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THE EFFECTS OF MAGNETIC FIELD ON GERMINATION OF SEEDS AND GROWTH OF SEEDLINGS OF STONE PINE

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ABSTRACT

Stone pine (Pinus Pinea L.) is a multi-purpose species for Mediterranean forestry owing to both economic and socio-economic importance. Thus, in this study the effects of magnetic field on the germination of seeds and growth of seedlings of stone pine were investigated. For this purpose, its seeds were treated by a magnetic field of 9.42 mT for a different period of time – 0 min (control), 15 min, 30 min and 40 min in a cylindrical shaped sample, made of a nonmagnetic thin transparent plastic sheet. Germination experiments were conducted in the greenhouse of Bartın University. Considered the germination results as a whole, while seeds exposed to a magnetic field for 30 and 45 minutes resulted in higher germination energy (43%) and percentage (55%), respectively. Both the lowest germination energy (6%) and germination percentage (32%) were found out to be in the seeds without applying magnetic field. Magnetic field increased shoot height, root collar diameter and also tap root length of stone pine seedlings. In terms of shoot height, 85% of 1+0 seedlings was proper for afforestation activities based the classification of TSI. Moreover, magnetic field treatments may be considered as an alternative method to enhance germination Stone pine seeds and to obtain better growth characteristics of their seedlings.

Keywords: Germination, Growth, Magnetic field, *Pinus pinea* L., Seed, Seedling quality.

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Contribution/ Originality

This study is important in terms of determining the effects of magnetic field on the germination of seeds and growth of seedlings of forest tree species.

1. INTRODUCTION

Socio-economic status of the district in the selection of the species used for afforestation activities is one of the important issues. In afforestations of these kinds of districts stone pine is primary forest tree species in terms of the forest-people relations, the contribution to forest villages and the maintenance of participation and sustainability of the forest resources. Stone pine forests in Turkey have a natural distribution of about 33742 ha and afforestation areas of about 591497 ha. This species is mostly preferred for afforestations of Aegean, Marmara and the Mediterranean region especially because of the high economic value of its seeds. Especially the western Anatolia has a very convenient location in the way of the distribution and private management of Stone pine [1]. According to General Directorate of Forestry in Turkey, about 6000-8000 tons shelled and 1200-1600 tons' shell-less pinon nuts per year are produced [2].

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The achievement of stone pine afforestations in Turkey depends on using the seeds with high germination energy as well as qualified seedlings. Likewise, it has known that there is a linear relation (y = a + bx) between germination energy and seedling percentage. Accordingly, the germination energy is more important than germination percentage in practice. Gezer and Yücedağ [3] have reported that when stone pine seeds are kept in warm water for 24-48 hours their germination energy increased. Cultural practices such as seedling spacing, fertilization, irrigation, shading, seedling age, nursery soil and altitude, root pruning and transplanting have an effect on the morphological characteristics of seedlings [4]. These applications are mostly essential to obtain qualified seedlings.

Another important practice for improving some characteristics of plants is magnetic field application. Many researches have been recently conducted about the effects of magnetic field on the various characteristics (germination, seedling growth, assimilatory pigments, nucleic acids, yield, soil microbial population, activities of some enzymes, etc.) of agricultural plant species [5-16]. In the majority of these studies, magnetic field has mostly a positive effect on the studied characteristics. In a study carried out by Özel, et al. [17] the germination percentages of beech seeds applied with magnetic field for 15 and 20 times were found to be much higher than those of control parcel (not exposed to magnetic field). Also, the root length of beech seedlings emerged as a result of the germination of the seeds exposed to magnetic field for 5 times was determined to be longer than those of control group as well as the other magnetic field application groups. So far, there has been no study investigating the effect of magnetic field on the various characteristics of stone pine. Thus, the aim of this study is to determine the effects of magnetic field on the germination of seeds and growth of seedlings of stone pine.

2. MATERIAL AND METHOD

Stone pine cones were obtained from Devrek Forest Nursery on December of 2011. They were desiccated under the room conditions and thus seeds were provided. The vital controls of the seeds were carried out through flotation and cutting methods. In the study, a total of 1200 healthy seeds were used. These seeds were treated by a magnetic field of 9.42 mT for a different period of time – 0 min (control), 15 min, 30 min and 40 min in a cylindrical shaped sample, made of a nonmagnetic thin transparent plastic sheet. The experiment was set on 300 seeds of each treatment. All treatments in the experiments were run simultaneously along with controls under similar conditions in Silviculture Laboratory of Bartın University, Turkey.

