Effect of Stationary Magnetic Fields on Medicinal Plants

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In recent decades, physical techniques based on the application of magnetic fields (MF) have been developed in the agricultural sector with favorable results in plant germination and growth. The main objective of this study is to determine the effects of magnetic treatment on the germination Salvia officinalis L. and Calendula officinalis L. seeds. Groups of seeds were exposed to MF of 125 mT for different times, other groups of seeds were subjected to magnetic pretreatment and others were used as control. Germination tests were performed under laboratory conditions. The parameters were: germination time of the first seed (T1), time for reaching 10 -75% of germination (T10, T25, T50 and T75), mean germination time (MGT) and number of germinated seeds (Gmax), provided by Seedcalculator software. The parameters recorded for both species with treatment and pretreatment were lower than the value of the corresponding control, chronic exposure at 125 mT provided the highest results; MGT was significantly reduced compared to controls. (T1-T50) were also significantly reduced.

Keywords: Magnetic treatment, seed germination, Bioelectromagnetism, *Salvia officinalis* L.,*Calendula officinalis*

1 Introduction

In Mediterranean countries there is a great development of medicinal, spice and aromatic plant crops due to their high added value as a consequence, among other reasons, of the reappearance of Phytotherapy. Recently, magnetic seed treatment has become very popular in the agricultural sector, the number of articles in Bioelectromagnetism focusing on the investigation of the magneto-sensitivity of living organisms has increased in the last decades. Seed germination and plant growth has become an attractive model for studying the biological effects of magnetic fields, in addition to the geomagnetic field [1]. This objective has a practical application in agricultural science: to obtain early growth of medical plants. Studies with rice and onion showed that magnetic pretreatment improved germination and vigor of seedlings from low viability seeds [2]. According to these studies, pretreatment with magnetic field had a positive effect on cucumber seedlings, stimulating the growth and development of the seedlings and their roots [3]. Higher germination percentage and germination rate of cereal seeds exposed to magnetic fields have been obtained; higher contents of albumin, gluten and starch were obtained in wheat seeds exposed to magnetic field [4,5]. A possible mechanism associated with magnetism has been proposed to accelerate tomato maturation [6].

"Calendula" and "salvia" are used as a condiment in food, but they also have some medicinal properties due to their essence content. They are cultivated for the food, herbal, cosmetic and liquor industries [7].

In previous studies, the authors found that magnetic treatment at 125 mT and 250 mT produced bio stimulation in the early growth stages and increased germination rate of rice, wheat and barley seeds [8-11]. The researchers studied the effect of corn seed germination and concluded that the time required for germination recorded for each magnetic treatment was less than the control values, so the germination rate of treated seeds was higher than that of untreated seeds. Growth data measured 7 and 10 days after sowing corroborated the effect observed in the germination tests. Significant differences were obtained between the length and weight of corn seedlings subjected to a magnetic field of 125 mT and 250 mT for different times versus the control [12]. A positive response has been observed in grasses; exposure to the magnetic field provides earlier germination, increases the number of germinated seeds, reduces germination velocity, and increases stem and root length of Festuca arundinacea Schreb. and seeds of Lolium perenne L. [13]. In addition, exposure to 125 mT and 250 mT MF has been studied in pea and lentil seeds [14], growth parameters (total and stem weight, total and stem length) measured on days 7 and 14 increased, and increased root development was observed.

The main objective of this study is to evaluate the effect of magnetic treatment on the germination of seeds of *Salvia officinalis* L. and *Calendula officinalis* L., by exposing seeds to a stationary magnetic field of 125 mT for different periods of time and pre-germinative exposure. This objective has a practical application in agricultural science: to obtain early growth of medicinal plants.

