Effect of Magnetic Field on Seed Germination and Transplant Growth of Tomato

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Abstract: Tomato *(Lycopersicon esculentum* Mill) cv. Castlrock seeds were exposed to different magnetic strengths (0.1, 0.15 and 0.2 Tesla) for periods of 1, 5, 10 and 15 minutes and the treated seeds were germinated under distilled water or in saline concentration levels of 2500, 5000 and 7500 ppm. The results indicated that the magnetic field treatments led to a significant increase in the germination percentage reduced the time needed for germination and improved seed germination under saline conditions. The best results were found by magnetic seed treatment with 0.1 Tesla for 15 min. On the contrary, high salinity concentrations decreased the germination of seeds, as for the saline concentration of the 2500 ppm activated the seed germination. In the nursery experiment, applying the optimal magnetic seed treatment (0.1 T for 15 min) and/or irrigation with magnetized water gave significant increases in transplant stem length, stem diameter, leaf area and fresh and dry weight than those in the control treatment which grew by untreated seeds and irrigated by ordinary (untreated water) water.
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1. Introduction

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important horticultural crops in the world, where it is cultivated on a large scale as annual vegetable crop as well as commercial importance as a horticultural cash crop. For these reasons tomato crop was selected as a model crop for these studies. Environmental stresses such as salinity stress greatly influence the growth and productivity of plants also it is considered as one of the most important determinants of crop cultivation and agricultural diversity especially in arid and semi arid regions. Salinity inhibits the germination of tomato seeds and lengthens the time needed for germination, it also discourages the overall growth of plants and reduces the final crop yield.

Magnetic seed treatment is one of the physical pre-sowing seed treatments as well as magnetically water treatment. The influence of magnetic field on various growth processes of plants such as seed germination, seedling growth, plant growth, yield and the properties of crop quality have been the object of much research. **Moon and Chung (2000)** found that the suitable magnetic seed treatment increased germination rates by about 1.1-2.8 times. More than that, it leads to increase the germination under stress conditions. **Rochalska and Rywka (2005**) as well as the germination of stored seeds of low viability **Alexander and Doijode (1995)**. **Fernandez *et al*, (1996)** reported that seedlings raised by magnetically treated water are more robust and healthier because the treated water increased nutrient uptake. Magnetize water increased pest and disease resistance **Diaz *et al* (1997)**. Plants raised from magnetically treated seeds grew higher and heavier **Florez *et al* (2007)**, improved their tolerance to salt stress conditions **Lihua and Jixun (2001)** as well as to low temperatures stress **Rochalska and Rywka (2005**) and the appearance of decay signs and senescence process were delayed **Piacentini *et al*. (2001)**. Magnetic field treatments increased the auxin content in plants **Mitrov *et al,* (1988**), stimulated synthesis and transport of hormones and enzymes metabolism **Esitken (2003)** and increased the final yield.

The magnetic field worth our attention, since it can change the course of some processes taking place in the seeds and so stimulates plant development, particularly under stress conditions. It had been widely used in some countries, since the magnetic field treatment is ecological and harmless technology **Carbonell *et al,* (2004)**. The aim of our study was quantify the possible effect of magnetic seeds treatment, as one of physical pre-sowing seed treatments, on seed germination particularly under saline conditions, and the impact of irrigation with magnetized water on tomato seedling growth.

2. Materials and Methods

1- Germination experiment:

This experiment was carried out at the laboratory of Horticulture Department, Faculty of Agriculture

and Physics Department, Faculty of Science, Ain Shams University during 2005 and 2006 spring seasons. Germination tests were carried out to study the effect of magnetically treated seeds on the germination percentage and germination rate of tomato seed *(Lycopersicon esculentum* Mill) using cv. Castlrock (Namdhari Seeds Comp) under saline stress and to choose the best magnetic force and the exposure period for application.

