

Effect of Magnetic Field on Seed Germination and Early Growth of *Calendula officinalis* L.

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In order to study on effect of magnetic field on germination characteristics and early growth of marigold (*Calendula officinalis* L.) seeds an experiment was carried out in laboratory conditions in Arak University of Iran. Seeds were magnetically exposed to magnetic field strengths, 100 or 200 mT for different periods of time; D₁ (control), D₂ (1 h), D₃ (6 h), D₄ (12h), D₅ (24 h) and D₆ (continuous). Mean germination time (MGT) and the time required to obtain 10, 25, 50, 75 and 90% of seeds to germinate were calculated. The germination time for each treatment were in general, higher than control values, in the other word in treated seeds time required for mean seed germination time increased nearly 4 hours in compared non treated control seeds. T₁₀ for doses D₃, D₄ and D₅ significantly higher than the control values. Mean germination time significantly increased when the time of seed exposed at magnetic field treatments increased, about 3 and 2 hour, respectively. According to experiment results of seedling dry weight (SLDW), seed resource depletion percentage (SRDP) and shoot length (STL) showed more decrease with increasing of the exposure time in the magnetic field.

Abstract

Keywords: Field intensity, Magnet, Seed resource depletion.

INTRODUCTION

Great development in medicinal plants has occurred in countries due to their high added value as a consequence of the reappearance of phytotherapy, among other reasons. Marigold (*Calendula officinalis* L.) is one of the ornamental and medicinal plants in green space and drug industry, which it can grow in unfavorable conditions. In recent years, physical techniques take an interest not only in the common and valued crop-farming factors, but also in those less expensive and generally underestimated such as ionizing, laser or ultra violet radiation and electric and magnetic field, and therefore, plants mean an attractive model for the study of biological effects of magnetic fields (Racuciu and Creangia, 2005; Sharafi *et al.*, 2010a).

Studies on wheat (Sharafi *et al.*, 2010 a,b), rice and onion showed that magnetic pre-treatment improved the germination of seedling vigor of low viable seeds (Alexander and Doijode, 1995). Magnetic field pre-treatment had also positive effect on cucumber, such as stimulating seedling growth and development (Yinan *et al.*, 2005). Also, research study reported that 125 and 250 mT magnetic treatment produces a bio-stimulation on the initial growth stages and increase the germination rate of several seeds as rice (Carbonell *et al.*, 2000; Flórez *et al.*, 2004), wheat (Martínez *et al.*, 2002), tomato (De Souza *et al.*, 2005) and barley (Martínez *et al.*, 2000).

Grewal and Maheshwari (2011) investigated on the effects of magnetic treatment of irrigation water on snow pea and Kabuli chickpea seeds emergence, early growth and nutrient contents under glasshouse conditions. Hozayn and Qados (2010) investigate the application of magnetic water for wheat crop production. It materializes that the study on utilization of magnetic water can led to improve quantity and quality of wheat. So, using magnetic water treatment could be a promising technique for agricultural improvements but extensive research is required on different crops.

External constant magnetic field may exert influence on speed and displacement direction of polarized particles of the substances. Stimulation of plants with magnetic field, as a way to increase the quantity and quality of yields, has caught the interest of many scientists in the entire world (Chastokolenko, 1984). The purpose of this study is to synchronize emergence, which leads to uniform stand and improved yield and also to shorten the time between planting and emergence and to protect seeds during critical or induced phase of seedling establishment.

MATERIALS AND METHODS

Germination tests were carried out at laboratory conditions with marigold (*Calendula officinalis* L.) seeds in Arak University of Iran. Germination tests were performed according to the guidelines issued by the International Seed Testing Association (ISTA, 2004). The petri dishes were placed in incubator at 25°C with 60% relative humidity with 14/10 photoperiod. The data regarding germination, days to 50% germination (G50) and mean germination time (MGT) were recorded up to 20th day of experiment. After 20 days of experiment, the data regarding shoot and

