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ORIGINAL ARTICLE

Exposure of *Satureia hortensis* L seeds to magnetic fields: effect on germination, growth characteristics and activity of some enzymes

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The objective of the present study investigated on the effects *Satureia hortensis* L seeds exposure to magnetic fields on seed germination, early growth and enzyme activity, under laboratory conditions *Satureia hortensis* seeds (dry and wet) were studied after treating with different intensities of magnetic field (0, 25, 50 and 75 mT) and exposure time (0, 30 and 60 min). There were significant effects among treatments for germination percentage, root length, shoot length, seedling dry mass and seedling vigor index in *Satureia hortensis* seeds under different magnetic intensity. In the germinating seeds enzyme activities of α-amylase, dehydrogenase and protease were significantly higher in treated seeds in contrast to control.

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Agricultural sciences take an interest not only in the common and valued crop-forming factors, but also in those less expensive and generally underestimated, though more pro-ecological ones, such as ionizing, laser or ultra violet radiation and magnetic field (Dorna *et al.*, 2010). Stimulation of plant with magnetic field (MF) as a way of increase the quality of yields has caught interest of many scientists in the entire world. The effect of physical factors on biological organisms affects the dielectric characteristics of biomembrans (Faqenabi *et al,.* 2009). Therefore, physical presowing seed treatment for enhancing the seed performance, if standardized, can lead to commercial application (Tahir and Karim, 2010). Exposure of the cucumber seeds to magnetic field for a short time was found to help in a rapid sprouting and growth of seedlings (Yinan *et al.*, 2005). It has been shown that magnetic field induces germination, fresh weight, stems length in two wheat cultivars (Gholami and Sharafi, 2010) and have a positive effect on seed vigor index in sunflower (Vashisth and Nagarajan, 2010). Seeds treated by magnetic stimulation seem to show higher enzyme activities which control the particular stages of seed germination (Racuciui, 2008).

The goals of the recent study were to investigate the possible effects of magnetic field intensity and the period of time on improving germination, growth and the activity of the enzymes involved in seed germination of *Satureia hortensis* L.

MATERIALS AND METHODS

Medicinal plant *Satureia hortensis* L was chosen as our research plant. Seeds were supplied by the Urmia Agricultural Research Center.

Magnetic field generation

The magnetic treatment of the seed was done in the Department of Physics at the Faculty of science in University of Urmia using an electromagnetic field generator made in Iran with variable horizontal magnetic field strength (1 mT–2 T) and was fabricated with a gap of 10 cm between pole pieces. A DC power supply model an English brand WAY NE KERR 100V/90A was used for the electromagnet with a continuously variable output current.

Magnetic treatment

A magnetic field of 25, 50 and 75 mT was applied on dry and wet *Satureia hortensis* seeds (wet seeds were obtained by imbibition in water for 12 h at 25 ºC) in 30 and 60-minute periods. Control cells were kept far enough from the magnetic field producing apparatus to avoid any potential exposure to the magnetic field.

Seed germination

After the treatments, treated and control seeds were sterilized by sodium hypochlorite and distilled water. Three replications, each containing 25 seeds were placed between two layers of moist germination papers. They were placed in a germination incubator at 22°C. The germination percentage was calculated based on normal seedlings, determined on 10^{th} day as a ratio of the number of germinated to the total number of seeds. Then such seedlings were randomly selected from each replicate to measure root length and shoot length. At the end of the germination test (14^{th} day), dry weight of seedlings after oven drying at 65°C for 72 h were determined. Seedling vigor was calculated by Abdul-Baki and Anderson (1973) as:

Vigor index I = Germination % × Seedling length (Root + Shoot)

Vigor index II = Germination % × Seedling dry weight (Root + Shoot)

Germination rate, germination index (MDG)

Seventy five *Satureia hortensis* seeds were divided into three equal replications and were placed and incubated at 22° C in moistened filter paper in a Petri dish. The germination rate was calculated according to Eq. (1): Germination rate = $\sum (n/t)$; Where n represents the number of newly germinating seeds at the time of t, and t is days of sowing (Vashisth and Nagarajan, 2010). In addition to the germination index (GI) was calculated according to Eq. (2): Germination index (MDG) = $\sum (ni \times Ti) / N$; Where: *ni* = number of seeds germinated at day *Ti*, *N* = total number of seeds germinated, *Ti* = number of days after starting the test (Hartmann *et al.,* 1990).

Enzymes activities during germination

Enzymes which were related to the germination process in magnetically exposed and unexposed germinating *Satureia hortensis* seeds were in distilled water at 25 ^{0}C were assayed after 24 hours of imbibition. For enzyme extraction 1g germinating seeds were taken. α-amylases activity was estimated following the method described by Black *et al.* (1996). Protease activity was estimated following the method of Kunitz (1994).

