EFFECTS ON SEEDLINGS OF PRE-SOWING TREATED TOMATO SEEDS WITH STATIC MAGNETIC FIELD

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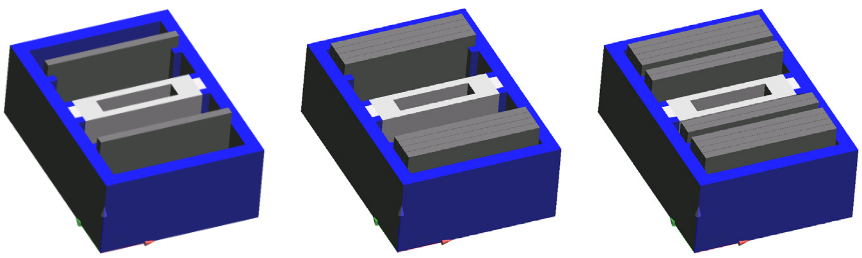
Abstract
Pre-sowing treatment of seeds with static magnetic field has been reported in the literature as a means of enhancing plant development. In the present work we have designed and constructed a setup for exposing vegetable seeds of tomato to static magnetic field (SMF). The results have shown that tomato seedlings significantly benefit from the pre-sowing treatment with magnetic flux density of 45 mT. The time of treatment that leads to improved growth is 90 min.

INTRODUCTION
Tomato is known as one of the most important vegetable crops that could be cultivated either in the open field or in the greenhouse [1], where transplants are the only choice for the grower. In the current study we investigate the effects of SMF on the seeds of the tomato. Although the effect of magnetic field on germination parameters has been studied in some plants [2]-[5], information on tomato is relatively scarce with limited data [6], brief exposure time [7] or the use of pulsed magnetic field [8]. The seed exposure to static magnetic field was performed with the use of permanent magnets in the present work. This type of exposure setup is not used very often in the literature [5]. In most cases the seeds are exposed to a magnetic field generated by electromagnets [3]. However, the spectral content of the electric current in the coil is rarely reported in such a setup [9], neither is the potential temperature rise in the coil due to ohmic losses [10]. Improvement of tomato seeds germination percentage or plant early growth rate is very important for the seedlings industry and of high value for a sustainable horticultural economy, especially in the Mediterranean area.

MATERIALS AND METHODS
Exposure set-up
The exposure setup was enclosed inside a Faraday cage, made of a metallic wireframe, in order to minimize the electromagnetic radiation of external sources that reaches the seeds. The magnet boxes were mounted on a non-metallic (wooden) base inside the Faraday cage and were equally spaced from each other. The magnetic field was generated by use of rectangular sintered neodymium ($Nd_2Fe_{14}B$) magnets with a permanent magnetic induction of 1.33 Tesla. The magnets were placed inside a plastic exposure box in three different configurations (Fig. 1), generating the required magnetic flux density values. The plastic boxes were fabricated using a 3D printer and polylactic acid material.



(a) (b) (c)

Figure 1: Exposure box configurations: (a) M1 configuration (2 magnets - 45 mT), (b) M2 configuration (8 magnets - 150 mT) and (c) M3 configuration (12 magnets - 300 mT).

Experimental design

Certified seeds of tomato (cv. 'Ace 55 VF') were used for the experiment. Seeds were exposed to three different magnetic field flux densities (M1, M2, M3) for four different time periods (ET1: 30 min, ET2: 60 min, ET3: 90 min, ET4: 120 min). The experiment included a repeated (four times) exposure of 25 seeds at each magnetic flux density and exposure time, plus a control exposure group. All treatments in the experiments were performed under similar environmental (temperature 21.80 ± 0.55 °C; relative humidity (RH) 47.06 ± 12.36%). Following exposure the four replicates of 25 seeds were sown on moistened filter paper disks in Petri dishes and kept in the dark in an incubator at 21 °C in an upright position and for seven days.

Investigated endpoints

Germination parameters

The daily number of germinated seeds was recorded with the criterion of germination to be was the visible radicle protrusion. Speed of germination was calculated according to Maguire (1962) as

$$Speed\ of\ germination = \sum \left(\frac{n}{t}\right) \quad (1)$$

where n is the number of seeds newly germinating at time t and t is days after sowing.

Growth parameters

The last day of experiment in all seedlings of each replicate root length, shoot length as well as total seedling length were determined. Subsequently, the fresh weight of the above seedlings was measured and then the seedlings were left to dry in an oven at 72 °C for 48 h for dry weight determination. Seedling vigour was calculated according to Abdul-Baki and Anderson (1973) as

$$Vigour\ (Index)\ I = Germination\ percentage\ \times Seedling\ length \quad (2)$$

$$Vigour\ (Index)\ II = Germination\ percentage\ \times Seedling\ dry\ weight \quad (3)$$

Statistical analysis

The control average value of each parameter was considered as 100 and all raw data were accordingly expressed. An analysis of variance was performed assuming the magnetic field and exposure time as variation factors. Data were analyzed by using a completely randomized design with four replications of 25 seeds each and the means were compared by the Duncan's multiple range test at the 0.05 level with MSTAT version 4.00/EM (Michigan State University).

RESULTS

Statistical analysis for tomato seeds showed that magnetic field had a significant effect on germination, speed of germination, seedling fresh weight and Vigour I, while exposure time did not affect any of the determined parameters (Table 1). However, magnetic field and exposure time interaction had a significant impact on root and seedling length, seedling fresh weight and Vigour I (Table 1).

