

Effect of magnetic field and arbuscular mycorrhizal fungi on germination and growth of tomato (*Lycopersicon esculentum* Mill.)

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ABSTRACT. Agricultural technology innovation such as application of low magnetic field and arbuscular mycorrhizal fungi (AMF) could improve growth of some vegetable plants, such as tomatoes. The objectives of the research were to determine: (1) the effect of low magnetic field treatment on germination of tomato seeds, and (2) the combined effect of mycorrhiza and magnetic field treatments on growth of tomato plants. The first experiment was conducted in the laboratory to test the germination of magnetized and non-magnetized seeds on different growing mediums. The second experiment was conducted in a screenhouse using Randomised Blocked Design with the treatments of exposure of magnetic field (0 and 0.2 mT) and AMF (*Glomus* sp., *Gigaspora* sp. and Combination of *Glomus* sp. and *Gigaspora* sp.). Both treatments were applied as pre-sowing seed treatments. Results revealed the exposure of seeds to magnetic fields increased the seedling germination percentage, especially in the treatments combined with *Gigaspora* sp. (90%). Further measurement of plant heights showed that magnetized seeds consistently showed a higher plant height compared to non-magnet treatments. *Gigaspora* sp. which applied either as single or in mixture with *Glomus* spp. have shown better effect than *Gigaspora* sp. alone on the growth of tomatoes

Keywords: low magnetic field, mycorrhiza, tomato production

INTRODUCTION

Tomatoes (*Lycopersicon esculentum* Mill.) are known to be one of the most important vegetable in the world. There have been researches and trials done to increase the production of tomato plants. The use of biofertilizer is known to improve tomato yields, and arbuscular mycorrhiza (AM) fungi are one of the biofertilizers known to improve plant's growth and yield (Kamal et al., 2018).

One of increasing interest is the utilization of magnetic fields as one of the eco-friendly technologies in agriculture. Magnetic field effect is known to increase soil and plant properties by enhancing absorption and uptake of nutrients and photosynthetic activities (Efthimiadou et al., 2014).

The magnetized seeds have shown a higher percentage of seed germination and significantly enhanced yield of plants such as sorghum ("Author", 2019), cucumber (Ibrahim, 2015), sweet pepper (Ahamed et al., 2013), pea (Iqbal et al., 2012; Mridha and Nagarajan, 2014); and tomato (De Souza et al., 2005).

To understand the mechanism of seed stimulation by magnetic exposure, there is a need for a comprehensive study that identifies the process following improvement of germination of pre-sowing seeds and subsequent responses of the plant yield (Pietruszewski and Martinez, 2015). Magnetic field has been recognized for positive effects on some plant properties, however, information about the impact of magnetic field on the growth of tomatoes, especially when combined with arbuscular mycorrhizal fungi, is still limited. Shabani et al. (2019) applied *Diversispora versiformis* and magnetized P nutrient solution on basil (*Ocimum basilicum* L.) and found higher nutrient efficiency, photosynthetic parameter, and plant growth. Therefore, the present study was conducted to find out the impact of magnetic field and subsequent application of AM fungi as seed pre-treatments on the seed germination, seedling vigour, and vegetative growth of tomatoes. For practical purposes, this study tried to introduce eco-friendly technology which farmers in Indonesia could use.

MATERIAL AND METHODS

Two experiments were performed. The first experiment was conducted to evaluate the effect of magnetic field (MF) seed pre-treatment on seed germination of tomato cultivar Servo F1. The seeds were exposed to low MF of 0.2 mT for 15 minutes (Listiana, 2016). The magnetic treatments were applied using cylindrical coils from 150 turns of enameled copper wired (0.5 mm), connected in sinusoidal voltage (200 volts). Petri dish (9 cm diameter) filled with tomato seeds were put on the top of cylindrical coils to expose for the magnetic field treatment followed by germinating those on three different mediums ie. rolled germination paper, tissue paper, and 300 g of sterile zeolite (size 2 mm) placed in 10x20 cm plastic tray. The germination was measured every day until the 5th day. percentage of germination (%), height of seedlings (cm), dry weight of seedlings (g), and vigour index were recorded.