Dehydrogenase activity was estimated following the method described by Kittock and Law (1968). There were three replications for each measurement.

Statistical analysis

The SPSS software was applied to analyze the data. Two factor analysis of variance (ANOVA) was performed on a split plot randomized complete block design, keeping magnetic field as the main plot and duration as the sub-plot.

RESULTS

Exposure of *Satureia hortensis* seeds to different intensities of magnetic fields prior to germination significantly increased germination-related characters, such as germination percentage (fig 1), speed of germination, germination index (GI), shoot and root length, seedling dry weight and seedling vigor indexes I and II (table 1). The improvement over untreated control seeds was 20–40 % in dry seeds and 23% in wet seeds for germination percentage, 12–41% in dry seeds and 39 % in wet seeds for speed of germination, 47-104 % in dry seeds and 2-63 % in wet seeds for germination index (MDG), 18-49 % in dry seeds and 16-50 % wet seeds for root length, 20-60 % in dry seeds and 25-60 % wet seeds for shoot length, 25-63% in dry seeds and 27-75 % in wet seeds for total seedlings length, 23-44% in dry seeds and 18-69 % in wet seeds for seedlings dry weight. The calculated vigor indices I increased by 81-177% in dry seeds, 31-116% in wet seeds and for vigor indices II also increased by 55-157 % in dry seeds and 44-129 % in wet seeds respectively.

α-Amylase, Dehydrogenase and protease activity accelerated significantly until 24 h of imbibition. The improvement over untreated control seeds was 36% in dry and 45% in wet seeds for α-Amylase activity (Figure 2a), 86% in dry and 90% in wet seeds for Dehydrogenase (Figure 2b) and 59% in dry and 80% in wet seeds for protase activity respectively (Figure 2c).

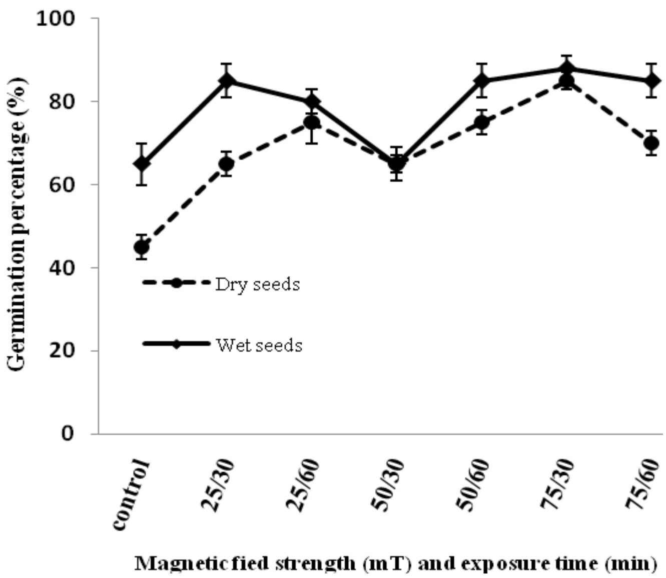

Figure 1. Seed germination percentages under different intensities of magnetic fields (0, 25, 50 and 75 mT) and exposure time (0, 30 and 60 min) treatments in dry and wet *Satureia hortensis* seeds.