Tomato seeds were exposed to different magnetic field strengths (0, 0.1, 0.15 and 0.2 Tesla) and different treatment periods (0, 1, 5, 10 and 15 min.) at the laboratory of Physics Department, Faculty of Science, using a magnet type N100 (Oxford company). The current was adjusted to produce the required magnetic field, and the stability of the current lies within ± 10¯5A. The magnetic strength was determined by a Teslameter (Misr. Fatramo Comp.). After the magnetic treatments, seeds were taken to the laboratory of vegetable physiology to complete the germination experiment. Tomato seeds were spread in sterile Petri dishes containing two layers of filter paper (Whatman No.1), each dish in the control treatments was moistened by distilled water while the others were moistened with one of the following saline solutions: 2500, 5000, or 7500 ppm. This experiment was factorial with three factors distributed in randomized complete design, and included 80 treatments which were the combinations of 4 magnetic field strengths, 5 exposure periods and 4 salinity concentrations at four replicates, with 100 seeds in each dish. Seeds were placed in Petri dishes and located in incubator at the optimal germination temperature for tomato seed at 26° C for 14 days. Tests were performed according to the guidelines issued by the **International Seed Testing Association (ISTA, 2004**).

Data recorded

1-1-Number of germinated seeds was recorded per day during the period of the germination to count the percentage of germinated seeds at the end of experiment.

1-2-The germination rate (number of days required for maximum germination), according to **Ranal and Santana (2006).**

Germination rate = (G1T1 + G2T2 +...+ GnTn) / (G1 + G2 +...+ Gn),

Where G: germination count on any counting day and T: time.

2- Nursery experiment:

The purpose of this experiment was to study the response of tomato transplants which raised from magnetically treated seeds and the irrigation with magnetized water with magnetic field using magnetic coils with intensity of about 0.1 Tesla.

The magnetically treated and untreated tomato seeds were sown in the nursery, on 2nd of February 2005 and 2006 for both tested seasons, in foam trays (84 eyes) filled with mixture of peat moss and vermiculite (1:1 volume basis) and adequate amounts of fertilizers and fungicide, calcium carbonate was added to modify the mixture p^H. Transplant trays were kept under green-house conditions with all agriculture managements required for the production of whole tomato transplants, except the irrigation water that was magnetized or untreated water (control treatment) according to the present treatment. The experimental design of this experiment was randomized complete design.

Data recorded

The following data were recorded after 45 days of sowing: transplant stem length and diameter, third leaf area, fresh and dry weight.

The obtained data were statistically analyzed using Duncan's multiple range tests at $P \leq 0.05$ level to verify differences among treatment means according to **Snedecor and Cochran (1982)**.

3. Results and Discussion

Germination Experiment:

Germination percentage:

The results showed that the effects of magnetic seed treatments depended on the dose of magnetic field and the time of exposure used. Table (1) reveals significant differences in various magnetic field strengths on germination percentage. In this regard 0.1 Tesla gave the best germination percentage while the 0.2 Tesla strength resulted in lowest germination percentage compared to the control treatment. Similar results were found by **Aladjadjiyan (2002)** who found that seed treatment with 0.15 Tesla strength was the more effective on maize seed germination percentage.

Regarding the effect of periods of magnetic field exposure, in general, all durations of exposure showed significant increase in germination percentage comparing with control treatment, the best period for magnetic seed treatment under this study was 15 minutes as showed in Table (1). **Aladjadjiyan (2002)** also found that 10 minute exposure was the most favorable period for maize seed germination.

Table 1. Effect of magnetic field strength & duration of exposure on germination percentage of tomato seeds cv. Castlrock under optimum germination temperature (26° C).

