in fruit diameter of plants from F4 and F5 treatments is true as a result of the treatment of *Fusarium* sp. considering the treatment of *Fusarium* sp. in F4 and F5 is done on the tomato stem when the plant is 28 days after seedling, so even though the plant is able to form the fruit faster but then the infection of *Fusarium* sp on the stems interfere with the metabolism of further fruit development although initially the magnetic field treatment has caused the plant show good growth and developmental qualities. More studies are needed to observe the role of magnetic field exposure in maintaining vigor and production of tomato plants infected by pathogens through stems.

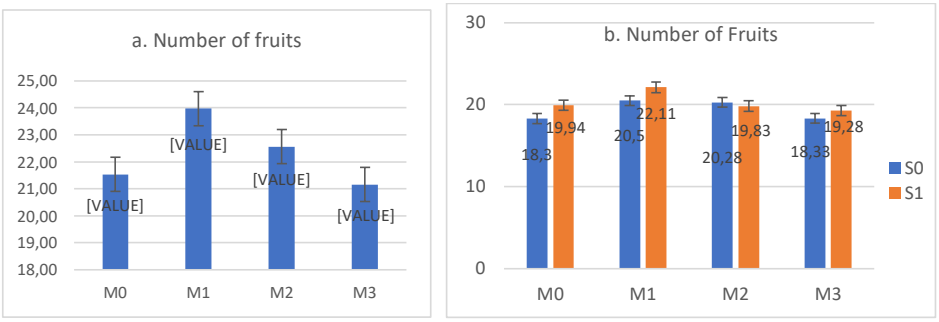


Figure 5. The effect of (a) the exposure of magnetic field 0,2 mT (M) and (b) the treatment combination between the exposure of magnetic field 0,2 mT and seed soaking (M x S) on the number of fruit.

The seed soaking treatment (S) alone did not have a significans effect on the parameters measured, but the treatment combination of seed soaking and magnetic field exposure significantly increased the number of flowers (Figure 3b), the rate of fruiting (Figure 4c), and the number of fruits (Figure 5b). Overall, the results of this study show that exposure to 0.2 mT magnetic field in tomato seeds can increase the production of tomato plants. Exposure to 0.2 mT magnetic field is able to retain the vigor of tomato seed infected by *Fusarium* sp. both infections through soaking the seeds in the suspension of the monospora isolate *Fusarium* sp. as well as through injection of monospora isolates on the stem at 28 days after seedling. As a result of magnetic field treatment on plants that survive from the attack *Fusarium* sp. can grow well and produce flowering and fruiting plants faster with more fruit. Exposure of 0.2 mT magnetic field to the seeds infected by *Fusarium* sp. it becomes more effective in increasing the generative growth rate when done on seeds soaked for 15 minutes before being treated with magnetic fields.

**Conclusion**

Exposure to 0.2 mT magnetic field for 7'48 "on tomato seed infected by *Fusarium* sp. produce plants with the highest rate of flowering and the largest number of tomatoes.

Exposure to 0.2 mT magnetic field for 11'36 "in tomato seed infected by *Fusarium* sp. produces plants with the most number of flowers and the highest rate of fruiting.

Soaking tomato seeds for 15 minutes before the 0.2 mT magnetic field treatment gives a better effect to increase the rate of the plants to form flowers, fruits, and increase the number of fruits.

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# Tomato Generative Growth from the Seeds Exposed to 0,2 mT of Magnetic Field and Infected by Fusarium sp.

Rochmah Agustrina, Endang Nurcahyani, Bambang Irawan
Jurusan Biologi Fakultas Matematik dan Ilmu Pengetahuan Alam Universitas Lampung
*E-mail: rochmah.agustrina@fmipa.unila.ac.id

Abstrak

Penelitian sebelumnya membuktikan bahwa medan magnet dapat meningkatkan vigor dan pertumbuhan tanaman tomat yang tahan terhadap serangan Fusarium sp. Dalam penelitian ini dikaji apakah peningkatan vigor dan pertumbuhan tomat yang tahan trhadap serangan Fusarium sp diikuti dengan peningkatan pertumbuhan generatif. Penelitian dilaksanakan secara faktorial dalam rancangan strip split plot terdiri dari faktor paparan medan magnet 0,2 mT (M: kontrol; 7'48 "; 11'42" and 15'36 "); infeksi Fusarium sp. (F); dan perendaman biji (P: biji direndam dan tidak direndam selama 15' sebelum perlakuan medan magnet) dengan tiga ulangan. Parameter pertumbuhan generatif yang diamati adalah jumlah bunga, kecepatan berbuah, jumlah buah, dan berat segar total buah per tanaman.

Hasil analisis varians pada $\alpha = 1$ s.d 5% menunjukkan bahwa perlakuan paparan medan magnet (M) dan kombinasi MxP mempengaruhi semua parameter yang diukur. Perlakuan infeksi Fusarium sp. (F) hanya mempengaruhi kecepatan pembentukan buah. Perlakuan P dan kombinasi MxF, FxP, dan MxFxP tidak mempengaruhi semua parameter yang diukur. Paparan medan magnet selama 7'48 " menghasilkan tanaman dengan kecepatan pembentukan bunga tertinggi dan jumlah buah terbanyak. Jumlah bunga terbanyak dan kecepatan tertinggi diperoleh dari hasil paparan medan magnet selama 11'42". Infeksi Fusarium pada batang tanaman dari benih yang direndam dan ditanam pada tanah steril menghasilkan tanaman dengan kecepatan pembentukan buah terendah (F5). Paparan medan magnet selama 7'48 " pada benih yang direndam mengahsilkan jumlah buah terbanyak. Jumlah bunga tertinggi diperoleh dari perlakuan paparan medan magnet pada biji yang tidak direndam dan kecepatan berbuah tertinggi diperoleh dari perlakuan biji yang direndam tanpa paparan medan magnet.

