Enhanced seedling germination and growth of sorghum through pre-sowing seed magnetic field treatment

A Nurbaity¹, A Nuraini², E Agustine³, M A Solihin¹, A Setiawan¹ and A Mbusango¹

¹ Department of Soil Science, Faculty of Agriculture, Universitas Padjadjaran
² Department of Agronomy, Faculty of Agriculture, Universitas Padjadjaran
³ Department of Physics, Faculty of Math and Natural Sciences, Universitas Padjadjaran
Jl. Raya Bandung-Sumedang km. 21, Jatinangor, West Java, Indonesia, 45363

Email: a.nurbaity@unpad.ac.id

Abstract. One of the emerging topics in agriculture is application of biophysical method such as the use of magnetic field (MF) to treat seeds for improved plants production. An experiment has been carried out to determine the effect of MF exposure on sorghum seeds and its subsequent growth in soil. The treatments were different strength of MF (control, 1 mT, 6 mT) and exposure duration (5, 10, 15 min). The magnetically treated seeds showed higher seed germination percentage, vigour index, seed germination index, seedling growth and chlorophyll content compared to non-magnetically treated seeds. The best duration of MF exposure was 15 minutes, either at MF strength 1 mT or 6 mT. It is suggested that pre-sowing MF treatment has the potential to improve crop productivity through the enhancement of germination, seedling emergence, and growth of plants.

1. Introduction
Research on biophysical methods on plant production provides an interdisciplinary approach to assist in improving crop productivity [1]. The use of magnetic field as a presowing treatment has been adopted by researchers as a noninvasive and environmental friendly technique [2]. Earth’s Magnetic Field (Geomagnetic, GMF) which is a natural component of the environment, is steadily acting on living systems, and is known to influence many biological processes [3].

The magnetically pre-sowing treated seeds have been showed by several workers as to have higher germination percentage, seedling growth and considerably improved yield of some plants such as tomato [4], pea [3], [5]; sweet pepper [6] and cucumber [7]. Because of the insufficient understanding of the biological action of MFs and its mechanism, researches needed to determine the effect of pre-sowing MF (especially low MF with intensities) on the development of different plants species [8].

Magnetic energy has been considered to have ability to improve the properties of soil and plant growth through better absorption and assimilation of nutrients by plants and photosynthetic activities [2]. An auxin-like effect of the magnetic field (magneto tropism) was suggested as main explanation of higher germinating seeds and ripening of some vegetables [8]. Another explanation would be as the result of enzymatic stimulation [4] and bioenergetics structural excitement and
In the case of pre-sowing stimulation of seeds, it is important to identify a physical value which can serve for the determination of the effect of MF on the process of germination and subsequently on the yields [9]. Magnetic field dose (strength and exposure duration) has been found to have strong effect on plant properties. Various treatments with these combinations resulted in various responses, depending on many factors including plant factors.

Sorghum (Sorghum bicolor) is one of important part of cropping systems of the world. Besides for food purposes, this plant has been used as a host plant in the production of arbuscular mycorrhizal inoculum as biofertilizer [10]. There is very limited information about effect of magnetic field on the germination of sorghum seeds and its consecutive growth when transferred to soil. Hence the aim of this study was to determine the effect of magnetic field exposure (strength and duration) on seed germination, vigor index, seed germination index, and vegetative growth and chlorophyll content of sorghum cultivated under soil conditions.

2. Materials and Methods

The sorghum seeds cultivar Kawali were obtained from Agronomy Laboratory Faculty of Agriculture Universitas Padjadjaran. The seeds of healthy, uniform size and shape were exposed to controlled magnetic field in the Department of Physics and sown in a greenhouse at Bandung, West Java.

The experiment was laid out in completely randomized design with seven treatments under three replications. The presowing magnetic treatments were controlled using magnetic device in funnel shaped that have magnetic field strength 1 and 6 milli Tesla (mT). Each magnetic field strength’s seeds were exposed for different duration which were 5, 10, and 15 minutes. Seeds were exposed to the MF in a cylindrical plastic sample holder for durations as arranged in treatment design.

