GERMINATION OF GRASS SEEDS SUBJECTED TO STATIONARY MAGNETIC FIELD

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ABSTRACT

The objective of the present study is to determine and quantify the effect produced by a stationary magnetic field in germination of patrense seeds (Festuca arundinacea and Medicago sativa, L). Seeds were exposed to 250 mT during different periods of time: 10 minutes, 20 minutes, 1 hour, 24 hours or in a chronic way, doses (B1-B5). Parameters used were average germination time (AGT) and the necessary time for germination of 1, 10, 25, 50 and 75% of seeds (T_1 – T_{75}).

According to results obtained with alfalfa seeds, it can be said that the AGT is significant less in seeds exposed to the magnetic field (20,40 hr for B5, 20,88 for B4, 21,36 for B2 vs 25.68 hr for the control group). Control T_{75} was

30,24 h while in treated seeds it was significant less: 22,32 hr, 23,76 hr, 24,48 hr, 24,72 hr, and 24,96 h for the B5- B1 dose respectively.
For festuca a reduction in AGT for treated seeds can be observed in comparison to the control group. T25 for the control group was 50,16 hr while for treated seeds it was 48,00h for B4 and 47,28 hr for B5. The rest of the parameters evaluated were also less. In consequence, the reduction in the parameters evaluated implies that the germination speed is greater.

KEYWORDS

Germination speed, magnetic treatment, pratense seeds, Medicago sativa L, festuca, Festuca arundinaces, precocity

RESUMEN

El objetivo de este estudio es determinar y cuantificar el efecto de un campo magnético estacionario en la germinación de semillas patrenses *(Festuca arundinacea Medicago sativa*, L.*)*. Las semillas fueron expuestas a 250 mT durante distintos periodos de tiempo: 10 minutos, 20 minutos, 1 hora, 24 horas ó de forma crónica, dosis (B1-B5). Los parámetros utilizados fueron de tiempo medio de germinación (TMG) y los tiempos necesarios para que germinen el 1, 10, 25, 50 y 75% de semillas (T_1-T_{75}) .

De los resultados obtenidos con semillas de alfalfa se desprende que el TMG fue significativamente menor en las semillas expuestas a campo magnético (20,40 hr para B5, 20,88 hr para B4, 21,36 hr para B2 *vs.* 25,68 hr para el control). El T_{75} del control fue 30,24 hr mientras que en las semillas tratadas fue significativamente menor: 22,32 hr, 23,76 hr, 24,48 hr, 24,72 hr y 24,96 hr para las dosis B5 - B1 respectivamente.

En las semillas de festuca se destaca la reducción en el TMG obtenido para las semillas tratadas frente al control. El T_{25} del grupo control fue 50,16 hr mientras que para las semillas tratadas se obtuvo 48,00 hr, para B4 y 47.28 hr para B5. Los demás parámetros evaluados también resultaron menores. En consecuencia, la reducción en los parámetros evaluados implica que la velocidad de germinación es mayor.

PALABRAS CLAVES

Velocidad de germinación, tratamiento magnético, semillas pratenses, alfalfa, Medicago sativa, L., festuca, Festuca arundinacea, precocidad

1. INTRODUCTION

The influence of magnetic fields on the behavior of living systems has been studied for a long time but the effects on plants have been studied only since the last decades, still the mechanism of action of magnetic field on plants are not well known.
Physical techniques based on the application of magnetic fields, are being developed in Agriculture. A systematic and extensive study is necessary to locate the mechanisms of magnetic action in vegetal tissues and identify its useful application. Beneficial effects of magnetic fields on different crops and yields have been reported. An increase of crops of different species subjected to magnetic field has been found. Some scientists have tried to determine some effects of the magnetic field on roots, such as changes of the biochemical activity, curvature and magnetotropism. Greater albumin, gluten and starch contents in wheat seeds exposed to magnetic field were obtained by Pietruszweski (1996). Aladjadjiyan (2002) detected that exposure to a 150 mT magnetic field stimulated shoot development and led to increase of the germination, fresh weight and shoot length of maize plants. Yano *et al.* (2002) observed the induction of primary root curvature in radish seedlings in a static magnetic field. The roots responded tropically to the static magnetic field, with the tropism appearing to be negative, these roots responded significantly to the south pole of the magnet. Recently, Yinan *et al.* (2005) published that the magnetic field pretreatment had a positive effect on cucumber seedlings, such as stimulating seedling growth and development.

The aim of the present study was to evaluate the effect on the germination of grass seeds (Festuca arundinacea and Medicago sativa,L.) of magnetic treatment by exposing the seeds to 250 mT magnetic field for different periods of time. In previous studies, the authors have found that magnetic treatment produces a biostimulation on the initial growth stages and an early sprouting of several seeds (Carbonell *et al.,* 2000; Martínez *et al.*, 2000, 2002; Flórez *et al,* 2004, 2007).