From the mean comparison of the interaction of magnetic field and exposure time significantly positive effect only for seedling dry weight was observed at 150 mT and 90 min (Fig. 2c). Additionally, root length, seedling length and Vigour I was higher from 2.5% to 9.5% for exposure at 45 mT for 60 and 90 min compared to control (Fig. 2a, b, d). However, there was a significant reduction compared to control for some treatments and parameters, such as in root length when seeds were exposed to 300 mT for 60 min (Fig. 2a), seedling dry weight for exposure at 45 mT for 30 min (Fig. 2c) and Vigour I for exposure at 45 mT for 30 min (Fig. 2d).

Table 1. Analysis of variance for germination, speed of germination, root length, shoot length, seedling length, seedling fresh weight, seedling dry weight, Vigour index I and Vigour index II of tomato seeds treated with different doses of magnetic field (0, 45, 150 and 300 mT) and various exposure times (0, 30, 60, 90 and 120 min) before sowing.

Source of variance	DF[Z]	Germination	Speed of germination	Root length	Shoot length	Seedling length	Seedling f. w.	Seedling d. w.	Vigour I	Vigour II
Magnetic field (A)	3	***	***	NS	NS	NS	***	NS	***	NS
Exposure time (B)	4	NS	NS	NS	NS	NS	NS	NS	NS	NS
A x B	12	NS	NS	*	NS	*	***	NS	***	NS
Error	60									

[Z] Degree of Freedom
*, **, *** Significant effect at the 0.05, 0.01 and 0.001 level, respectively
NS not significant

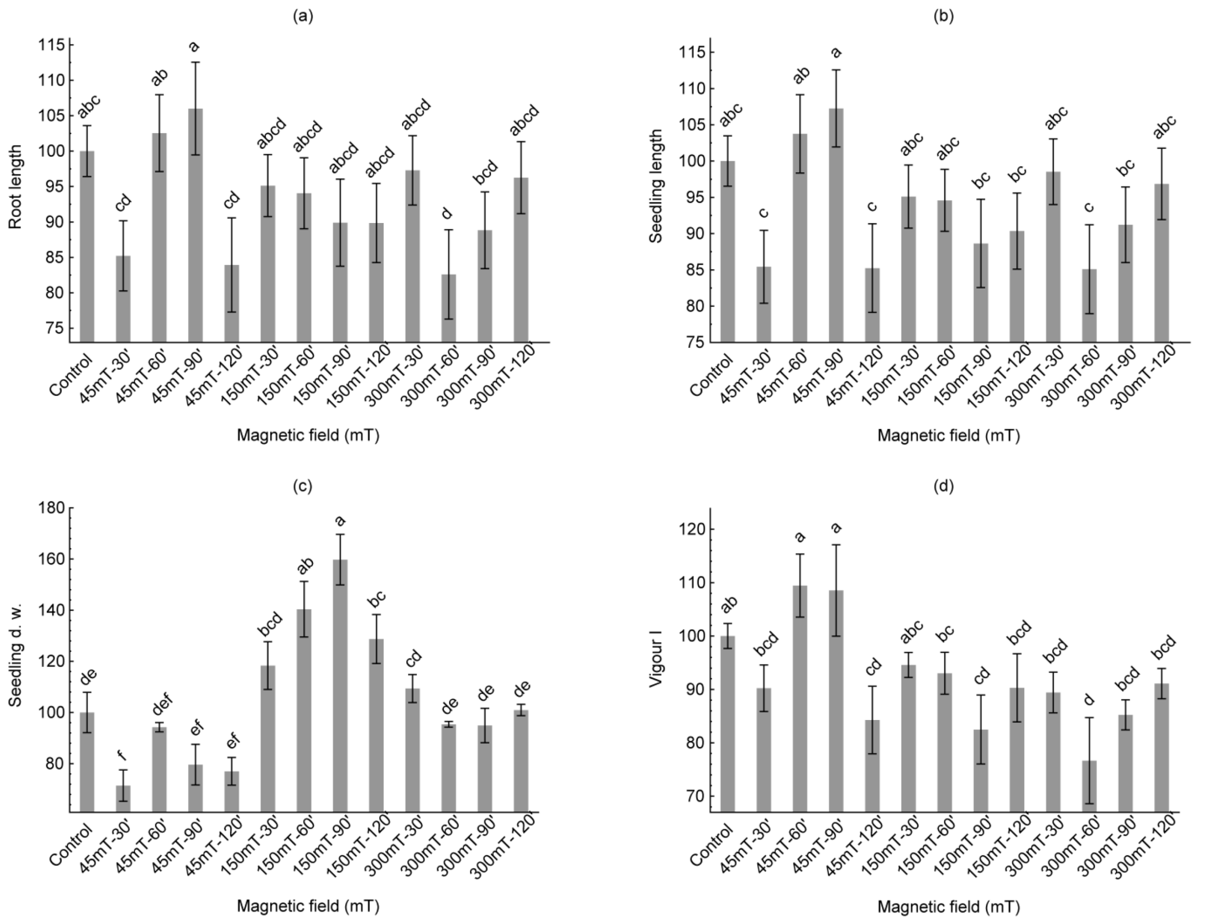


Figure 2. Germination characteristics of tomato seeds exposed to different levels of magnetic field for various exposure times before sowing. Different letters at each column denote significant differences between means (Duncan's multiple ran ge test, $P < 0.05$).

CONCLUSIONS

In the current work we have presented the design and the construction of an exposure setup that allows simultaneous treatment of tomato seeds to SMFs, including a control-exposed group. The results have shown that tomato seedlings significantly benefit from the pre-sowing treatment with magnetic flux density of 45 mT. The time of treatment that leads to improved growth is 90 min.

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