The germination was determined by using paper methods as described by Mridha and Nagarajan [5]. Ninety seeds in three replications (30 in each) were placed between two layers of moist germination papers (20x25 cm). The papers were rolled and wrapped in a sheet of plastic to reduce evaporation and placed in an incubator at 25°C in upright position. The rate of germination was checked daily until no more seed germinated and the percentage of seeds germinated was calculated at 3rd day. Germination (%), shoot length (cm), root length (cm), shoot and root dry weight (g), vigour index, and Seed Germination Index (SGI) were calculated. Seedling vigour and SGI was calculated as:

\[
\text{Vigour index I} = \text{Germination} \times \text{Seedling Length (Root + Shoot)}
\]

\[
\text{Seed Germination Index (SGI)} = \left(\frac{\text{No. of germinated seedlings/day of the first count}}{\text{No. of germinated seedlings/day of the final count}}\right) + \ldots + \frac{\text{No. of germinated seedlings/day of the final count}}{\text{No. of germinated seedlings/day of the final count}}
\]

After germination, magnetically exposed and unexposed seeds were sown in plastic pots filled with 750 g soils and grown in a greenhouse for three weeks. The treatments were arranged in a complete randomized design with three replications. The medium used was soils obtained from Lembang West Java (Andisols). Physico-chemical analysis of Andisols were: pH H2O 5.3; Organic Carbon 3.6 %; Total N 0.5%; Available P 131.1 ppm; Available K 4.2 (mg/100 g); CEC 40.7 cmol.kg-1; Base Saturation 30.9%; Sand 22%; Silt 50%; Clay 28%; and soil texture was clay loam.

The growth parameters which were plant height (cm), number of leaves, shoot diameter (cm), shoot fresh weight (g) and chlorophyll content (CCI) were determined after three weeks. Chlorophyll content was measured using chlorophyll meter (apogee CCM-200 plus). Statistical analysis (one-way ANOVA) of the parameters followed by LSD test (P<0.05) was done using SPSS-22 software.
3. Results and Discussion
The seedling of sorghum was observed as compared to control. Pre-sowing magnetic treated seeds showed improvements in vigour index, seed germination index, shoot length, root length, and seedling dry weight (Table 1 & 2). For percentage of germination, maximum seed germination reached when the seeds exposed to MF for 15 minutes, irrespective of the field strength (Table 1). Seed germination index was observed higher in most MF treatments.

Table 1. Effect of pre-sowing magnetic field (MF) strength combined with different exposure time on germination, vigour index and seed germination index of sorghum.

| Treatments (Magnetic-Time) | % Germination | Vigour Index | Seed Germination Index |
|----------------------------|---------------|--------------|------------------------|
| Control                    | 96.7 a        | 944.0 a      | 27.7 a                 |
| 1 mT-5 min                 | 96.7 a        | 1143.1 d     | 29.0 b                 |
| 1 mT-10 min                | 98.8 c        | 1029.8 b     | 28.8 b                 |
| 1 mT-15 min                | 100.0 d       | 1174.7 d     | 29.3 b                 |
| 6 mT-5 min                 | 96.7 a        | 1161.1 cd    | 28.0 ab                |
| 6 mT-10 min                | 97.5 b        | 1141.5 c     | 29.0 b                 |
| 6 mT-15 min                | 99.5 cd       | 1168.1 d     | 29.1 b                 |

Means in the same column with the same letters are not significantly different according to LSD 5% test

Seedling growth and dry weight of pre-sowing magnetic treated seeds were higher than the control (Table 2). Seedling shoot length, root length and shoot dry weight were higher when MF applied at 6 mT, however there were no differences between 1 mT and 6 mT on root dry weight. In general, results showed that the exposure of the seeds of sorghum 6 mT for 15 minutes was the best among different combinations of magnetic field and exposure time.

Table 2. Effect of pre-sowing magnetic field (MF) strength combined with different exposure time on sorghum seedling shoot length, root length, shoot dry weight and root dry weight at 3 days of germination.

| Treatments (Magnetic-Time) | Shoot Length (cm) | Root Length (cm) | Shoot Dry Weight (g) | Root Dry Weight (g) |
|----------------------------|-------------------|------------------|----------------------|---------------------|
| Control                    | 3.36 a            | 6.40 a           | 0.87 a               | 0.32 a              |
| 1 mT-5 min                 | 3.89 b            | 7.21 c           | 0.92 bc              | 0.37 b              |
| 1 mT-10 min                | 3.68 b            | 6.98 b           | 0.90 b               | 0.35 b              |
| 1 mT-15 min                | 4.26 cd           | 7.86 d           | 1.03 d               | 0.39 b              |
| 6 mT-5 min                 | 4.17 c            | 7.91 d           | 1.02 d               | 0.35 b              |
| 6 mT-10 min                | 3.89 b            | 7.81 d           | 0.95 c               | 0.36 b              |
| 6 mT-15 min                | 4.46 d            | 7.81 d           | 1.03 d               | 0.35 b              |

Means in the same column with the same letters are not significantly different according to LSD 5% test

The growth of sorghum plant from magnetic treated seeds grown under greenhouse condition were significantly gave higher results on plant height, shoot diameter, shoot fresh weight, chlorophyll content. However, MF strength and duration only gave higher number of leaves when seeds treated with both MF 1 mT for 15 minutes (Table 3).