2. MATERIAL AND METHODS

The grass seeds used were Festuca arundinacea and Medicago sativa,L., which had high viability and homogeneity. Germination tests were carried out to study the effect of the exposure of grass seeds to stationary magnetic fields. Test was performed under laboratory conditions with natural light and the temperature average was 20 ± 2ºC. Test was used in order to determine the effect on the germination rate of seeds and select the best magnetic doses which provide a germination rate significantly greater than the control.

Magnetic treatment of seeds was provided as different doses, B1 to B5 by varying the exposure time (t). The static magnetic field was generated by permanent ring magnets with 250 mT strength. Geometrical characteristics of the ring magnet are external diameter 7.5 cm, internal diameter 3 cm, and height 1.5 cm. Analogous rings like the ring magnets, manufactured with the same material but without magnetic induction were used as blind (Control). Magnetic treatments applied were obtained by exposing the seeds to magnetic field for 10 min, 20 min, 1 h, 24 h or chronic exposure. An experimental design using four replicates (n=4), with 25 seeds in each one was carried out. Thus, groups of 100 seeds were subjected to each magnetic treatment, and analogous groups were used as control.

The germination test was performed according to the guidelines issued by the International Seed Testing Association (ISTA Rules, 1999) with slight modifications. Seeds were germinated by placing 25 seeds per Petri dish on filter papers soaked with 12 ml of distilled water. The seeds were placed around a circular line; in this way, all the seeds were subjected to the same magnetic field strength, when the Petri dish is placed on top of a permanent magnet. To obtain dose B5 Petri dishes were placed onto the magnets for all the experimental time, then the seeds were chronically exposed. To obtain the other doses the Petri dishes were placed onto the magnets for the corresponding time 10 min (B1), 20 min (B2), 1 h (B3), and 24 h (B4). After that, they were placed on a blind-ring without magnetic induction. The control group of Petri dishes was located on blind-rings right from the beginning; then, the seeds were not exposed to magnetic field.

Experimental groups B1-B5 and control C ran simultaneously for the germination test. For each treatment the number of germinated seeds was registered three times per day for the time necessary to achieve the final maximum percentage of germinated seeds (G_{max}). Seeds were considered as germinated when their radicle was at least 2 mm long. The rate of germination was assessed by determining the mean germination time (MGT) and time required to germinate 1, 10, 25, 50 and 75% of seeds (parameters $T_{1,}$ T_{10}, T_{25}, T_{50} and T_{75}). Germination curves were plotted for each treatment using the Seedcalculator software developed for seed germination data analysis by Plant Research International.

Statistical analysis. Data of germination obtained for the magnetic treatments were compared by the t-student valued and the p-values were calculated to test for significant differences between each treatment and the control using the Seedcalculator software for seeds germination data analysis.

TAbla 1. Magnetic Treatment applied for 250 mT (E1-E5), and control (C).

Exposure Time	Magnetic Treatment (B) B=250 mT
0 (Control)	C
10 minutes	B1
20 minutes	B2
1 hour	B3
24 hours	B4
Chronic Exposure	B5

3. RESULTS AND DISCUSSION

Table 2 shows the germination parameters calculated for tall fescue and alfalfa seeds, respectively. Germination data corresponding to all the doses were analyzed and the cumulative curves were plotted, but in this paper only the curves of the doses which provided the greatest differences versus control are presented. Results show that the mean germination time (MGT) of tall fescue seeds was significantly reduced when seeds were exposed to magnetic field. The greatest differences between treated seeds and control were obtained when seeds were treated for 24 h and chronically exposed (53.28 h for B4, 53.52 h for B5 vs. 57.84 for control). In addition, most of parameters were also reduced, i.e. T_{25} of seeds not exposed to magnetic field was 50.16 h while this value was significantly reduced for B4 (48.00 h) and B5 (47.28 h); similar reductions were obtained for the other parameters, in consequence the germination rate of seeds chronically exposed was increased.

Data obtained for alfalfa seeds (*Medicago sativa*, L) shows that MGT was significantly reduced compared to control when seeds were exposed to magnetic field (20,40 hr for B5, 20,88 hr for B4, 21,36 hr for B2 vs. 25,68 hr for control). The time taken for 75% of the control seeds to germinate (T_{75}) was 30,24 hr while the T_{75} of treated seeds were significantly reduced, i.e. 22.32 h for B5, 23,76 hr for B4, 24,48 for B3, 24,72 hr for B2 and 24,96 hr for B1. It is remarkable that parameters T_1 and T_{10} were reduced when seeds were exposed for 10 minutes (B1); these values are 29,04 hr vs. 37,92 hr and 40,56 vs. 45.12 hr, therefore, the onset of germination of alfalfa treated seeds started earlier than the control.