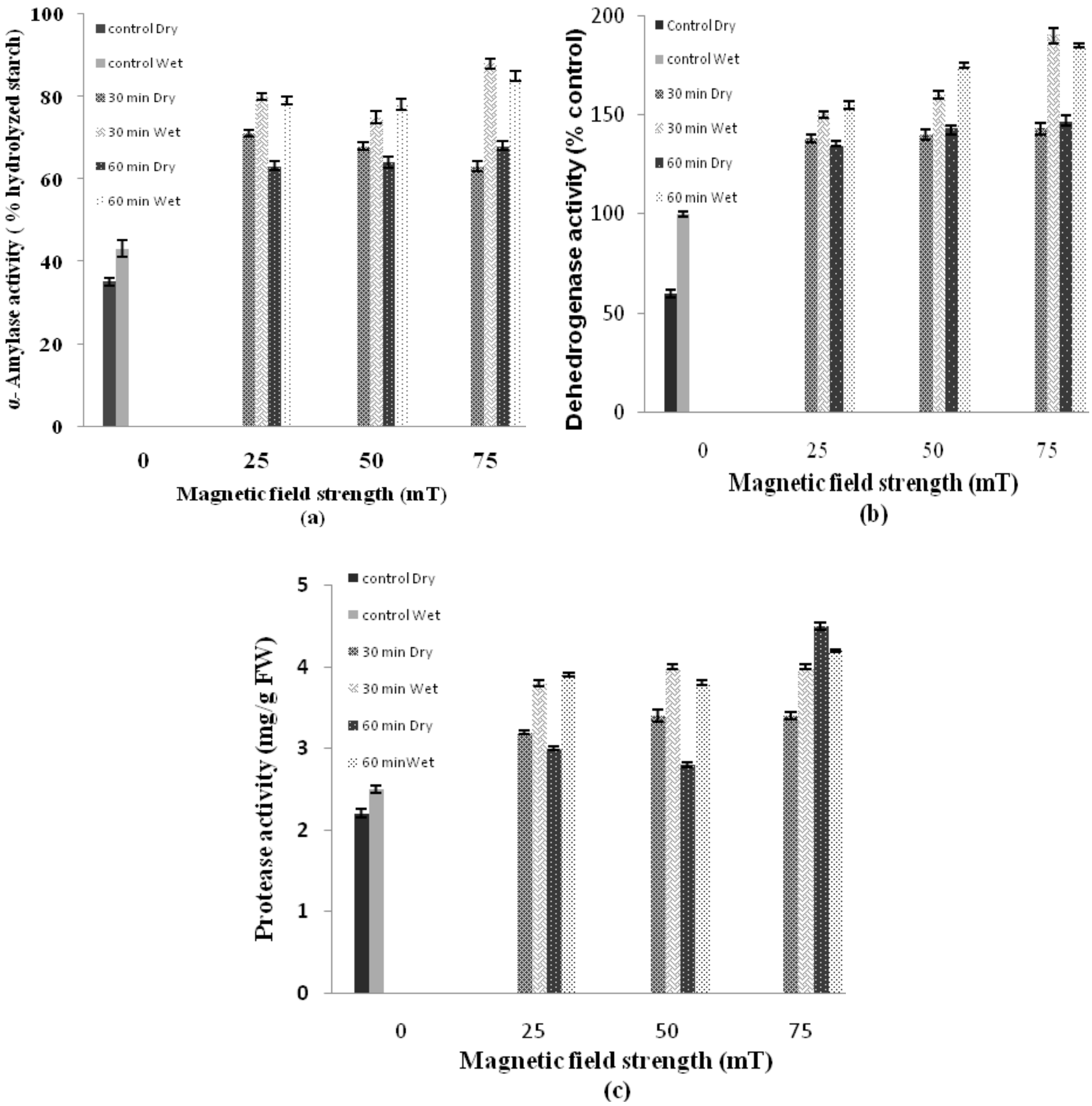

Figure 2. (a–c) Changes in the activities of germination enzymes, (a) α-amylase, (b) dehydrogenase and (c) protease after 24 hours of imbibition in water at 25°C under different intensities of magnetic fields (0, 25, 50 and 75 mT) and exposure time(0, 30 and 60 min) treatment in dry and wet *Satureia hortensis* seeds.

Table 1. Growth parameters and germination characteristics of *Satureia hortensis* seeds, under different magnetic fields and exposure time treatments (average value ± standard errors). GS- germination speed, MDG-germination index, RL-root length, SL-shoot length, TL-total seedling length, TDW-total dry weight, VI-seedling vigor index I and VII-seedling vigor index II.