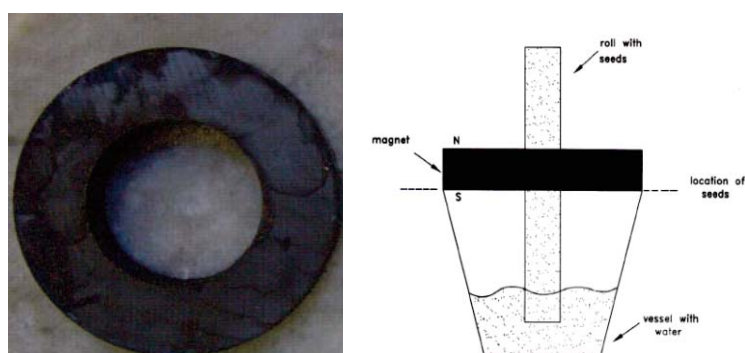


Fig. 1. (left) Magnet and (right) vessel containing distilled water. Roll of filter paper with seeds and the hollow cylindrical magnet. N, S: North and South poles of magnet (Fig. from Sharafi *et al.*, 2010).

root length, shoot and root fresh and dry weights were also recorded. The rate of germination was assessed by determining the mean germinating time (MGT).

The procedure of study was conducted according to Florez *et al.*, (2007). The magnetic fields generated by ring magnets with magnetic induction values B1 =100 mT and B2 = 200 mT; the geometric characteristics are 7.5 cm external diameter, 3 cm internal diameter, 1cm high for B1 and 1.5 cm high for B2 (Fig. 1). The magnet was placed at the top of the vessel to generate each magnetic dose, and each roll containing 20 seeds was placed into hole of the magnet. All the vessels containing rolls with seeds were labeled with numbers and randomly located to carry out the test. The results were subjected to an analysis of variance (ANOVA) to detect differences between mean parameters. Means were compared using with LSD test at 5% level of probability to detect differences between parameters of treated plants and control (Steel and Torrie, 1984).

RESULTS AND DISSCUSION

The variable magnetic field is a very significant factor in influencing the germination process of marigold grains. It must be remembered, however, that this influence is varied and depends on the power of magnetic field. Both for a weak magnetic field (100 mT) and for a strong one (200 mT) the effect was very short-lasting and appeared in the initial phase of germination. The percentage of germinated seeds (G_{mx}), time required for germination (parameters MGT, T_{10} - T_{90}) were determined for each treatment, expressed as the means of the 3 replicates and are provided in Table 1. The germination time for each treatment were in general, higher than corresponding control values, in the other word in treated seeds time required for mean seed germination time increased nearly 1 (D_2) and 12 (D_4) hours in compared non treated control seeds. Thus the rate of germination of treated seeds was lower than the untreated seeds (Table 1). Results showed that time required for T_{10} for doses D_1 and D_2 for 100 mT, and D_1 for 200 mT were 130, 140 and 120 hours respectively, the same or significantly higher than the control values for marigold (Table 1).

As T_{10} in closely related to the onset of germination, these results indicate no response (for 5 treatments) and the delay of germination (for 3 treatments) of marigold seeds to magnetic field. Mean germination time (MGT) significantly increased when the time of seed exposed at magnetic field treatments increased, about 1 and 12 hours respectively, for marigold.

Magnetic field treatments exerted a significant effect on seedling dry weight, weight of mobilized seed reserve, seed reserve utilization rate and seed reserve depletion percentage. According to experiment results, seedling dry weight (g), weight of mobilized seed reserve (mg seed⁻¹), seed reserve depletion percentage (%) and seed reserve utilization rate (g g⁻¹) characteristics in marigold exposure of seed at magnetic field with D_3 , D_5 and D_6 caused seed germination significantly reduced but germination at D_2 and D_4 significantly increased (Fig. 2).

Table 1. Effect of magnetic field on germination of marigold seeds.