2 Material and Methods

Germination tests were performed to study the effect of seed exposure to a stationary magnetic field of 125 mT. The test was carried out under laboratory conditions with natural light and average temperature of 20 ± 2°C for *Salvia officinalis* L. and 25 ± 2°C for *Calendula officinalis* L. Seeds of uniform size and shape without visible defects and malformations were selected. Groups of salvia seeds were exposed to magnetic field varying the exposure time (A1-A5) and another group of seeds was subjected to magnetic pretreatment (P1) for 24 hours prior to sowing. The CM was generated by 125 mT magnets. The geometrical characteristics of the cylindrical magnet are external diameter of 7.5 cm, internal diameter of 3 cm and height of 1 cm. Analogous rings, made of the same material, but without magnetic induction, were used as control. Exposure times were: 10 min (A1), 20 min (A2), 1 h (A3), 24 h (A4) or chronic exposure (A5). An experimental design with four replicates (n=4) was carried out, with 25 seeds in each. Thus, groups of 100 seeds were subjected to each magnetic treatment and analogous groups were used as controls. Groups of *Calendula officinalis* L. seeds were exposed to 125 mT for 24 h (A4) or chronic exposure (A5) and compared with the control (C1), another group of seeds was subjected to magnetic pretreatment (P1) for 24 h. Prior to sowing and compared with the control (C2).

Germination tests were performed according to the guidelines issued by the International Seeds Testing Association [15] with some minor modifications. The seeds from each replicate were placed in Petri dishes on filter papers soaked with 12 ml of distilled water. The seeds were placed around a circular line; thus, all seeds were subjected to the same magnetic field intensity, and the Petri dish was placed onto the magnet. For dose A5, Petri dishes were placed over the magnets for the entire experimental time. For the other doses, the Petri dishes were placed on the magnets for the corresponding time 10 min, 20 min, 1 h and 24 h (A1-A4) or magnetic pretreatment before seeding (P1). Subsequently, they were placed on a ring without magnetic induction. The control group of Petri dishes was placed in blind rings (without magnetic induction) from the beginning of the experiment.

The number of germinated seeds for each treatment was recorded three times a day during the test period. Seeds were considered germinated when their radicle was at least 2 mm long. The germination parameters evaluated were elapsed time to germination of the first seed (T1), germination time of 10, 25, 50 and 75 % (T10, T25, T50 and T75), number of germinated seeds (Gmax), and mean germination time (MGT) and correlation coefficient (R2), all provided by the Seedcalculator software package developed for seed germination data analysis by Plant Research International.

2.1 Statistical Analysis

Germination data obtained for the magnetic treatments were compared using the t-Student value and significant differences between each treatment and the control were calculated using Seedcalculator software. Statistical analysis of growth data was performed using SPSS 11.0 software for Windows. Results were subjected to analysis of variance (ANOVA) to detect differences between mean parameters. Means were compared using Tukey´s test (multiple comparisons) and Dunnet´s test to detect significant differences between parameters of treated and control plants.

3 Results and Discussion

Salvia officinalis

The germination parameters obtained for *salvia* seeds are shown in Table 1. The results show that the germination percentage (G_{max}) was higher for the magnetically treated seeds. Parameters T1 and T10 were significantly reduced for all magnetic treatments, implying that the onset of germination occurred before. The T1 value of seeds not exposed to magnetic field was 72.96 h while this value for A4, A5 and P1 were 23.04, 22.56 and 25.20 h, respectively. Significant reductions were also obtained for the parameter T25. The mean germination time (MGT) of salvia seeds was significantly reduced when the seeds were exposed to FM. The highest differences between treated and control seeds were obtained when seeds were treated for 24 h and chronically exposed (81.84 h for A4, 75.60 h for A5 vs. 95.28 h for the control). In addition, the other parameters evaluated, MGT, T_{50} and T_{75}, were also reduced. Consequently, the percentage and germination rate of salvia seeds exposed to a stationary magnetic field of 125 mT were increased.