Germination experiments were conducted in the greenhouse of Bartın University. Greenhouse lighting was dependent on daylight. Its ventilation was carried out automatically. The greenhouse temperature was kept between 25-30 °C. Humidification of greenhouse was done by irrigating twice a day. Sowings were done on the seedbeds that were 1.2 m wide with 7 rows in a completely randomized design with three replications. Seeds were sown in the depths of 2-3 times their size and with 7 cm intervals on 15th April 2012.

Germinated seeds were counted once every three to four days starting from the first germination. Germination percentage (GP) and energy (GE) were calculated for each treatment. The formula used for calculating the germination percentage was as follows: $GP = \frac{\sum ni}{N} x100$, with GP germination percentage, ni the number of seeds germinated in ith day and N the number of total seeds put into germination experiment. Germination energy (GE) was found by the number of total seeds put into germination experiment by the number of seeds germinated in 7th day.

Cultivation activities such as irrigation (twice a day by sprinkling) and weed control (manually once a month) were regularly performed for seedbed in the experiment during the growing season of 2012. In November of 2012 a total of 1200 seedlings (300 seedlings for each experimental treatment) were uprooted without harming the roots.

The hand-lifted seedlings were examined in terms of morphological traits, such as shoot height, root collar diameter and tap root length. Assessments of cull seedling (root collar diameter < 2 mm and shoot height < 15 cm) ratios were also performed in accordance with the Turkish Standards Institute (TSI) guidelines [18].

Statistical analyses were carried out by SPSS Inc [19]. An ANOVA was performed to determine whether or not the means of treatments were all equal. The means were compared by using the adjusted Duncan's multiple range test ($p < 0.05$). Statgraphics program was also used seedlings to be determined the distribution to quality classes based on TSI.

3. RESULTS AND DISCUSSION

The first seed germination started on the 2nd May 2012 and continued up to 28 days. The highest germination energy (43%) was observed in the seeds exposed to magnetic field for 30 minutes. The highest germination percentage of 55% was obtained from the seeds exposed to magnetic field for 45 hours. Both the lowest germination energy (6%) and germination percentage (32%) were found out to be in the seeds without applying magnetic field (Figure 1).

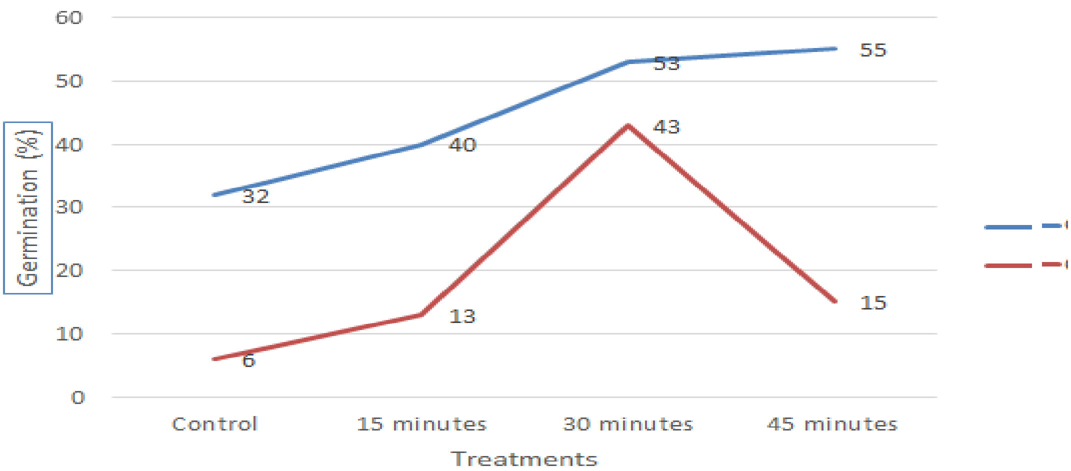

Figure-1. Germination percentage (GP) and energy (GE) of Stone pine seeds

In the current study, the effects of magnetic field on stone pine seeds' germination, and seedlings' growth were investigated. In this sense, it was found that the seeds exposed to magnetic field for 45 minutes had the highest germination percentage (55%). Accordingly, magnetic field treatments applied in this study provided a superiority for the germination of the stone pine having germination obstacle. Nevertheless, magnetic field increased the germination percentage in studies [5-10, 13-16, 20] conducted for various agricultural plants. Also, the germination of *Albizia procera* and *Leucaena leucocephala* [21] beech [17] and Anatolian pine [22] seeds increased with magnetic field. The germination results in this study showed a similarity with the germination increases of magnetic field reached for both agricultural plants and forest tree species although not obtaining high germination percentage.