Kata Kunci: Medan magnet 0,2 mT; Fusarium sp.; perendaman benih; pertumbuhan generatif

Abstract

Previous research has shown that magnetic fields can increase the vigor and growth of tomato plants resistant to Fusarium sp. In this study we investigated whether the increase of vigor and tomato growth of plants resistant to Fusarium sp. attack will continue with the resulting increase in generative growth. The research was conducted factorially using a split strip plot design consisting of 0.2 mT magnetic field exposure (M) as the main plot; infection of Fusarium sp. (F) as a sub plot; and seed soaking (S) for 15 'before the magnetic field treatment as strip plots. Each treatment unit was repeated 3 times. The generative growth parameters studied were the number of flowers, the rate of fruiting, the number of fruits, and the total fresh weight of the fruit per plant.

The results of the analysis of variance at α = 1 and 5% indicate that the magnetic field exposure (M) treatment and combination of magnetic field exposure and seed soaking treatment (MxS) affect all parameters measured. Treatment of infection of Fusarium sp. (F) only affect the speed of fruit formation. The S treatment and treatment combinations of MxF, FxS, and MxFxS do not affect all parameters measured. Exposure to magnetic fields for 7'48 "produces plants with the highest rate of flower formation and the greatest number of fruits.

The highest number of flowers and the highest rate of fruiting was obtained from the treatment of magnetic field exposure for 11'42 ". Fusarium infection of plant stems from soaked seeds and grown on sterile soil produces plants with the lowest of fruiting rate (F5). Exposure of magnetic field for 7'48 "to the soaked seed yields the largest amount of fruit. The highest amount of flower was obtained from the treatment of magnetic field exposure on un-soaked seed while the highest rate of fruiting obtained from the treatment of the soaked beans without exposure to the magnetic field.

Keywords: 0,2 mT of magnetic field; Fusarium sp.; seed soaking; generative growth.

## Introduction

Growth and development of plants is strongly influenced by various environmental factors that surround them including magnetic field (Majd and Shabrangi, 2011), because the earth is a source of natural magnetic field which then known the earth's magnetic field or geomagnetic field. However, since the energy emitted by the Earth's magnetic field is very low, 25 to 65 microtesla (Finlay et al., 2010), its presence and influence on plants is not widely recognized.

However, the last few decades it has known that the results of research that examines the prospect of the utilization of magnetic field energy to various types of plants began to appear. Although there are still many unexplained problems on how the reaction mechanism of energy generated by magnetic fields with plant cell systems (Belyavskaya et al., 2002), but the results of previous studies have proven that magnetic fields can improve the viability of seeds from tobacco ( Aladjadjiyan and Ylieve, 2003), corn (Florez and Martinez, 2007), soybeans (Agustrina and Handayani, 2008 and Atak et al., 2003), tomatoes (Agustrina et al., 2012 and De Souza et al., 2005), growth vegetation of various plants as indicated by the increase of dry weight (Agustrina et al., 2012), nutrient content (Esitken and Turan, 2004), chlorophyll content

(Zdyrska et al., 2016; Radhakrishnan and Kumari, 2013; Racuciu et al. 2006, and Rochaska, 2005), and various plant carbohydrates (Small et al., 2012), as well as production of crops characterized by increased fruit quantities (De Souza, 2005), fruit weight (De Souza, 2005 and Esitken and Turan, 2004) produced.

The role of the magnetic field in improving vigor and crop production is heavily associated with the ability of the magnetic field to change the physical-chemical properties of water molecules. Cai et al. (2009) proves that the magnetic field lowers the surface tension and increases the viscosity of water. As a result water becomes more stable with lower molecular energies but higher activation energy. Morejon et al. [4] (2007) proved that the treated water of magnetic field increases the percentage of seed germination of Pinus Tropicalis M. The hypothesis is that magnetic fields cause changes in the physics-chemical properties of water, among others: surface pressure, dissolving power, refractive index, and pH. As a result the water becomes more easily absorbed by the seed so that it can break the dormancy faster and shorten the latent period of the seed.

[0] Observations on water media for soybean germination under magnetic field treatment (Agustrina, 2008) show that the results are consistent with the above proofs and hypotheses where the magnetic field strength of 110 and 160 A/m can increase the water evaporation rate respectively by 15.87% and 41.47%, while the magnetic field strength of 275 A/m increases the media temperature by 2.5°C and the evaporation rate of 135.96%.

Other studies have shown that magnetic field treatment is also known to increase peroxide enzyme activity (Mousavizadeh, 2013, Radhakrishnan and Kumari, 2013; and Atak et al., 2007). Peroxidase is an enzyme that plays an important role in the formation of polysaccharides within cell walls such as phenol oxidation, suberation, and lignification that plants will use as defense against pathogens (Ray et al., 1998). Fusarium sp. is an important pathogenic fungus causes Fusarium wilt disease, and in tomatoes cultivation this fungus also often becomes as a major constraint (Novita, 2011 and Sussana et al., 2010).

This paper discusses the effect of 0.2 mT magnetic field exposure on the seeds of tomatoes infected by Fusarium sp on the number of flowers, the rate of fruiting, as well as the number and weight of the fruit.

## Methods

The tomato seeds used are obtained from the farm shop with the germination percentage reaching 95%. Before the magnetic field is exposed, the seeds are soaked for 15 minutes (S1) and the un-soaked seeds ase the control for the immersion treatment (S0). The treatment exposures of 0.2 mT magnetic fields (M) given respectively are 7'48" (M1); 11'42" (M2), 15'36 "(M3), and control (M0) or without exposure to magnetic fields

Monospora Fusarium sp. which is used for seed infections is obtained from propagation of Fusarium sp. isolates from IPB Culture collection. Fusarium sp. infections are performed in two ways: [2] first, by soaking the seeds exposed to the magnetic field in a monospore suspension with a density of 1x107 for 12 hours for 12 hours, and the second, injecting of 50 µl monospore suspension in to the stem of tomato plant when the age of the plant reaches 28 days after seeding. The notation for Fusarium sp. are as follows.