Table 1: Salvia germination parameters

Dose	R^2	G_{max}(%)	Time (hour) $\bar{x} \pm SEM$					
			T_1	T_{10}	T_{25}	T_{50}	T_{75}	MGT
C	0.98	47±4.4	72.9±0.7	78.9±0.7	83±0.7	88.8±8	97.4±1.9	95.3±2.1
A1	0.96	60±4.3	34.1±4.3^b	57.4±4.3^a	73±3.2	91±4.3	110±5.5^a	92±2.2
A2	0.96	63±4.4^b	27.3±1.4^d	48.2±2.4^d	62.6±2.9^d	79.7±3.3^b	97.7±4.1	80.6±3.3^b
A3	0.94	56±4.3	25.4±3.4^b	46.8±1.1^b	61.7±5.9^b	79±4.1^a	98±1.2	79.7±3.6^b
A4	0.97	69±1.9^b	23±2.9^d	44.2±2.6^d	59.8±2.1^d	79.2±2.4^b	101±4.5	81.8±2.9^c
A5	0.98	58±5	22.6±5.2^d	41.3±2.8^d	55±2.4^d	72.5±4.3^b	92.6±5.5	75.6±2.6^c
P1	0.94	65±5^a	25.2±5.1^b	47±3.3^b	62.4±6.1^b	80.6±4.5	99.8±2.2	81.6±5.8^a

Figures 1a, b and c show the cumulative germination curves of *Salvia officinalis* L. for the applied magnetics treatments and control. In the graphs, it can be observed that, in all cases, the germination curve of the control is below the curves of the treated seeds, which implies that the germination rate of the control is lower than that corresponding to all the magnetic doses. The germination percentage of the control seeds is always below that corresponding to all magnetic treatments.

Germination parameters of *Salvia officinalis* L. seeds exposed to 125 mT, expressed as mean (±) standard error. Exposure times: 10 min (A1), 20 min (A2), 1 h (A3), 24 h (A4), chronic exposure (A5), pretreatment (P1) and control (C). G_{max}: number of germinated seeds (%); MGT: Mean Germination Time; T_1, T_{10}, T_{25}, T_{50}, T_{75}: time required to obtain 1, 10, 25, 50 and 75% of germinated seeds expressed in hours. R2: Correlation coefficient. Superscripts indicate differences vs. control: ^{d}(p<0.001): extremely significant; ^{c}(0.001<p<0.01) very significant; ^{b}(0.01<p<0.05); significant; ^{a}(0.05<p<0.1): differences.

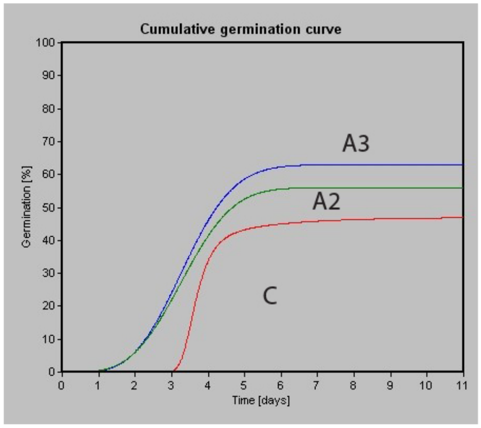

Figure 1a. Germination curves of *Salvia officinalis* L. seeds exposed to 125 mT for 20 minutes (A2), 1 hour (A3) and control (C).
......
A3
.....A2
.......C

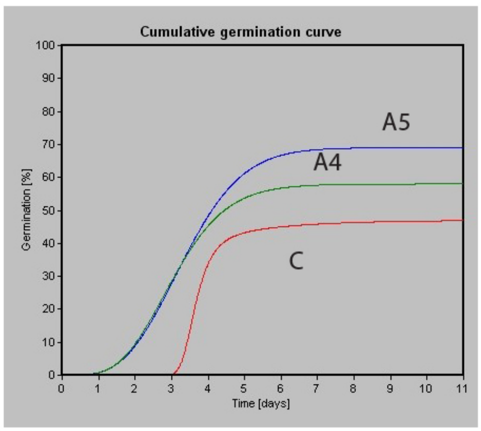

Figure 1b. Germination curves of *Salvia officinalis* L. seeds exposed to 125 mT for 24 h (A4), chronic exposure (A5) and control (C).