B=100mT	T10(h)	T25(h)	T50(h)	T75(h)	T90(h)	MGT (h)	Gmx (%)
C	140 ^{cd}	170 ^c	240 ^c	270 ^d	330 ^{bc}	230 ^c	96.05 ^a
D1	130 ^d	170 ^c	210 ^d	252 ^d	330 ^{bc}	220 ^c	96 ^a
D2	155 ^c	195 ^{bc}	243 ^c	305 ^c	362 ^b	250 ^{bc}	97.95 ^a
D3	150 ^c	180 ^{bc}	270 ^c	350 ^b	390 ^a	270 ^b	90.5 ^b
D4	170 ^c	200 ^b	250 ^c	310 ^c	340 ^b	258 ^{bc}	98 ^a
D5	230 ^b	290 ^a	330 ^b	360 ^b	400 ^a	325 ^a	96.2 ^a
D6	270 ^a	310 ^a	360 ^a	400 ^a	-	270 ^b	79.22 ^c
B=200mT	T10(h)	T25(h)	T50(h)	T75(h)	T90(h)	MGT (h)	Gmx (%)
D1	120 ^d	157 ^c	187 ^c	225 ^d	300 ^c	190 ^c	96.5 ^a
D2	140 ^d	180 ^c	201 ^c	285 ^c	315 ^{bc}	226 ^c	94 ^a
D3	142 ^d	165 ^c	185 ^c	240 ^d	285 ^c	204 ^c	96.5 ^a
D4	205 ^c	255 ^b	295 ^b	325 ^b	352 ^b	285 ^b	90 ^b
D5	355 ^a	382 ^a	412 ^a	450 ^a	480 ^a	417 ^a	89.2 ^b
D6	315 ^b	-	-	-	-	-	-

*Means sharing similar letters in a column are statistically non significant at $p \leq 0.05$.

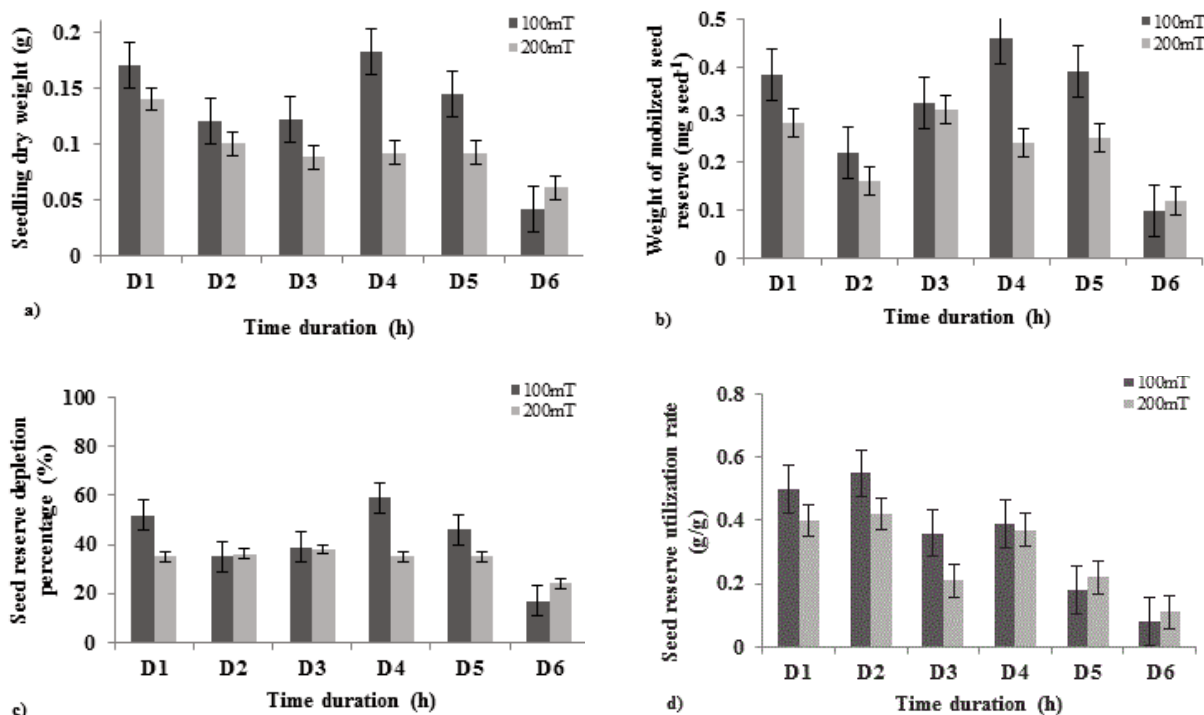


Fig. 2. The effect of magnetic field on: (a) seedling dry weight, (b) Weight of mobilized seed reserve, (c) seed reserve depletion percentage, and (d) seed reserve utilization rate of marigold.