F0 = control, seeds not infected by Fusarium sp. and planted on sterile soil,
F1 = seeds not infected by Fusarium sp. and planted on non-sterile soil,
F2 = seed is infected by Fusarium sp. through soaking the seeds and planted on sterile soil
F3 = seed is infected by Fusarium sp. through soaking the seeds and planted on unsterile soil
F4 = seed infected by Fusarium sp. through the stem of the plant at 28 days after seedling and planted on sterile soil
F5 = seed infected with Fusarium sp. through the stem of the plant at 28 days after seedling and planted on unsterile soil.

This research was conducted factorially with a split-strip plot design. Exposure to magnetic field is as main plot (M), treatment of infection of Fusarium sp. (F) is as sub plot, and seed soaking (S) as sub-sub plot. All treatment units were repeated 3 times. The process of seeding, planting, and maintaining crops in the field follows a common way of tomato farmers. The generative growth parameters observed were the number of flowers, the rate of fruiting, the number of fruits, and the total fresh weight of the fruit. The data obtained were analyzed by variance at α = 1 and / or 5% and continued with the test between treatments using the LSD Test at α = 5%

## Results and Discussion

The results of variance analysis in this study can be seen in Table 1 below which shows the effect of soaking treatment (S0 and S1), exposure to magnetic fields (M0, M1, M2, and M3), and Fusarium sp. infection (F0, F1, F2, F3, F4, and F5) against the measured generative parameters.

Tablel 1. The results of variance analysis of the effect of 0.[3]2 mT magnetic field exposure on tomato seeds infected by Fusarium sp.

| № | Generative Parameters | Treatments | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | S | M | F | M x F | M x S | F x S | M x F x S |
| 1 | Rate of flowering | ns | 1% | ns | ns | ns | ns | ns |
| 2 | Number of flower | ns | 1% | ns | ns | 5% | ns | ns |
| 3 | Rate of fruiting | ns | 1 % | 1% | ns | 5 % | ns | ns |
| 4 | Number of fruit | ns | 1 % | ns | ns | 1 % | ns | ns |

Note: S = seed soaking, M = magnetic field exposure, F = Fusarium sp. infectiom, ns = not significans, and the numbers in % show the level of α.

The table above shows that the Fusarium sp. infection only gives a significans effect on the rate of fruiting, while the magnetic field exposure treatment (M) affects all parameters measured. The combination of treatment between magnetic field exposure and soaking of seeds before magnetic field treatment (M x S) affects the number of fruits, the rate of flower, and the number of fruiting.

Figure 1. Flowers of tomato have begun to appear when the plants were 42 days after seedling (4 weeks after planting).

In this study, the plants start flowering between 3-4 weeks after planting. The rate of flowering is significantly influenced by magnetic field treatment. Exposure period to the magnetic field that yields the plant with the highest rate of flowering is for 7'48 "(M1) (Fig. 2).

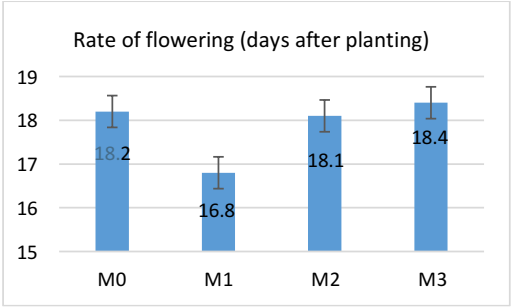



Figure 2. The effect of the exposure of magnetic field 0,2 mT (M) on the rate of flowering

The results of this study confirm the results of previous research De Souza (2005) which proved that the 120 mT magnetic field treatment for 10 minutes and 80 mT for 5 minutes can increase

the rate of flowering of tomato plants compared to the control. Racuciu et al. (2006) proves that exposure to 10 mT magnetic fields for 1, 2 and 4 hours every day within 10 days can increase assimilation pigments and nucleic acids of corn and sweet pumpkin so as to increase the content of chlorophyll a and b. Increased chlorophyll content in response to exposure to magnetic fields is also found in sugar beets (Rochalska, 2005) and soybeans (Atak et al., 2007). Increased

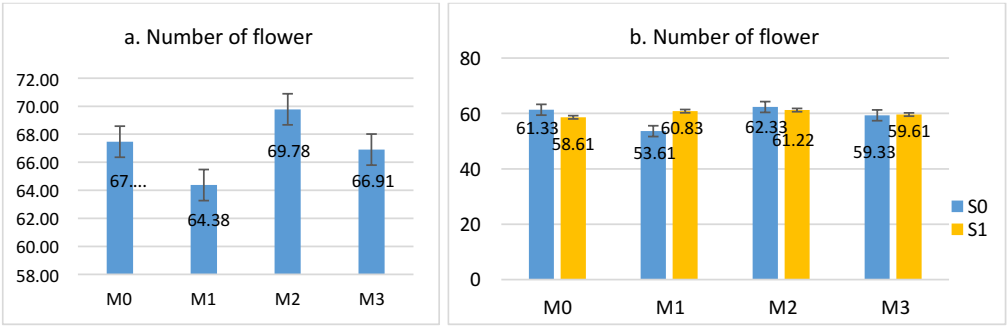



Figure 3. The effect of (a) the exposure of magnetic field 0,2 mT (M) and (b) the treatment combination between the exposure of magnetic field 0,2 mT and seed soaking (M x S) on the number of flower.

chlorophyll content will increase detectable photosynthetic rates by increasing carbohydrate and biomass contents (Small et al., 2012). According to (Agustrina et al., 2012) the increase in chlorophyll as a result of magnetic field treatment is thought to be closely related to the increase in dry weight of plants and may eventually increase other growth rate parameters, such as the rate of flowering.