Cumulative germination curves of tall fescue seeds subjected to 250 mT stationary magnetic field for 24 hour (B4), chronically exposure (B5) and control curve are presented in Figure, 1a and 1b.

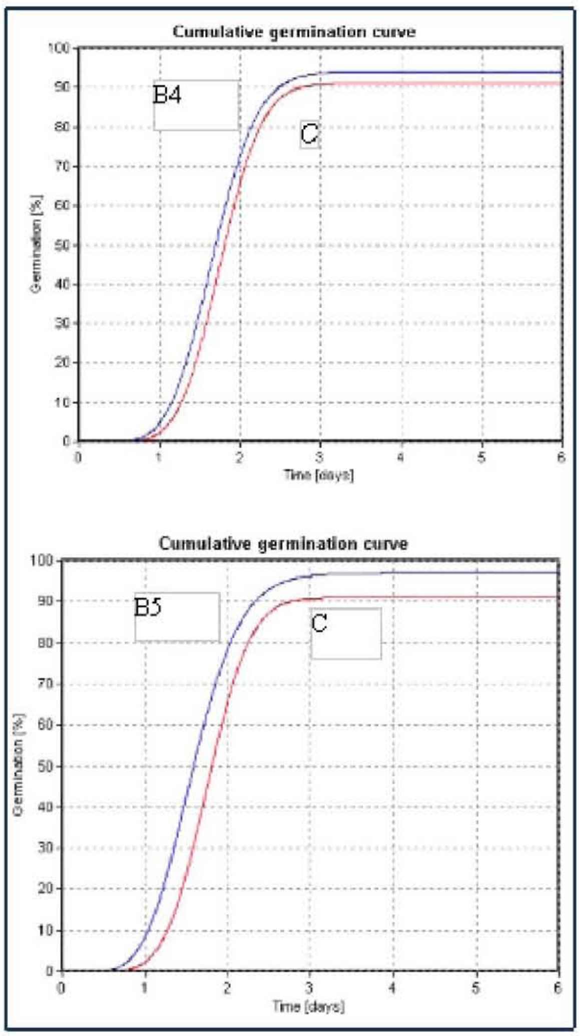

Figure 1. Germination curves of tall fescue seeds.

Cumulative germination curves of Medicago sativa seeds subjected to 250 mT stationary magnetic field for 24 hour (B4), chronically exposure (B5) and control curve are plotted in figure 2a and 2b.

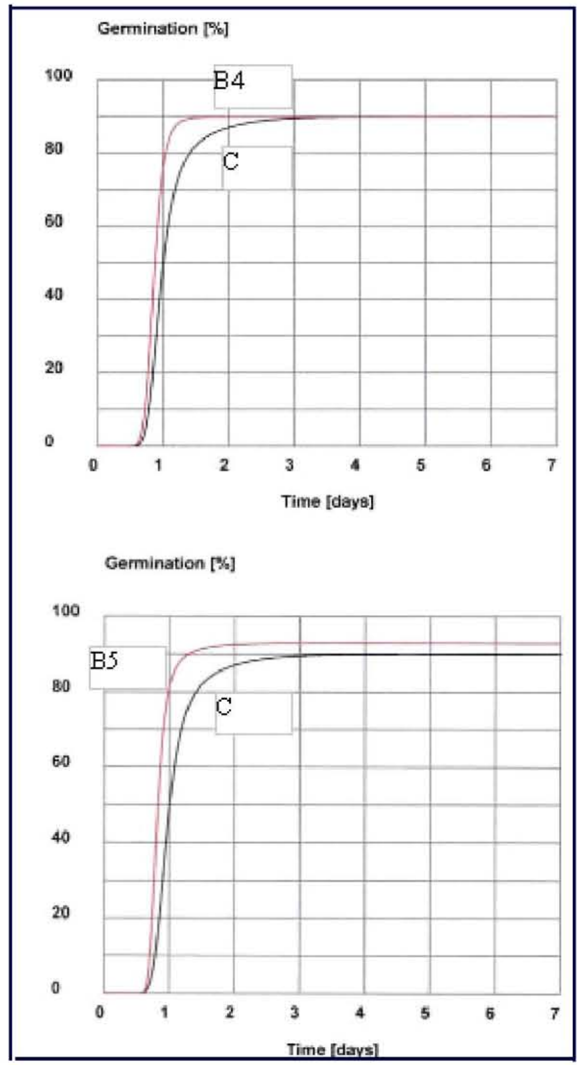

Figure 2. Germination curves of alfalfa seeds.