Magnetic strength (Tesla)	Exposure periods (min)					
	0	1	5	10	15	Mean Strength
0	76.3 ef	76.3 ef	76.3 ef	76.3 ef	76.3 ef	76.3 C
0.1	76.3 ef	82.0 c	82.8 c	90.5 b	94.3 a	85.2 A
0.15	76.3 ef	82.3 c	79.3 d	77.3 de	91.0 b	81.2 B
0.2	76.3 ef	78.5 de	73.3 g	73.5 fg	68.8 h	74.1 D
Mean exposure period	76.3 D	79.8 B	77.9 C	79.4 BC	82.6 A	

The increase in salt concentrations caused decrement in final germination percentage Table (2). The reduction being strong particularly at the highest levels of salt concentration (5000 and 7500 ppm) compared with control, whereas 2500 ppm treatment showed the higher germination percentage as compared with the control treatment. Similar results were found by **El-Habbasha *et al* (1996)** and **Hajer *et al* (2006)** who found that increasing salt concentration up to 2500 ppm significantly reduced tomato seed germination.

The interaction effect of magnetic field strength and the duration of exposure on germination percentage was significant, the highest value was noticed when seeds were treated with 0.1 Tesla strength for 15 minutes. On the contrary, the lowest germination percentage was noticed when 0.2 Tesla and 15 min was applied. Similar results were obtained by **Souza *et al* (1999)** who mentioned that the best germination percentage of tomato seeds was obtained by magnetic field strength 0.1 Tesla with exposure time of 10 minute.

Significant effect was observed in Table (2) between magnetic field strength and water salinity regarding germination percentage, however the better germination value was recorded by seeds treated with 0.15 Tesla strength and moistened with 2500 ppm salt solution. This result is in harmony with that of **Rochalska (2001)** who indicated that magnetic field treatment improved the germination process under stress conditions.

Table (2) showed that the effect between the duration of exposure and water salinity on germination percentage was significant. Seeds that treated for 5, 10, and 15 minutes and germinated in distilled water or 2500 ppm salt solution showed the highest germination percentage, while tomato seeds that treated with 7500 ppm for 5 and/or 15 min showed the lowest germination percentage. Concerning the interaction effect of magnetic field strength, exposure duration and salinity, the same data in Table (2) show that the highest value was recorded by tomato seed treated with 0.1 or 0.15 Tesla strength for 10 or 15 min and watered by distilled water or that of 2500 salinity dilution, On the contrary, the lowest value was recorded by the seeds which subjected to 0.2 Tesla for 15 min and 7500 ppm saline solution.

Germination rat:

Data in Table (3) clearly show that magnetic field strengths showed significant reductions in the number of days required for germination comparing with control treatment (untreated seeds). Strength of 0.2 Tesla recorded the lowest number of days required for germination and followed by that of 0.1 Tesla as compared to control treatment. Similarly, **Pietruszewski (1999)** reported that wheat seeds which previously treated with magnetic field germinated faster than untreated ones.

The duration of exposure to magnetic field showed significant effect on germination rate, the different exposure periods reduced the time needed for germination as compared with untreated ones. In this respect, the lowest time required for germination was recorded when tomato seeds were exposed for 5 or 10 min compared to that of control which recorded the longest time for germination.

The required time for germination increased with increasing levels of salinity in comparison with distilled water as show in Table (4). In other words, the higher salt concentration needed longer time for germination. The drastic effects were recorded at salinity level 7500 ppm. Similar results were found by **Cuartero and Munoz (1999)** and **El-Habbasha *et al* (1998)** who noticed that increasing salt concentration had delayed the germination of tomato seeds.

Table (3) revealed that there was significant interactive effect between magnetic field strength and the exposure durations on seed germination rate. Using 0.1 Tesla for 15 min treatment significantly reduced the time needed for germination as compared to control treatment. However**, Florez *et al* (2007)** showed that the time needed for germination in each magnetic treatment of various strengths and periods were lower than values recorded by control.