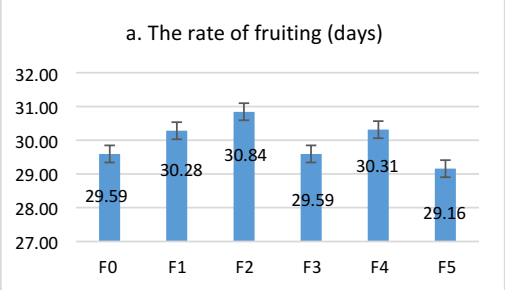
[0]

[3]

The response of the rate of flowering (Fig. 2) and the number of flowers (Fig. 3a) to the rate of fruiting (Fig. 4b) and the number of fruits (Fig. 5a) does not show a positive relationship, but the rate of the flowering (Fig. 2) in line with the response of the number of fruits (Figure 5a) to the magnetic field treatment. Treatment of 0.[0]2 mT magnetic field exposure on the seeds for 7'48" (M1) produced the plant with the highest flowering rate (Figure 2), but the least number of flowers produced (Figure 3a) with the slowest fruiting rate (Fig. 4a), however, produces the largest number of fruits (Figure 5a). In contrast, for the treatment of 0.2 mT magnetic field exposure on the seeds for 11'36 "(M2) yielding plants with flowering rate significantly lower than the flowering rate of the plants of M1 treatment results (Fig. 1). The plants from M2 treatment yielded the highest number of flowers (Fig. 3a) and the fastest fruiting rate (Fig. 4a),

and the number of fruits produced is quite large, the second most after the treatment of M1 (Fig. 5a).

Figure 4a below hows that the treatment of Fusarium sp. affect the speed of fruit formation. In the results of the research team in our lab (Listiany, personal communication), it was found that the treatment of Fusarium sp. also affect the size of the fruit, especially on small fruits. The vegetative growth parameters did not show a significans response to the treatment of Fusarium sp. on the seeds exposed to magnetic field (Nastiti, personal communication). Thus the data on the results of this study are in line with the results of the study of Steinkellner et al. (2005) indicating that the symptoms of Fusarium sp. attack in early growth will cause plant death, but when the symptoms of Fusarium sp. seen after adult plants, plants can still grow but the production will decrease. This result led to the allegation that the treatment of 0.2 mT magnetic field exposure in the seeds prior to infection of Fusarium sp. able to maintain the vigor of tomato plants so as to escape the attack of Fusarium sp. especially for the treatment of Fusarium sp F2 and F3 wherein infections of the Fusarium monospora inoculates are administered by soaking the seeds. In this case means exposure to the magnetic field in the seed is able to prevent and cause the plant resistant to the spread of infection Fusarium sp. derived from infected seeds, so that the plant does not show symptoms of Fusarium wilt disease during the vegetative phase, however, it appears that the effects of Fusarium sp. is still there so affect the size of the fruit produced (Listiany, personal communication). This means that the magnetic field treatment is suspected to be able to increase the vigor of the plant originating from the seeds that escaped the Fusarium sp attack through soaking the seeds.



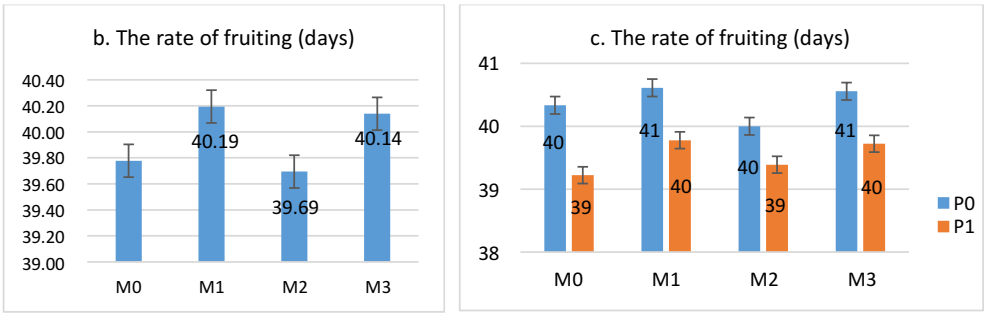



Figure 4. The effect of Fusarium sp. infection/F (a), 0,2 mT magnetic field exposure/M (b), and the combination treatment of magnetic field exposre and seed soaking/M x S (c) on the rate of fruiting

Treatment of infection of Fusarium sp. F3 and F5, produce plants with a lowest fruiting rate (Fig. 4a) and yield a small average diameter of fruits (Listiany, personal communication) and this represents an opposite response to each other. The low size of the fruit diameter of the plants from the treatment of F4 and F5 which have high fruiting rate can not be explained yet how the interrelationship between each other. Whether the decrease in fruit diameter of plants from F4 and F5 treatments is true as a result of the treatment of Fusarium sp. considering the treatment of Fusarium sp. in F4 and F5 is done on the tomato stem when the plant is 28 days after seedling, so even though the plant is able to form the fruit faster but then the infection of Fusarium sp on the stems interfere with the metabolism of further fruit development although initially the magnetic field treatment has caused the plant show good growth and developmental qualities. More studies are needed to observe the role of magnetic field exposure in maintaining vigor and production of tomato plants infected by pathogens through stems.