A5
A4
C

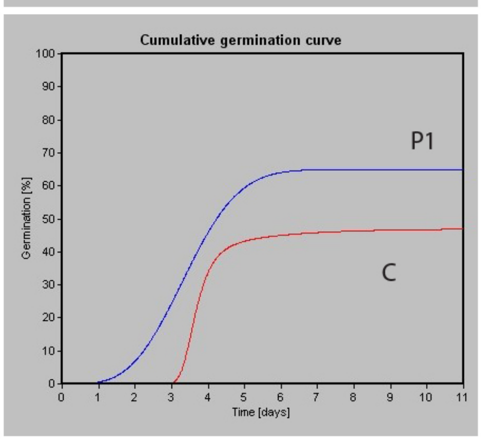

Figure 1c. Germination curves of *Salvia officinalis* L. seeds exposed to magnetic pretreatment with 125 mT (P1) and control (C).

P1
.....C

Figure 1: *Cumulative germination curves of Salvia officinalis L. seeds.*

Calendula officinalis L.

The germination parameters calculated for the seeds of Calendula officinalis L. are recorded in Table 2. The results show that the times required to obtain the different germination percentages were reduced. In most cases, for magnetic treatment (A4, A5) vs. control (C1) and all germination parameters were reduced for pretreatment (P1) vs. control (C2). The improved results were obtained for chronic exposure (A5).

Germination parameters of *Calendula officinalis* L. seeds exposed to 125 mT, expressed as mean standard

Table 2: Calendula germination parameters

Dose	R^2	G_{max}(%)	Time (hour) $\bar{x} \pm SEM$					
			T_1	T_{10}	T_{25}	T_{50}	T_{75}	MGT
C1	0.99	72±4.7	25.2±2.7	36.5±1.7	44.4±0.9	54±0.5	65.3±1	56.2±0.2
A4	0.98	71±4.4	27.4±2.4	37.4±2.9	44.4±3.8	53±3.9	63.4±4.5	55.2±4.1
A5	0.99	80±4.3	28.3±2.2	36.5±1.7	41.8±1.4	48.7 ± 1.2^{d}	57.4 ± 1.7^{d}	50.8 ± 1.7^{c}
C2	0.94	80±4.7	14.9±2.9	21.6±3.1	25.9±1.4	31±0.5	36.2±1.7	31.2±0.7
P1	0.97	84±3.3	10.8 ± 3.8^{b}	17.3 ± 2.2^{b}	21.8 ± 0.5^{b}	27.8±1.4	34.8±3.6	29±1.7

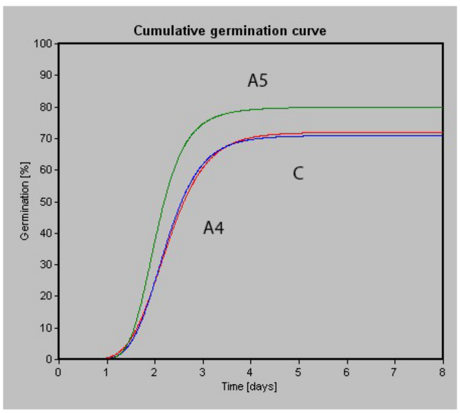

Figure 2a. Cumulative germination curves of seeds of *Calendula officinalis* L. with CM of 125 mT for 24 hours (A4), chronic exposure (A5) and control (C).