MF (mT)	Time (min)	Type	GS	MDG (day)	RL(cm)	SL(cm)	TL (cm)	TDW (g)	V I	V II
0 (control)		Dry	1.93 ±0.03	2.18 ±0.011	1.7 ±0.015	1.5 ±0.005	3.2 ±0.021	0.041 ±0.0003	144 ±5.2	1.85 ±.003
		Wet	2.67 ±0.002	3.18 ±0.016	1.73 ±0.013	1.6 ±0.008	3.32 ±0.042	0.039 ±0.0006	216 ±7	2.53 ±0.001
25	30	Dry	2.72 ±0.061*	3.21 ±0.036*	2.43 ±0.016*	2.13 ±0.015*	4.56 ±0.023*	0.049 ±0.0001	296 ±11*	3.19 ±0.009*
		Wet	2.73 ±0.052^{ns}	4.56 ±0.042*	2.36 ±0.015**	2.5 ±0.009*	4.86 ±0.009*	0.048 ±0.0003**	4.13 ±13*	4.08 ±0.007*
	60	Dry	2.54 ±0.063**	4.36 ±0.039*	2.5 ±0.013*	2.4 ±0.012*	5.23 ±0.019*	0.048 ±0.0005*	392 ±7*	3.6 ±0.008*
		Wet	2.78 ±0.043^{ns}	4.88 ±0.051*	2.5 ±0.023*	2.06 ±0.01^{ns}	4.5 ±0.026*	0.048 ±0.0003**	360 ±23*	3.84 ±0.009*
50	30	Dry	2.61 ±0.046**	3.73 ±0.041*	2.46 ±0.015**	2.16 ±0.013*	4.63 ±0.015*	0.047 ±0.0003**	260 ±19*	3.06 ±0.009
		Wet	2.65 ±0.037^{ns}	3.23 ±0.019**	2.26 ±0.018**	2.16 ±0.015*	4.36 ±0.016*	0.056 ±0.0005*	283 ±16*	3.64 ±0.015*
	60	Dry	2.39 ±0.041^{ns}	4.45 ±0.043*	2 ±0.012**	2.16 ±0.008^{ns}	4 ±0.014**	0.059 ±0.0003*	300 ±13*	4.42 ±0.012*
		Wet	2.62 ±0.033*	4.9 ±0.046*	2 ±0.009**	2.23 ±0.005*	4.2 ±0.012**	0.052 ±0.0006*	357 ±12*	4.42 ±0.012*
75	30	Dry	2.63 ±0.056*	4.43 ±0.029*	2.5 ±0.009*	2.2 ±0.007*	4.7 ±0.024*	0.056 ±0.0004*	399 ±11*	4.76 ±0.008*
		Wet	3.7 ±0.062*	5.13 ±0.055*	2.6 ±0.011*	2.26 ±0.010*	5.3 ±0.025*	0.066 ±0.0001*	467 ±9*	5.81 ±0.019*
	60	Dry	2.17 ±0.033**	4.25 ±0.048*	2.53 ±0.014*	1.8 ±0.009^{ns}	4.33 ±0.03*	0.041 ±0.0002^{ns}	303 ±12*	2.87 ±0.009**
		Wet	2.54 ±0.045^{ns}	5.18 ±0.042*	2.2 ±0.007**	2 ±0.006^{ns}	4.2 ±0.026**	0.046 ±0.0001**	357 ±16*	3.66 ±0.002*

± Standard error; NS: not significant; ** significant at 1% level; * significant at 5% level of probability.

DISCUSSION

The results indicate that a magnetic field did have effects on germination and seedling growth of *Satureia hortensis* seeds. It is believed that MFs may improve the ability of life and these effects would change by altering duration of exposure (Khosh-khui and Bonyanpour, 2010). Exposure of *Satureia hortensis* seeds to different magnetic field intensities showed an overall total stimulating effect with respect to all germination characteristics. Such enhanced performance of seeds in their germination characteristics have been reported in other plants (Aladjadjiyan, 2010). In this research germination percentage, speed of germination and germination index (GI) was increased due to magnetic treatment. Similar enhancements in these characteristics due to magnetic field exposure of seeds have been reported in *Festuca arundinacea Schreb* and *Lolium perenne* L. (Carbonell *et al.*, 2008). Seedlings root length and seedling shoot length grown from pre-treated seeds increased in all intensities and duration of exposure. Other researchers (Gholami and Sharafi, 2010) have optained similar results with other seeds. Fresh weight and dry weight of 14-d-old seedlings were higher than control in all treatments. Vashisth and Nagarajan (2010) reported that sunflower seedlings exposed to magnetic fields showed significant increases in total fresh weight. Seedling vigor indexes showed significant increases in most intensities and duration of exposure. This result is similar to experiences of Vashisth and Nagarajan (2009) on maize seeds. One of the possible hypotheses for explanation of observed positive effects of the magnetic treatment could be found in paramagnetic properties of some atoms in plant cells and pigments chloroplasts (Aladjadjiyan, 2010). On the other hand, the magnetic field, causes the stimulation of cell division and cell lengthening, and thereby, increases the hypocotyl and root length (Dao-lian *et al.*, 2009). Racuciui (2008) reported various changes in enzyme activity in seeds treated with magnetic fields. In the present study, α-amylase, dehydrogenase and protease activities of the magnetically exposed seeds was greater than that of unexposed seeds. α-Amylase is an endohydrolase that cleaves the α-1, 4-linkages between glucosyl residues, liberating smaller glucans. Consequently, during α-amylolytic amylopectin degradation, α-limit dextrins are also produced (Demirkan, 2011). An increase in germination speed in magnetically treated seeds can be explained as a consequence of increased activity of α-amylase compared with unexposed controls. An increase in dehydrogenase activity has been reported in tomato (Pandita *et al.*, 2003) compared with unprimed seeds. Protease is involved in the degradation of proteins in the germinating seeds and the reduction being initiated by endoproteases, which convert the water in soluble storage protein in to soluble peptides that can be further hydrolyzed to amino acids by exopeptidases (Palma *et al.*, 2002). However, most studies have suggested that MFs affect water absorption (Pang and Deng, 2008).

The results of this research indicated that due to vigor index I and II which is known as the growth power of the plant ultimately determines the efficiency of the plant's annual performance, a magnetic field with the intensity of 75 mT in a wet condition of the seed and a 30 minute interval had the best effect on *Satureia hortensis* seed.

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