The second experiment was carried out in a greenhouse. The seeds were treated with different types of AM fungi species (without AM fungi; *Glomus* sp.; *Gigaspora* sp.; combination of both species) along with the magnetic field treatments (without and with 0.2 mT exposed for 15 minutes). AM fungi inoculum consisted of spores and colonized roots in zeolite medium. The density of AM fungi was 100 spores per pot. Magnetic field treatments for tomato seeds and AM fungi were as used in first experiment.

Tomatoes seeds and AM fungi were sown in plastic tray with zeolite accordingly. Three weeks old seedlings were then transplanted into polybag containing 500 g soils. The medium used was Andisols from Tanjung Sari, West Java, Indonesia with the properties as follows: pH H₂O 6.3; Organic Carbon 3.08 %; Total N 29.54%; Sand 8%; Silt 35%; and Clay 57%.

The tomatoes grown for six weeks, and number of leaves, plant height (cm), and chlorophyll content (CCI, apogee CCM-200 plus) were determined. SPSS-22 software was used to conduct statistical analysis (ANOVA) followed by DMRT (P<0.05).

RESULT AND DISCUSSION

The seedling of tomatoes treated with magnetic field was generally performed improved results than non-magnetic treatments. The seeds which treated with magnetic field showed higher percentage of germination in all germination mediums used at five days of germination. The germination of seeds using different mediums of germination showed maximum when they grow on zeolite medium (Table 1).

Table 1. Percentage of germination of tomato seeds on different medium at day 5 as affected by magnetic field

Treatments	Germination on Paper (%)	Germination on Tissue Paper (%)	Germination on zeolite (%)
Without magnet	69	52	75
With magnet	77	77	85

Good seed quality exhibit high vigour which can be shown from its high percentage of germination, rapid germination and form normal seedlings. The magnetic treatment was also showed improvements in dry weight of seedlings, length of seedlings, and vigour index (Table 2). These beneficial effects of magnetic field treatment coincided with other experiments either used same plant (De Souza *et al.*, 2005) or different plants (Iqbal *et al.*, 2012; Ahamed *et al.*, 2013; Mridha and Nagarajan, 2014).

Table 2. Dry weight, length and vigour index of tomato seeds grown on germination paper at day 5 as affected by magnetic field

Treatments	Seedlings dry weight (g)	Seedlings length (cm)	Vigour Index
Without magnet	1.41	6.49	447,9
With magnet	1.52	7.15	550,5

Further experiment to clarify the effect of AM fungi inoculum and magnetic field on tomato seedlings showed vary in percentage of germination (Table 3). Zeolite medium in plastic tray was chosen in this experiment based on results from the first experiment. It was shown that magnetic treatment produces higher percentage of germination only when *Gigaspora* sp. presents either single or in mixture with *Glomus* sp. There was no effect of magnetic treatment in germination at *Glomus* sp. and even when no AM fungi used, the non-magnetic treatment resulted in higher percentage of germination (Table 3).

Table 3. The germination percentage of tomato seeds grown on zeolite medium inoculated with non-magnetic and magnetic mycorrhizal fungi at day 5

Treatments	Without mycorrhiza	With mycorrhiza (<i>Glomus</i>)	With mycorrhiza (<i>Gigaspora</i>)	With mycorrhiza (<i>Glomus</i> and <i>Gigaspora</i>)
Without magnet	75	75	85	85
With magnet	70	75	90	90

Results from second experiment showed that in general, magnetic treatment gave higher plant height compared to non-magnetic treatment at weeks 4 to 6, while AMF treatments were different for each type (Table 4). *Gigaspora* sp. consistently gave highest plant height when treated with magnetic field compared to *Glomus* sp. or mixture inoculants and control especially at week 4 and 5. However, at 6 weeks, both *Glomus* sp. and *Gigaspora* sp. gave highest height and no significant differences between the two AMF genus.