A4
A5
C

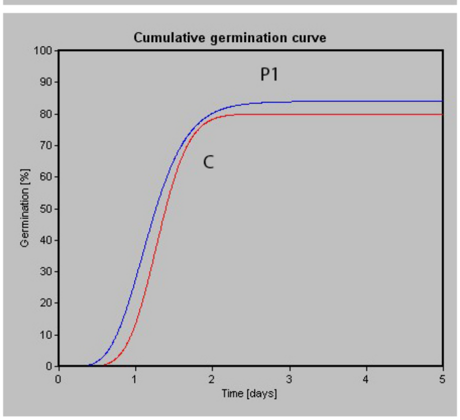

Figure 2b. Cumulative germination curves of seeds of *Calendula officinalis* L. with CM pretreatment of 125 mT (P1) and control (C).

P1
C

Figure 2: *Cumulative germination curves of seeds.*

error. Exposure times: 24 h (A4), chronic exposure (A5), pretreatment (P1) and controls (C1 and C2). Gmax: number of germinated seeds (%); MGT: Mean Germination Time; T_1, T_{10}, T_{25}, T_{50}, T_{75}: time required to obtain 1, 10, 25, 50 and 75% of germinated seeds expressed in hours. R2: correlation coefficient. Superscripts indicate differences vs. control: ^{d}(p<0.001): extremely significant; ^{c}(0.001<p<0.01) very significant; ^{b}(0.01<p<0.05); significant; ^{a}(0.05<p<0.1): differences.

Figure 2a shows the cumulative germination curves of Calendula officinalis L. seeds exposed to 125 mT for 24 h (A4), chronic exposure (A5) and control (C1). Figure 2b shows the cumulative germination curves of pretreated seeds of calendula (P1) and control (C2). The germination rate and percentage of germination of untreated seeds is higher in the magnetically treated seeds.

The results obtained for both medicinal plants are in agreement with other studies on the influence of a stationary magnetic field on seed germination and plant growth, which reveal that the treatment produces an improvement in the percentage and velocity of germination of the exposed seeds. An increase in germination and sprout development was obtained by exposing maize seeds to a 150 mT magnetic field for 10, 15, 20 and 30 min [16]. Similar results were obtained with tobacco seeds [17]. Primary root curvature was observed in radish seedlings in a static magnetic field and the roots responded to the static magnetic field, significantly with the south pole of the magnet [18]. A positive effect of magnetic treatment on germination and emergence of bean cultivars was proved; plant emergence from magnetized seeds was 2 to 3 days earlier compared to the control, yield increased due to more pods per plant [19]. It was observed that the length of young maize plants exposed to a magnetic field between 50 to 250 mT was greater than the control for all exposed samples [20].

A significant increase in germination, seedling vigor and shoot/root growth of one-month-old plants of chickpea seeds exposed to static magnetic fields has also been published. Cicer arietinum L. seeds were exposed in lots to static CM from 0 to 250 mT in steps of 50 mT for 1-4 h in steps of 1h. The results showed that the magnetic treatment improved the germination performance compared to the control. The combinations of field intensity and exposure time: 50 mT for 2 h, 100 mT for 1 h and 150 mT for 2 h exposure gave the best results [21]. Improvement in seedling growth and root characteristics was also observed in 1-month-old maize plants [22]. Recently, other research conducted with triticale shows that the application of CM of 125 mT or 250 mT favors and advances germination, and plants of greater length and weight are obtained, the most significant differences were obtained for exposure times greater than 1 h [23, 24].

4 Conclusion

The results obtained for "Salvia" and "Calendula" seeds show that the germination parameters (MGT, T_1-T_{75}) were reduced for the treatment and magnetic pretreatment compared to the controls. The best results were obtained for 24-hour exposure and chronic exposure. The results indicate that the application of magnetic fields improved the germination rate and germination percentage of treated seeds compared to unexposed seeds in both cases. Consequently, the stationary magnetic field could be used as a physical technique to improve the germination of *Salvia officinalis* L. and *Calendula officinalis* L. seeds.

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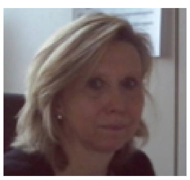

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