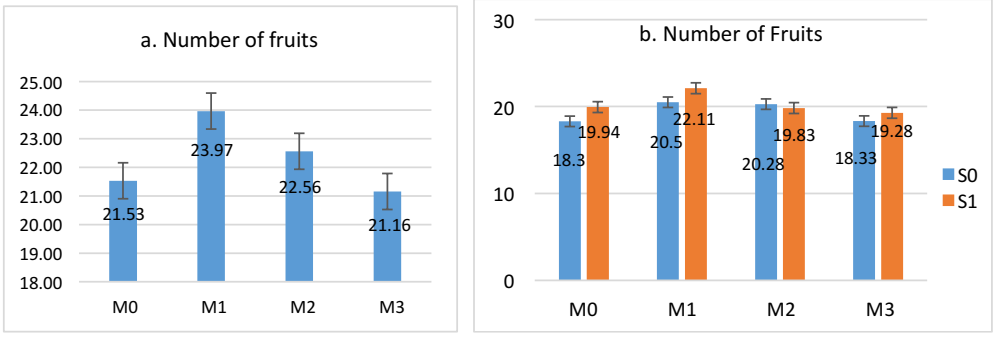



Figure 5. The effect of (a) the exposure of magnetic field 0,2 mT (M) and (b) the treatment

combination between the exposure of magnetic field 0,2 mT and seed soaking (M x S) on the number of fruit.

The seed soaking treatment (S) alone did not have a significans effect on the parameters measured, but the treatment combination of seed soaking and magnetic field exposure significantly increased the number of flowers (Figure 3b), the rate of fruiting (Figure 4c), and the number of fruits (Figure 5b). Overall, the results of this study show that exposure to 0.2 mT magnetic field in tomato seeds can increase the production of tomato plants. Exposure to 0.2 mT magnetic field is able to retain the vigor of tomato seed infected by Fusarium sp. both infections through soaking the seeds in the suspension of the monospora isolate Fusarium sp. as well as through injection of monospora isolates on the stem at 28 days after seedling. As a result of magnetic field treatment on plants that survive from the attack Fusarium sp. can grow well and produce flowering and fruiting plants faster with more fruit. Exposure of 0.2 mT magnetic field to the seeds infected by Fusarium sp. it becomes more effective in increasing the generative growth rate when done on seeds soaked for 15 minutes before being treated with magnetic fields.

## Conclusion

Exposure to 0.2 mT magnetic field for 7'48 "on tomato seed infected by Fusarium sp. produce plants with the highest rate of flowering and the largest number of tomatoes.

Exposure to 0.2 mT magnetic field for 11'36 "in tomato seed infected by Fusarium sp. produces plants with the most number of flowers and the highest rate of fruiting.

Soaking tomato seeds for 15 minutes before the 0.2 mT magnetic field treatment gives a better effect to increase the rate of the plants to form flowers, fruits, and increase the number of fruits.

## Anknowledgments

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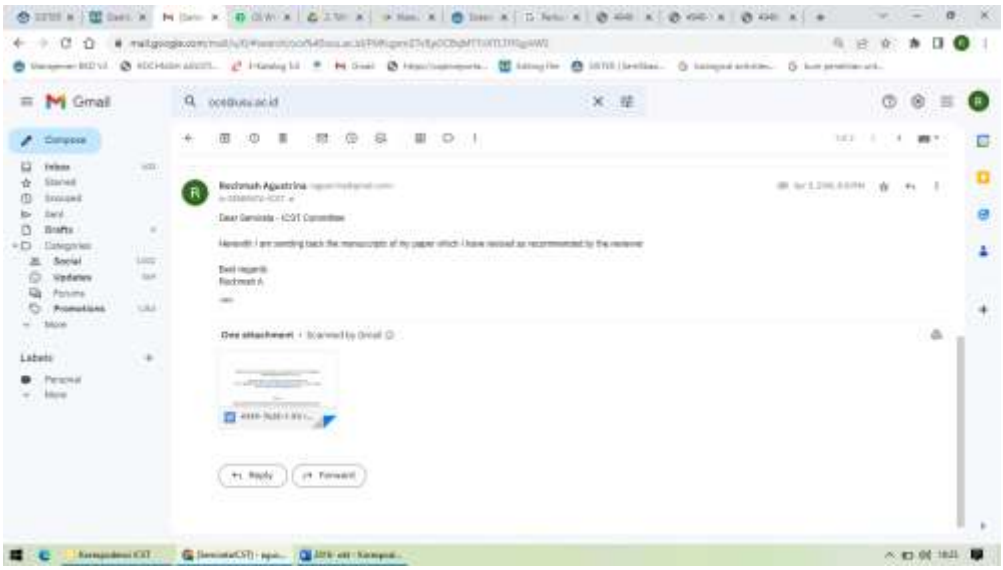

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**Rochmah Agustrina, Endang Nurcahyani, Bambang Irawan**
**Jurusan Biologi Fakultas Matematik dan Ilmu Pengetahuan Alam Universitas Lampung**
***E-mail:** rochmah.agustrina@fmipa.unila.ac.id*

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## Abstract

Previous research has shown that magnetic fields can increase the vigor and growth of tomato plants resistant to *Fusarium* sp. In this study we investigated whether the increase of vigor and tomato growth of plants resistant to *Fusarium* sp. attack will continue with the resulting increase in generative growth. The research was conducted factorially using a split strip plot design consisting of 0.2 mT magnetic field exposure (M) as the main plot; infection of Fusarium sp. (F) as a sub plot; and seed soaking (S) for 15 'before the magnetic field treatment as strip plots. Each treatment unit was repeated 3 times. The generative growth parameters studied were the number of flowers, the rate of fruiting, the number of fruits, and the total fresh weight of the fruit per plant.

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**Keywords: 0,2 mT of magnetic field; *Fusarium* sp.; seed soaking; generative growth.**

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## Introduction

Growth and development of plants is strongly influenced by various environmental factors that surround them including magnetic field (Majd and Shabrangi, 2011), because the earth is a source of natural magnetic field which then known the earth's magnetic field or geomagnetic field. However, since the energy emitted by the Earth's magnetic field is very low, 25 to 65 microtesla (Finlay et al., 2010), its presence and influence on plants is not widely recognized.