On the other hand, from the aspect of germination energy of the stone pine seeds, it was determined that the highest germination energy was achieved in the seeds exposed magnetic field for 30 minutes. When germination percentage and energy were evaluated together magnetic field treatment for 30 minutes was the most proper one in terms of nursery practices. Because germination energy was more important than germination percentage [3]. In this context, Majd and Shabrangi [23] stressed that the mean germination time showed a reduction for most of magnetic treatments, therefore their rate of germination was increased.

The results of variance analysis and Duncan test were presented in Table 1. Accordingly, in stone pine seedlings, magnetic field increased shoot height, root collar diameter and also tap root length, i.e. the highest values for these three characters were observed for the seeds exposed to magnetic field for 45 minutes. It was determined that there is statistically significant difference among the applied magnetic field treatments in terms of shoot height, root collar diameter and tap root length ($p<0.01$). According to Duncan test, magnetic field treatments were separated to three groups for both shoot height and rot collar diameter, and four groups for tap root length (Table 1).

Table-1. The effects of magnetic field on the shoot height, root collar diameter and tap root length

Treatments	**Shoot Height (cm)**	**Root Collar Diameter (mm)**	**Tap Root Length (cm)**
	F=19.02**	***F=18.70*****	***F=40.99*****
Control	17.97b[1]	0.22b	18.42b
15 minutes	16.11a	0.19a	15.80a
30 minutes	17.43b	0.21b	20.42c
45 minutes	18.92c	0.25c	24.81d

[1] Means within each column followed by the same letter are not significantly different ($p < 0.05$)

The root growths of stone pine seedlings based on the magnetic field treatments were given in Figure 2. It was obvious that the root lengths of the seedlings exposed to magnetic field for 45 minutes were higher than those exposed to magnetic field for 15 and 30 minutes, and of control group.

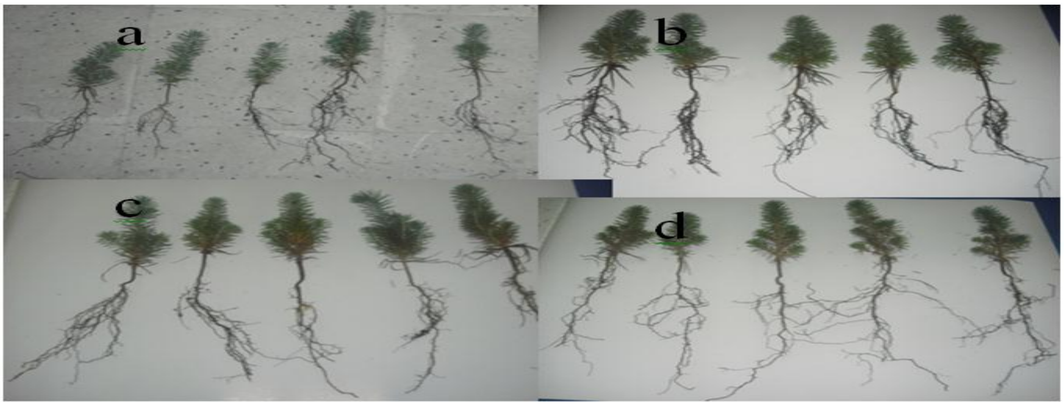

Figure-2. Stone pine seedlings obtained from seeds exposed to magnetic field for various durations (a: control, b: 15 minutes, c: 30 minutes and d: 45 minutes)