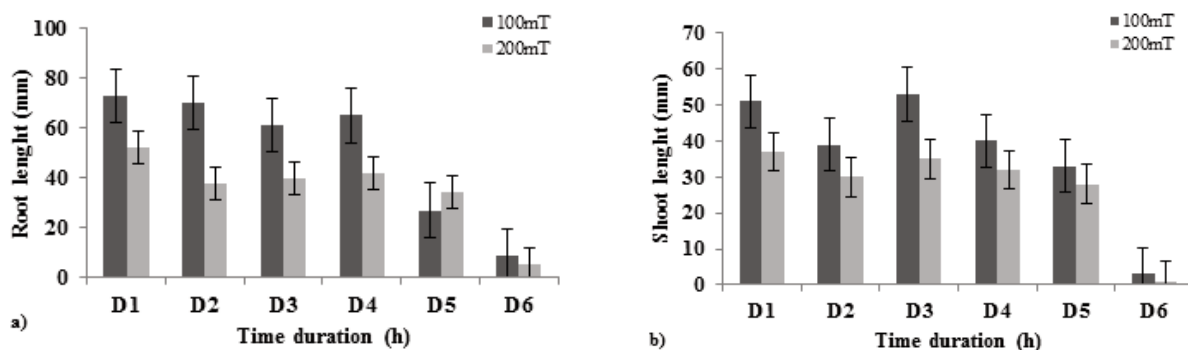


Fig. 3. The effect of magnetic field on: (a) root length (mm) and (b) shoot length (mm) of marigold.

The stimulatory effect of the application of different magnetic doses on the germination is in agreement with that obtained by other researchers. Florez *et al.* (2007), observed an increase for initial growth stages and an early sprouting of rice and maize seeds exposed to 125 and 250 mT stationary magnetic fields. Martinez *et al.* (2000; 2002), observed similar effects on wheat and barley seeds magnetically treated. Alexander and Doijode (1995) reported that pre-germination treatment improved the germination and seedling. Vigor of low viability rice and onion seeds. Kavi (1977) found that seeds exposed to a magnetic field absorbed more moisture. Carbonell *et al.* (2000) found that magnetic treatment produced a bio-stimulation of the germination. Also, the results of three-year investigation into the influence of constant magnetic field on the dynamics of growth, development and yield of spring wheat showed that in general it was not favorable to development and yield of the plant (Zhu, 2001). But, the mechanisms at work when plant and other living systems are exposed to a magnetic field are not well known yet, but several theories have been proposed, including biochemical changes or altered enzyme activities by Phirke *et al.* (1996).

Seed germination rate is an important parameter to analyze the initial growth of seed under laboratory condition and also useful to evaluate the effectiveness of any particular endeavor to enhance the crop yield. It was observed from the experiment that seed germination start one to three days earlier with the application of magnetic field as compared to control (Fig. 3). Similar finding

were found by other researcher as Florez *et al.* (2004) affirmed an increase for the initial growth stages and an early sprouting of rice seeds exposed to 125 and 250 mT stationary magnetic field. Furthermore Sharafi *et al.* (2010 a,b) and Martinez *et al.* (2000, 2002) observed similar effects on wheat and barley seeds. Dry weight was decreased due to magnetic field (Fig. 1a). The increased plant biomass might be due to synchronized germination and early stand establishment in treated seeds (Penuelas *et al.*, 2005). These findings are similar with earlier research on pepper (Zhang *et al.*, 1994) and Canola (Zhu, 2001). An increase in root length was recorded in magnet treatment which might be the result of higher embryo-cell wall extensibility (Fig. 3b).

CONCLUSION

Results of the present laboratory experiments revealed few beneficial effects of magnetic field for marigold seed germination. The germination time for each treatment were in general, higher than control values, in the other word in treated seeds time required for mean seed germination time increased nearly 4 hours in compared non treated control seeds. T₁₀ for doses D₃, D₄ and D₅ significantly higher than the control values. Mean germination time significantly increased when the time of seed exposed at magnetic field treatments increased, about 3 and 2 hour respectively. According to experiment results of seedling dry weight (SLDW), seed resource depletion percentage (SRDP) and shoot length (STL) showed more decrease with increasing of the exposure time in the magnetic field. As magnetic field treatment is environment friendly technique and easy to handle but further studies are needed to understand the mysterious mechanism behind magnetic treatment and in turning it into technique to technology for end user benefits.

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