The highest values in plant height were measured in 1 mT-15 min treatment, but it has no differences with other 6 mT at all duration of exposure. Shoot diameter showed significant difference when seeds exposed to MF at all strength and duration combinations compared to control.
Table 3. Effect of pre-sowing magnetic field (MF) strength combined with different exposure time on growth of sorghum plants cultivated on Andisols at 3 weeks after planting.

| Treatments (Magnetic-Time) | Plant Height (cm) | Number of leaves per plant | Shoot diameter (mm) | Shoot fresh weight (g per plant) | Chlorophyll Content (CCI) |
|---------------------------|------------------|---------------------------|--------------------|---------------------------------|-------------------------|
| Control                   | 54.0 a           | 18.0 a                    | 4.2 a              | 7.50 a                          | 25.0 a                  |
| 1 mT-5 min                | 67.0 b           | 18.7 ab                   | 6.2 b              | 10.01 bc                        | 27.3 b                  |
| 1 mT-10 min               | 64.0 b           | 18.0 a                    | 5.9 b              | 9.62 b                          | 29.4 bc                  |
| 1 mT-15 min               | 75.3 c           | 20.3 c                    | 6.5 b              | 13.71 d                         | 29.7 bc                  |
| 6 mT-5 min                | 70.0 bc          | 18.0 a                    | 5.6 b              | 10.60 bc                        | 28.3 b                  |
| 6 mT-10 min               | 69.8 bc          | 18.3 a                    | 6.5 b              | 10.96 c                         | 31.4 cd                  |
| 6 mT-15 min               | 68.8 bc          | 19.3 b                    | 5.9 b              | 12.14 cd                        | 33.2 d                  |

Means in the same column with the same letters are not significantly different according to LSD 5% test

Shoot fresh weight was found higher for MF 1 mT-15 min, but has no difference with 6 mT-15 minutes. Control treatment had significantly lower shoot fresh weight than all magnetic treated plants. Furthermore, the effect of MF treatment on chlorophyll was also found significantly different between control and MF treated plants, where the highest reached at 6 mT for the duration of exposure 10 and 15 minutes.

The influence of a low frequency magnetic field treatment on the germination of seeds and subsequent growth of sorghum plants in this experiment concurred with many other works on similar area but with different plants [1, 4-7]. Requirement of good seed quality means seeds of the highest vigour which can be indicated from its germination percentage (100%), germinate quickly and develop normal seedlings. This experiment showed that seeds treated with MF performed better quality compared to non-magnetic treated seeds (control). The duration of exposure to the MF also affect the seeds germination and following growth. In general, the more the time was applied, the better the seeds quality in term of percentage of germination, vigour index and seed germination index.

The mechanism of improvement of the seeds by activity of magnetic field is still need to be elaborated. It was suggested that MF accelerated seed germination, seedling growth and activates proteins formation and root development, which may be due to the interaction with ionic current in the plant embryo cell membranes [6] which play important role in regulating the assimilation of the nutrients need for its function. The MF influences mostly cell membranes which can protect cell organelles surrounded with membranes, and also known to stimulate seed respiration and their energetic metabolism [1]. Another positive effect of MF appeared to be related to the enhancement in total amylase activity, soluble sugars, RNA, K+/Na+ ratio and chlorophylls level [7]. In this experiment, it was clear that the chlorophylls level increased as increase of MF strength and duration (6 mT at 10 and 15 minutes).

The enhancement of plant vegetative parameters derived from the MF treated seeds comprising plant height, number of leaves, shoot diameter and shoot dry weight may also due to the increase in the concentration of photosynthetic pigments such as chlorophyll that provided greater amount of assimilates available for vegetative growth. It was also proposed that there is an auxin-like effect of the MF on germinating seeds which is known as magnetotropism [9]. Nevertheless, the effects of magnetic exposure on plant growth still require accurate explanation and further investigations.

4. Conclusion
The present results indicate that magnetically treated seeds showed higher seed germination percentage, vigour index, seed germination index, seedling growth, plant height, number of leaves, shoot diameter, shoot fresh weight, and chlorophyll content compared with non-magnetically treated seeds. The treatment of 1 mT and 6 mT with the expose duration 15 minutes, gave the best results.
5. **Acknowledgement**

The project was supported by a research grant from The Ministry of Research, Technology and Higher Education, Indonesia (PTUPT 2019).

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