Magnetic field increased shoot height, root collar diameter and also tap root length of stone pine seedlings. Similar results were obtained for different agricultural plants such as maize [20] radish [24] chickpea [6] wheat and bean [7] lentil [9] *Nigella sativa* L. [25] soybean [15] sweet pepper [13]. Tanvir, et al. [21] reported that seed exposure to magnetic fields resulted in higher collar diameter and plant height in both *Albizia procera* and *Leucaena leucocephala* seedlings. However, Pourakbar [25] stated that magnetic field treatments have an effect on the root length of chamomile but no effect on its short length. Besides, in study carried out by Yalçın and Tayyar [10] it was found out that the magnetic field implementation had no positive effects on the highest root length and seedling height of lemon balm. Similarly, Özel, et al. [17] found that magnetic field treatments have negative effects on the root length and seedling height of beech seedlings. Larger seedlings could also provide significant advantages because of reduced cultural activities and an expected higher growth and survival rate [26]. Plants having higher root collar diameter were tolerant to drought [27]. Therefore, these kinds of seedlings were more suitable in the afforestation activities and preferred more. The proportional distribution of the obtained stone pine seedlings based on the quality classes of Turkish Standard Institute [18] were given in Table 2. Hence, 14% and 32% of seedlings were discarded in terms of shoot height and root collar diameter, respectively.

Table-2. Distribution to Quality Classes of Shoot Height and Root Collar Diameter based on TSI Seedling Standards [18]

	TSI Seedling Standards (1988)		Distribution to Quality Classes	
	Class	**Range**	**Number**	**%**
Shoot Height (SH)	I	SH≥18 cm	106	44
	II	15 cm≤SH<18 cm	99	41
	Cull	SH<15 cm	35	14
Root Collar Diameter (RCD)	I	RCD≥2 mm	163	68
	Cull	RCD<2 mm	77	32

In terms of shoot height, 85% of 1+0 seedlings was suitable for afforestation activities based the classification of TSI (1988). Bilir, et al. [28] stressed that more than 90% of 2+0 stone pine seedlings had quality seedlings for plantations according to the same classification. Why the results of these studies was different may depend on the seedling ages. Finally, 1+0 stone pine seedlings might be used for afforestation activities. In conclusion, the present study showed that magnetic field treatments enhanced the germination percentage and energy, and had a positive effect on some characteristics of seedlings. Moreover, magnetic field treatments may be considered as an alternative method to enhance germination Stone pine seeds and to obtain better growth characteristics of their seedlings.

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Competing Interests: The authors declare that they have no competing interests.

Contributors/Acknowledgement: All authors contributed equally to the conception and design of the study.

REFERENCES

[1] S. Bilgin, "Seed-seedling relationship and nursery techniques of Stone pine pinus pinea L," Süleyman Demirel University, Doctorate Thesis, Isparta, 2008.

[2] Anonymous, *Action plan for stone pine 2006-2010*. Ankara: General Directorate of Forestry, 2006.

[3] A. Gezer and C. Yücedağ, *Forest tree seeds and seedling growth techniques*, 2nd ed.: Süleyman Demirel University Publications No. 57, 2013.

[4] A. K. Eyüboğlu, "Fidanlıkta değişik sıklık derecelerinde yetiştirilmiş, şaşırtılmış ve şaşırtılmamış Doğu ladini (Picea orientalis (L.) Link) fidanlarının arazideki durumları," *Ormancılık Araştırma Enstitüsü, Teknik Bülten No: 201 Ankara*, p. 16, 1988.

[5] H. H. Huang and S. R. Wang, "The effects of inverter magnetic fields on early seed germination of mung beans," *Bioelectromagnetics*, vol. 29, pp. 649-657, 2008.

[6] A. Vashisth and S. Nagarajan, "Exposure of seeds to static magnetic field enhances germination and early growth characteristics in chickpea cicer arietinum L," *Bioelectromagnetics*, vol. 29, pp. 571-578, 2008.

[7] T. Çakmak, R. Dumlupinar, and S. Erdal, "Acceleration of germination and early growth of wheat and bean seedlings grown under various magnetic field and osmotic conditions," *Bioelectromagnetics*, vol. 31, pp. 120-129, 2010.

[8] A. Gholami, S. Sharafi, and H. Abbasdokht, "Effect of magnetic field on seed germination of two wheat cultivars," *World Academy of Science, Engineering and Technology*, vol. 44, pp. 956-958, 2010.

[9] M. R. Asgharipour and M. R. Omrani, "Effects of seed pretreatment by stationary magnetic fields on germination and early growth of lentil," *Australian Journal of Basic and Applied Sciences*, vol. 5, pp. 1650-1654, 2011.

[10] S. Yalçın and Ş. Tayyar, "Oğulotu tohumlarının çimlenmesi ve fide gelişimi üzerine manyetik alanın etkisi," *Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisi*, vol. 21, pp. 190-197, 2011.