However, the last few decades it has known that the results of research that examines the prospect of the utilization of magnetic field energy to various types of plants began to appear. Although there are still many unexplained problems on how the reaction mechanism of energy generated by magnetic fields with plant cell systems (Belyavskaya et al., 2002), but the results of previous studies have proven that magnetic fields can improve the viability of seeds from tobacco ( Aladjadjiyan and Ylieve, 2003), corn (Florez and Martinez, 2007), soybeans (Agustrina and Handayani, 2008 and Atak et al., 2003), tomatoes (Agustrina et al., 2012 and De Souza et al., 2005), growth vegetation of various plants as indicated by the increase of dry weight (Agustrina et al., 2012), nutrient content (Esitken and Turan, 2004), chlorophyll content (Zdyrska et al., 2016; Radhakrishnan and Kumari, 2013; Racuciu et al. 2006, and Rochaska, 2005), and various plant carbohydrates (Small et al., 2012), as well as production of crops characterized by increased fruit quantities (De Souza, 2005), fruit weight (De Souza, 2005 and Esitken and Turan, 2004) produced.

The role of the magnetic field in improving vigor and crop production is heavily associated with the ability of the magnetic field to change the physical-chemical properties of water molecules. Cai et al. (2009) proves that the magnetic field lowers the surface tension and increases the viscosity of water. As a result water becomes more stable with lower molecular energies but higher activation energy. Morejon et al. (2007) proved that the treated water of magnetic field increases the percentage of seed germination of *Pinus Tropicalis* M. The hypothesis is that magnetic fields cause changes in the physics-chemical properties of water, among others: surface pressure, dissolving power, refractive index, and pH. As a result the water becomes more easily absorbed by the seed so that it can break the dormancy faster and shorten the latent period of the seed.

Observations on water media for soybean germination under magnetic field treatment (Agustrina, 2008) show that the results are consistent with the above proofs and hypotheses where the magnetic field strength of 110 and 160 A/m can increase the water evaporation rate respectively by 15.87% and 41.47%, while the magnetic field strength of 275 A/m increases the media temperature by 2.5℃ and the evaporation rate of 135.96%.

Other studies have shown that magnetic field treatment is also known to increase peroxide enzyme activity (Mousavizadeh, 2013, Radhakrishnan and Kumari, 2013; and Atak et al., 2007). Peroxidase is an enzyme that plays an important role in the formation of polysaccharides within cell walls such as phenol oxidation, suberation, and lignification that plants will use as defense against pathogens (Ray et al., 1998). *Fusarium* sp. is an important pathogenic fungus causes Fusarium wilt disease, and in tomatoes cultivation this fungus also often becomes as a major constraint (Novita, 2011 and Sussana et al., 2010).

This paper discusses the effect of 0.2 mT magnetic field exposure on the seeds of tomatoes infected by *Fusarium* sp on the number of flowers, the rate of fruiting, as well as the number and weight of the fruit.

**Methods**

The tomato seeds used are obtained from the farm shop with the germination percentage reaching 95%. Before the magnetic field is exposed, the seeds are soaked for 15 minutes (S1) and the un-soaked seeds ase the control for the immersion treatment (S0). The treatment exposures of 0.2 mT magnetic fields (M) given respectively are 7'48" (M1); 11'42" (M2), 15'36"(M3), and control (M0) or without exposure to magnetic fields.

Monospora Fusarium sp. which is used for seed infections is obtained from propagation of *Fusarium* sp. isolates from IPB Culture collection. *Fusarium* sp. infections are performed in two ways: first, by soaking the seeds exposed to the magnetic field in a monospore suspension with a density of 1x107 for 12 hours for 12 hours, and the second, injecting of 50 µl monospore suspension in to the stem of tomato plant when the age of the plant reaches 28 days after seeding. The notation for Fusarium sp. are as follows.

F0 = control, seeds not infected by Fusarium sp. and planted on sterile soil,
F1 = seeds not infected by Fusarium sp. and planted on non-sterile soil,
F2 = seed is infected by Fusarium sp. through soaking the seeds and planted on sterile soil
F3 = seed is infected by Fusarium sp. through soaking the seeds and planted on unsterile soil
F4 = seed infected by Fusarium sp. through the stem of the plant at 28 days after seedling and
planted on sterile soil
F5 = seed infected with Fusarium sp. through the stem of the plant at 28 days after seedling and
planted on unsterile soil.

This research was conducted factorially with a split-strip plot design. Exposure to magnetic field is as main plot (M), treatment of infection of Fusarium sp. (F) is as sub plot, and seed soaking (S) as sub-sub plot. All treatment units were repeated 3 times. The process of seeding, planting, and maintaining crops in the field follows a common way of tomato farmers. The generative growth parameters observed were the number of flowers, the rate of fruiting, the number of fruits, and the total fresh weight of the fruit. The data obtained were analyzed by variance at $\alpha = 1$ and / or 5% and continued with the test between treatments using the LSD Test at $\alpha = 5\%$

**Results and Discussion**

The results of variance analysis in this study can be seen in Table 1 below which shows the effect of soaking treatment (S0 and S1), exposure to magnetic fields (M0, M1, M2, and M3), and *Fusarium* sp. infection (F0, F1, F2, F3, F4, and F5) against the measured generative parameters.

Tablel 1. The results of variance analysis of the effect of 0.2 mT magnetic field exposure on tomato seeds infected by Fusarium sp.

| No | Generative Parameters | Treatments | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | S | M | F | M x F | M x S | F x S | M x F x S |
| 1 | Rate of flowering | ns | 1% | ns | ns | Ns | ns | ns |
| 2 | Number of flower | ns | 1% | ns | ns | 5% | ns | ns |
| 3 | Rate of fruiting | ns | 1 % | 1% | ns | 5 % | ns | ns |
| 4 | Number of fruit | ns | 1 % | ns | ns | 1 % | ns | ns |

Note: S = seed soaking, M = magnetic field exposure, F = *Fusarium* sp. infectiom, ns = not significans, and the numbers in % show the level of $\alpha$.