In all cases, the germination curve of control is underneath the curves of treated seeds, then, control germination rate is lower than the corresponding to magnetic doses. Results obtained for grass seeds are according with other studies about the influence of a stationary magnetic field on several seed germination and plant growth which reveal that magnetic treatment produces: an improvement of percentage and rate of germination of exposed seeds (Carbonell et al.). A biostimulation on the initial growth stages of barley and wheat have been found by Martínez et al. (2000, 2002). An early sprouting and first stages of growth of treated rice plants have been publish by Flórez et al. (2004); results obtained showed increases in germination rate and plant weight and length greater when seeds were subjected to magnetic treatment than their controls. Podlesni et al. (2004) confirmed the positive effect of the magnetic treatment on the germination and emergence of bean cultivars; plant emergence from magnetized seeds was 2-3 days earlier compared to the control, the yield was increased due to the higher number of pods per plant. Racuciu et al. (2006) reported that the length of young plants of maize exposed to a magnetic field varying from 50 to 250 mT, were higher than control for all exposed samples.

Legend of table 2: C (Control), B1 (10 min.), B2 (20 min), B3 (1hour), B4 (24 hour), B5 (chronic exposure), G_{max}: number of germinated seeds (%); T_1, T_{10}, T_{25}, T_{50} and T_{75}: time needed to obtain 1, 10, 25, 50 and 75 % of germination; MGT: mean germination time. Asterisks indicate significant differences vs. control: **** ($p<0.001$) very strongly significant; strongly significant ***($0.001<p<0.01$); significant **($p<0.05$).

Table 2. Germination parameters for grass seeds exposed to a stationary magnetic field, expressed as mean and standard error.

Seed	Magnetic Treatment 250 mT	G_{max}	T_1	T_{10}	T_{25}	T_{50}	T_{75}	MGT
		(%)	($\bar{x}$ ± SE) hour					
Festuca arundinacea	C	87 ±3,42	37,92 ±3,36	45,12 ±1,20	50,16 ±0,72	57,36 ±1,44	69,12 ±3,12	57,84 ±0,24
	B1	89 ±1,91	29.04** ±2,16	40,56*** ±1,20	47,76** ±0,96	56,40 ±0,96	66,72 ±1,92	54,72*** ±0,72
	B2	85 ±3,00	34,56 ±1,92	42,24** ±0,48	47.52*** ±0,96	54,24 ±1,92	64,80 ±3,12	53,28** ±1,44
	B3	81 ±1,91	35,04 ±3,60	43,44 ±1,92	48,96 ±0,96	56,16 ±0,96	68,16 ±5,28	54,00**** ±0,24
	B4	85 ±4,3	35,52 ±3,60	42,96 ±1,20	48,00*** ±0,24	54,24 ±0,96	63,846 ±3,36	53,28**** ±0,24
	B5	83 ±1,91	37,66 ±2,16	42,76 ±1,20	47,28**** ±0,24	52,56*** ±0,72	58,80*** ±1,92	53,52**** ±0,24
Medicago sativa	C	90 ±2,58	15,84 ±0,96	18,72 ±0,72	20,88 ±0,48	24,00 ±0,24	30,24 ±1,44	25,68 ±0,96
	B1	90 ±1,15	16.08 ±0,72	18,24 ±0,48	19,68** ±0,48	21,60**** ±0,72	24,96**** ±0,72	22,32*** ±0,72
	B2	89 ±1,91	15.12 ±0,72	1,7.52** ±0,24	19,20*** ±0,24	21,60**** ±0,48	24,72**** ±0,72	21,36**** ±0,48
	B3	90 ±2,58	16.56 ±0,72	18,00 ±,48	1,20*** ±0,24	20,88**** ±0,72	24,48*** ±2,40	22,32*** ±1,20
	B4	90 ±2,00	14.88 ±0.72,84	17,28*** ±0,24	18,96**** ±0,24	20,88**** ±4,80	23,76**** ±1,20	20,88**** ±0,72
	B5	93 ±1,91	15.12 ±0,48	16,80*** ±0,24	18,00**** ±0,24	19,68**** ±0,24	22,32**** ±0,48	20,40**** ±0,72

4. CONCLUSION

For both studied seeds (Festuca arundinacea and Medicago sativa, L) the mean germination time (TMG) and parameters T_1-T_{75} were reduced for all magnetic doses applied, then, germination rate of treated seeds is higher than the control. In summary, stationary magnetic field could be used as a physical technique to improve the germination of grass seeds.

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