Table 2. Effect of magnetic field strength, exposure duration and water salinity on germination percentage (%) of tomato seeds under optimum germination temperature (26)

Salinity (ppm)																				
Distilled water						2500					5000					7500				
Magnetic strength (Tesla)																				
Duration	0	0.1	0.15	0.2	Mean	0	0.1	0.15	0.2	Mean	0	0.1	0.15	0.2	Mean	0	0.1	0.15	0.2	Mean	Mean
0	86 gh	86 gh	86 gh	86 gh	86 c	93 bcde	93 bcde	93 bcde	93 bcde	93 ab	76 i	76 i	76 i	76 i	76 e	50 l	50 l	50 l	50 l	50 g	76.3 D
1	86 gh	93 bcde	94 abcd	91 defg	91 b	93 bcde	96 abcd	95 abcd	93 ncde	94 a	76 i	91 defg	84 h	83 h	84 d	50 l	50 l	56 k	47 l	50 g	80 B
5	86 gh	95 abcd	93 Bcde	95 abcd	92 ab	93 bcde	94 abcd	94 abcd	95 abcd	94 a	76 i	87 fgh	83 h	78 i	81 d	50 l	55 k	47 l	25 n	44 h	78 C
10	86 gh	96 abcd	94 abcd	95 abcd	93 ab	93 bcde	95 abcd	97 abc	95 abcd	95 a	76 i	93 bcde	78 i	78 i	81 d	50 l	78 I	40 M	26 n	49 g	79 BC
15	86 gh	96 abcd	99 a	96 abcd	94 a	93 bcde	97 abc	98 ab	92 cdef	95 a	76 i	96 abcd	92 cdef	65 j	83 d	50 l	88 efgh	75 i	22 n	59 f	83 A
Mean	86 d	93 ab	93 ab	93 b	91 B	93 ab	95 ab	95 a	94 ab	94 A	76 f	89 c	83 e	76 f	81 C	50 i	64 g	54 h	34 j	50 D	

Table 3. Effect of magnetic field strength and duration of exposure on germination rate of tomato seeds cv. Castlrock under optimum germination temperature (26° C).

	Exposure periods (min)					
Magnetic strength (Tesla)	0	1	5	10	15	Mean Strength
0	7.28 a	7.28 a	7.28 a	7.28 a	7.28 a	7.28 A
0.1	7.28 a	6.41 de	6.34 e	6.13 ef	5.91 f	6.41 C
0.15	7.28 a	6.71 cd	7.11 ab	6.91 bc	6.76 c	6.95 B
0.2	7.28 a	5.95 f	6.00 f	5.56 g	6.22 ef	6.20 D
Mean exposure period	7.28 A	6.59 BC	6.68 C	6.47 C	6.54 BC	

With respect to the interaction between magnetic field strength and water salinity, Table (4) showed significant effect. Treating seeds with 0.15 Tesla strength and 7500 ppm gave the highest germination rate, whereas the lowest value was recorded by the seeds that treated with 0.1 T and distilled water. In the other words, magnetically seed treatment with suitable magnetic field was more tolerant to salt stress conditions. This was evident through germination of magnetically treated seeds under 5000 and 7500 ppm.

A significant effect between the tested water salinity levels and durations of exposure was also observed (Table 4), The seeds that were treated for 5 minutes with 7500 ppm recorded the highest number of the days required for germination.

Concerning the interaction among the three tested factors, seeds treated with 0.15 Tesla for 5 min in saline water of 7500 ppm recorded the highest number of days required for germination. While the lower number of days for germination was observed by the seeds that were treated with 0.1 Tesla for 5 min under 2500 ppm saline concentration.

Nursery experiment:

Transplant height

Transplant height was significantly increased by different magnetic field treatments (magnetic seed treatment and/or magnetic water treatment) as presented in Table (5). The highest value was found in transplant grown from magnetically treated seeds and irrigated with magnetized water while the lowest value was obtained by transplant grown from check seeds. Our results are in agreement with those obtained by **Amaya *et al* (1996) and Souza *et al* (2005)** who noticed positive effect for magnetic seed treatment on tomato transplant height.