The table above shows that the *Fusarium* sp. infection only gives a significans effect on the rate of fruiting, while the magnetic field exposure treatment (M) affects all parameters measured. The combination of treatment between magnetic field exposure and soaking of seeds before magnetic field treatment (M x S) affects the number of fruits, the rate of flower, and the number of fruiting.

Figure 1. Flowers of tomato have begun to appear when the plants were 42 days after seedling (4 weeks after planting).

In this study, the plants start flowering between 3-4 weeks after planting. The rate of flowering is significantly influenced by magnetic field treatment. Exposure period to the magnetic field that yields the plant with the highest rate of flowering is for 7'48 "(M1) (Fig. 2).

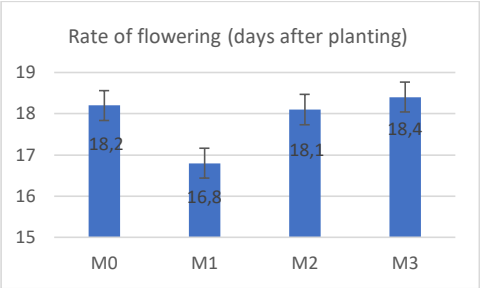


Figure 2. The effect of the exposure of magnetic field 0,2 mT (M) on the rate of flowering

The results of this study confirm the results of previous research De Souza (2005) which proved that the 120 mT magnetic field treatment for 10 minutes and 80 mT for 5 minutes can increase the rate of flowering of tomato plants compared to the control. Racuciu et al. (2006) proves that exposure to 10 mT magnetic fields for 1, 2 and 4 hours every day within 10 days can increase assimilation pigments and nucleic acids of corn and sweet pumpkin so as to increase the content of chlorophyll a and b. Increased chlorophyll content in response to exposure to magnetic fields is also found in sugar beets (Rochalska, 2005) and soybeans (Atak et al., 2007). Increased

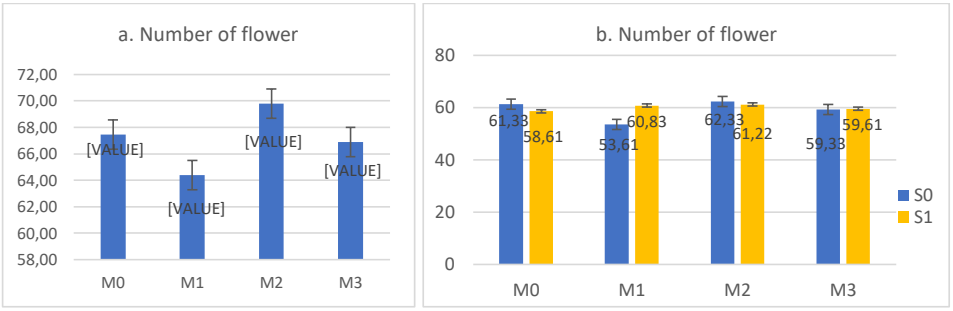


Figure 3. The effect of (a) the exposure of magnetic field 0,2 mT (M) and (b) the treatment combination between the exposure of magnetic field 0,2 mT and seed soaking (M x S) on the number of flower.

chlorophyll content will increase detectable photosynthetic rates by increasing carbohydrate and biomass contents (Small et al., 2012). According to (Agustrina et al., 2012) the increase in chlorophyll as a result of magnetic field treatment is thought to be closely related to the increase in dry weight of plants and may eventually increase other growth rate parameters, such as the rate of flowering.

The response of the rate of flowering (Fig. 2) and the number of flowers (Fig. 3a) to the rate of fruiting (Fig. 4b) and the number of fruits (Fig. 5a) does not show a positive relationship, but the rate of the flowering (Fig. 2) in line with the response of the number of fruits (Figure 5a) to the magnetic field treatment. Treatment of 0.2 mT magnetic field exposure on the seeds for 7'48" (M1) produced the plant with the highest flowering rate (Figure 2), but the least number of flowers produced (Figure 3a) with the slowest fruiting rate (Fig. 4a), however, produces the largest number of fruits (Figure 5a). In contrast, for the treatment of 0.2 mT magnetic field exposure on the seeds for 11'36 "(M2) yielding plants with flowering rate significantly lower than the flowering rate of the plants of M1 treatment results (Fig. 1). The plants from M2 treatment yielded the highest number of flowers (Fig. 3a) and the fastest fruiting rate (Fig. 4a), and the number of fruits produced is quite large, the second most after the treatment of M1 (Fig. 5a).

Figure 4a below hows that the treatment of *Fusarium* sp. affect the speed of fruit formation. In the results of the research team in our lab (Listiany, personal communication), it was found that the treatment of *Fusarium* sp. also affect the size of the fruit, especially on small fruits. The vegetative growth parameters did not show a significans response to the treatment of *Fusarium* sp. on the seeds exposed to magnetic field (Nastiti, personal communication). Thus

the data on the results of this study are in line with the results of the study of Steinkellner et al. (2005) indicating that the symptoms of *Fusarium* sp. attack in early growth will cause plant death, but when the symptoms of Fusarium sp. seen after adult plants, plants can still grow but the production will decrease. This result led to the allegation that the treatment of 0.2 mT magnetic field exposure in the seeds prior to infection of *Fusarium* sp. able to maintain the vigor of tomato plants so as to escape the attack of *Fusarium* sp. especially for the treatment of Fusarium sp F2 and F3 wherein infections of the *Fusarium* monospora inoculates are administered by soaking the seeds. In this case means exposure to the magnetic field in the seed is able to prevent and cause the plant resistant to the spread of infection *Fusarium* sp. derived from infected seeds, so that the plant does not show symptoms of *Fusarium* wilt disease during the vegetative phase, however, it appears that the effects of *Fusarium* sp. is still there so affect the size of the fruit produced (Listiany, personal communication). This means that the magnetic field treatment is suspected to be able to increase the vigor of the plant originating from the seeds that escaped the *Fusarium* sp attack through soaking the seeds.