[11] E. M. Florez and M. V. Martinez, "Carbonell, effect of magnetic field treatment on germination of medicinal plants salvia officinalis L. and calendula officinalis L," *Polish J. Environmental Studies*, vol. 21, pp. 57-63, 2012.

[12] M. Racuciu, "Influence of extremely low frequency magnetic field on assimilatory pigments and nucleic acids in zea mays and curcubita pepo seedlings," *Romanian Biotechnological Letters*, vol. 17, pp. 7662-7672, 2012.

[13] M. E. M. Ahamed, A. A. Elzaawely, and Y. A. Bayoumi, "Effect of magnetic field on seed germination, growth and yield of sweet pepper capsicum annuum L," *Asian Journal of Crop Science*, vol. 5, pp. 286-294, 2013.

[14] W. A. Jabail, R. Ch. Abul. Hail, and H. F. Hussein, "Effect of magnetic field on seed germination of triticum aestivum," *World Journal of Agricultural Sciences*, vol. 1, pp. 168-171, 2013.

[15] R. Radhakrishnan and B. D. R. Kumari, "Influence of pulsed magnetic field on soybean (Glycine Max L.) seed germination, seedling growth and soil microbial population," *Indian Journal of Biochemistry & Biophysics*, vol. 50, pp. 312-317, 2013.

[16] M. A. Samani, L. Pourakbar, and N. Azimi, "Magnetic field effects on seed germination and activities of some enzymes in cumin," *Life Science Journal*, vol. 10, pp. 323-328, 2013.

[17] H. B. Özel, E. Kırdar, and N. Bilir, "The effects of magnetic field on germination of the seeds of oriental beech (Fagus Orientalis Lipsky) and growth of seedlings," *Agriculture & Forestry*, vol. 61, pp. 195-206, 2015.

[18] Anonymous, *Coniferous forest tree seedling*. Ankara: Publications of Turkish Standards Institute, TS 2265, 1988.

[19] SPSS Inc, *SPSS 11.0 guide to data analysis*. Upper Saddle River, NJ, USA: Published by Prentice Hall, 2002.

[20] A. Aladjadjiyan, "Study of the influence of magnetic field on some biological characteristics of Zea mais," *Journal of Central European Agriculture*, vol. 3, pp. 89-94, 2002.

[21] M. A. Tanvir, Z. Haq, A. Hannan, M. F. Nawaz, M. T. Siddiqui, and A. Shah, "Exploring the growth potential of Albizia procera and Leucaena leucocephala as influenced by magnetic fields," *Turkish Journal of Agriculture and Forestry*, vol. 36, pp. 757-763, 2011.

[22] S. Ayan, T. D. Günlü, and A. Hançerlioğulları, "The effect of electromagnetic field applications on attributes of Anatolian black pine seeds," presented at the International Scientific Conference (Forestry: Bridge to the Future), Book of Absracts, Sofia, Bulgaria, 2015.

[23] A. Majd and A. Shabrangi, "Effect of seed pretreatment by magnetic fields on seed germination and ontogeny growth of agricultural plants," presented at the Progress in Electromagnetics Research Symposium, March 23–27, Beijing, China, 2009.

[24] A. Yano, Y. Ohashi, T. Hirasaki, and K. Fujiwara, "Effectsof a 60 Hz magnetic fieldon photosynthetic CO2 uptake and early growth of radish seedlings," *Bioelectromagnetics*, vol. 25, pp. 572-581, 2004.

[25] L. Pourakbar, "Effect of static magnetic field on germination, growth characteristics and activities of some enzymes in chamomile seeds matricaria chamomilla L," *International Journal of Agronomy and Plant Production*, vol. 4, pp. 2335-2340, 2013.

[26] C. Yücedağ and O. Gailing, "Effects of seedbed density on seedling morphological characteristics of four broadleaved species," *Forest Systems*, vol. 21, pp. 218-222, 2012.

[27] Y. Şimşek, *Ağaçlandırmalarda kaliteli fidan kullanma sorunları*. Ankara: Orman Araştırma Enstitüsü Dergisi, Sayı 65, 1987.

[28] N. Bilir, C. Kaya, and M. D. Ulusan, "Aydın orijinli fıstıkçamı (Pinus Pinea L.) fidanlarında morfolojik özellikler ve fidan kalitesi," *Kastamonu Üniversitesi Orman Fakültesi Dergisi*, vol. 10, pp. 37-43, 2010.