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Table 6. Number of leaves per tomato plants grown on Andisols at 4, 5, and 6 weeks after planting as affected by magnetic field seeds and mycorrhizal fungi

Mycorrhizal fungi	Week 4		Week 5		Week 6	
	non magnet	magnet 0.2 mT	non magnet	magnet 0.2 mT	non magnet	magnet 0.2 mT
without mycorrhiza	18.3a A	19.6a A	41.7a A	60.3b B	77.0ab A	83.3ab A
<i>Glomus</i>	22.3b A	21.3ab A	60.0b A	60.0b A	82.0ab A	81.3ab A
<i>Gigaspora</i>	25.3c B	23.3c A	67.6c A	68.0c A	90.0b A	91.0b A
<i>Glomus + Gigaspora</i>	18.7a A	22.7bc B	66.0c B	48.7a A	75.7a A	72.0a A

Similar letters in columns (lower case) and rows (capital) correspond to statistically similar effects ($p < 0.05$) according to Duncan Multiple Range Test.

Measurements on the growth of tomato seedlings exposed with magnetic field in screenhouse provided superior results on height of plants, chlorophyll content and number of leaves. Application of AMF especially *Gigaspora* sp. exhibited better response on the parameters measured in compared to the control plants.

The effect of a magnetic field treatment on the germination of seeds and following growth of tomato plants in these experiments supported other findings (De Souza *et al.*, 2005; Rochalska *et al.*, 2005; Racuciu *et al.*, 2008). This experiment in general indicated that seeds treated with magnetic field performed higher quality compared to control. Arbuscular mycorrhizal fungi also showed effect on the growth of tomato plants when treated with magnetic field and some researchers found the similar results when tomato plants inoculated with *Glomus* sp. (Hadianur, 2016) and *Gigaspora* sp. (Kuswandi, 2015).

The process of increased of biological activity by low magnetic field treatment need to be justified through comprehensive studies. Ahamed *et al.* (2013) suggested that acceleration of seed germination, activate proteins formation and root development, could resulted from interaction of ionic current in the cell membranes of plant embryo. Theses influences of magnetic field on cell membranes could also accelerate respiration and other energetic metabolisms (Racuciu *et al.*, 2008). Furthermore, an auxin-like effect of the magnetic field on seeds germination (magneto-tropism) has been proposed by Maffei (2014). Enhancement in chlorophylls level, soluble sugars, total amylase activity, and K^+/Na^+ ratio were also stated by Ibrahim (2015). This process in turn will plays significant regulation in assimilation of the nutrients available for vegetative growth of the plants. In this experiment, it was found that the chlorophylls level increased with magnetic and AMF treatments. Mycorrhiza has been known to improve nutrient availability, especially Phosphorus (“Author”, 2016).

The soils used in the experiment have low available P, hence the presence of AM fungi improved the nutrients available for plants. Shabani *et al.* (2019) found that application of mycorrhiza *Diversispora versiformis* and magnetized P nutrient solution increased nutrient efficiency, photosynthetic parameter and growth of *Ocimum basilicum* L.

Despite findings of beneficial effects from pre-sowing magnetic treatments of seeds on plant growth are extending, accurate explanation and further investigations are importantly needed to be continue, especially in elucidating combined effect of magnetised seed and arbuscular mycorrhizal fungi on the growth, yield and quality of plants.

CONCLUSION

Application of low magnetic exposure 0.2 mT for 15 minutes on tomato seeds improved the percentage of germination, vigour index, growth of seedlings, height of plants, number of leaves, and chlorophyll content. Arbuscular mycorrhizal fungi especially *Gigaspora* sp. showed better effect on the growth of tomato plants when combined with magnetic-treated plants.

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