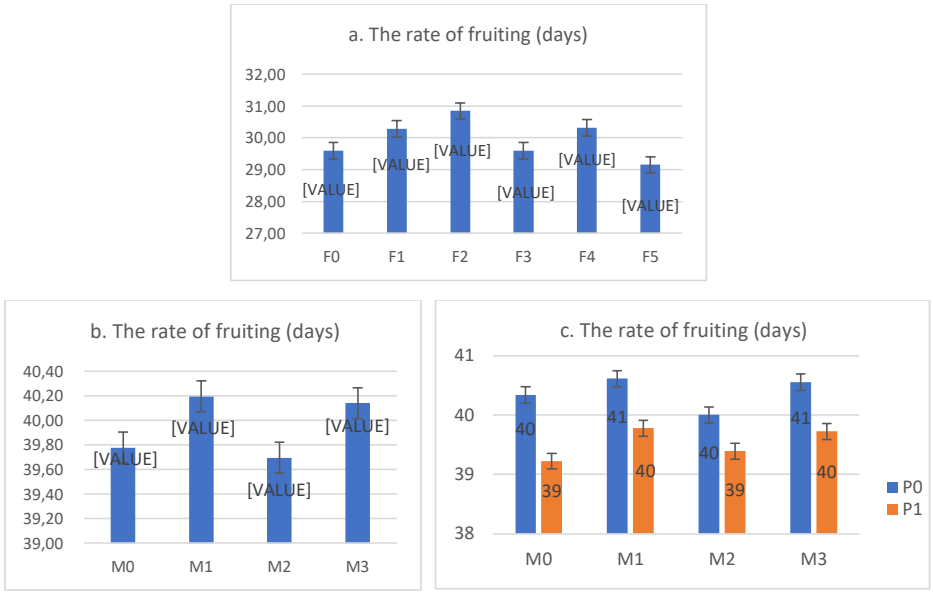


Figure 4. The effect of *Fusarium* sp. infection/F (a), 0,2 mT magnetic field exposure/M (b), and the combination treatment of magnetic field exposre and seed soaking/M x S (c)

on the rate of fruiting

Treatment of infection of *Fusarium* sp. F3 and F5, produce plants with a lowest fruiting rate (Fig. 4a) and yield a small average diameter of fruits (Listiany, personal communication) and this represents an opposite response to each other. The low size of the fruit diameter of the plants from the treatment of F4 and F5 which have high fruiting rate can not be explained yet how the interrelationship between each other. Whether the decrease in fruit diameter of plants from F4 and F5 treatments is true as a result of the treatment of *Fusarium* sp. considering the treatment of *Fusarium* sp. in F4 and F5 is done on the tomato stem when the plant is 28 days after seedling, so even though the plant is able to form the fruit faster but then the infection of *Fusarium* sp on the stems interfere with the metabolism of further fruit development although initially the magnetic field treatment has caused the plant show good growth and developmental qualities. More studies are needed to observe the role of magnetic field exposure in maintaining vigor and production of tomato plants infected by pathogens through stems.

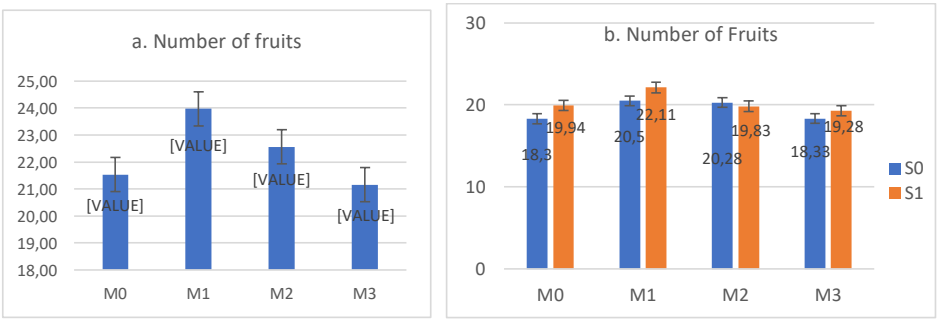


Figure 5. The effect of (a) the exposure of magnetic field 0,2 mT (M) and (b) the treatment combination between the exposure of magnetic field 0,2 mT and seed soaking (M x S) on the number of fruit.

The seed soaking treatment (S) alone did not have a significans effect on the parameters measured, but the treatment combination of seed soaking and magnetic field exposure significantly increased the number of flowers (Figure 3b), the rate of fruiting (Figure 4c), and the number of fruits (Figure 5b). Overall, the results of this study show that exposure to 0.2 mT magnetic field in tomato seeds can increase the production of tomato plants. Exposure to 0.2 mT magnetic field is able to retain the vigor of tomato seed infected by *Fusarium* sp. both infections through soaking the seeds in the suspension of the monospora isolate *Fusarium* sp. as well as through injection of monospora isolates on the stem at 28 days after seedling. As a result of magnetic field treatment on plants that survive from the attack *Fusarium* sp. can

grow well and produce flowering and fruiting plants faster with more fruit. Exposure of 0.2 mT magnetic field to the seeds infected by *Fusarium* sp. it becomes more effective in increasing the generative growth rate when done on seeds soaked for 15 minutes before being treated with magnetic fields.

**Conclusion**

Exposure to 0.2 mT magnetic field for 7'48 "on tomato seed infected by *Fusarium* sp. produce plants with the highest rate of flowering and the largest number of tomatoes.

Exposure to 0.2 mT magnetic field for 11'36 "in tomato seed infected by *Fusarium* sp. produces plants with the most number of flowers and the highest rate of fruiting.

Soaking tomato seeds for 15 minutes before the 0.2 mT magnetic field treatment gives a better effect to increase the rate of the plants to form flowers, fruits, and increase the number of fruits.

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**Comment [U8]:** numbering (1),(2) etc