Transplant stem diameter

In general, transplant stem diameter was better with magnetic field treatments comparing with control treatment. The data reported in Table (5) show that the increase in stem diameter was not significant in the first season, while in the second season significant differences was noticed. On the other hand, the magnetic water treatment granted a significant increase in both seasons. The maximum stem diameter was obtained when magnetic seed treatment and magnetically treated water were jointly applied as compared to control treatments. Similar result was noticed by **Ibrahim and Khafagi (2004)** who found that seedlings from seeds treated with magnetic field were thicker than those of the control treatment**.**

Table 4. Effect of magnetic field strength, exposure duration and water salinity on mean germination rate (days) of tomato seeds under optimum germination temperature (26° C)

Salinity (ppm)																					
Distilled water						2500					5000					7500					
Magnetic strength (Tesla)																					
Duration	0	0.1	0.15	0.2	Mean	0	0.1	0.15	0.2	Mean	0	0.1	0.15	0.2	Mean	0	0.1	0.15	0.2	Mean	Mean
0	3.5 m	3.5m	3.5 m	3.5 m	3.5 g	6.9 h	6.9 h	6.9 h	6.9 h	6.9 e	8.7 g	8.7 g	8.7 g	8.7 g	8.7 d	9.9 f	9.9 f	9.9 f	9.9 f	9.9 c	7.3 A
1	3.5 m	3.4 m	3.3 m	3.1 m	3.3 g	6.9 h	5.0 jk	4.8 jkl	4.6 jkl	5.3 f	8.7 g	6.2 hi	6.8 h	6.4 hi	7.1 e	9.9 f	11.0 de	12.0 bc	9.7 f	10.7 ab	6.6 BC
5	3.5 m	3.3 m	3.2 m	3.6 m	3.4 g	6.9 h	4.3 l	5.9 i	4.3 kl	5.4 f	8.7 g	6.6 hi	6.5 hi	6.3 hi	7.0 e	9.9 f	11.2 de	12.7 a	9.8 F	10.9 a	6.7 C
10	3.5 m	3.2 m	3.6 m	3.4 m	3.4 g	6.9 h	4.6 jkl	5.1 j	4.5 jkl	5.3 f	8.7 g	6.1 i	6.8 h	6.1 i	6.9 e	9.9 f	10.6 e	12.1 abc	8.2 g	10.2 c	6.5 C
15	3.5 m	3.1 m	3.5 m	3.5 m	3.4 g	6.9 h	4.4 kl	4.7 jkl	4.4 jkl	5.1 f	8.7 g	4.6 jkl	6.3 hi	8.6 g	7.1 e	9.9 f	11.5 cd	12.4 ab	8.2 g	10.5 b	6.5 BC
Mean	3.5 k	3.3 k	3.4 k	3.4 k	3.5 D	6.9 g	5.0 j	5.5 i	5.0 j	5.6 C	8.7 e	6.5 h	7.1 fg	7.2 f	7.4 B	9.9 c	10.9 b	11.8 a	9.2 d	10.5 A	

Transplant fresh weight

The data reported in Table (5) reveal that in 2005 season insignificant differences was noticed between magnetically treated seed and those of control regarding transplants fresh weight. While in 2006 season, a significant difference was recorded. Magnetic water significantly increased treatment the transplant fresh weight in both growing seasons compared with control treatment. The interactive effect of seed and water magnetic treatments, reveal significant interaction where the highest seedling fresh weight was obtained from those resulted from magnetically treated seeds grown in magnetized water. These results coincide with those of **Florez *et al* (2007)** who reported that maize seedling treated with magnetic field were significantly heavier than the control, **Souza *et al* (2005)** indicated that the pre-sowing magnetic treatment of tomato seeds, that led to significant increase in seedling root and stem fresh weight. Also **Fernandez *et al* (1996)** reported that seedling developed with magnetically irrigation weighed 5.38 g, compared with 2.60 g for seedling irrigated by untreated water**.**

Transplant dry weight

Data in Table (5) clearly indicated that there was a significant increase in transplant dry weight by applying magnetic seed treatment and/or irrigated with magnetize water in both seasons in comparison with non-treated treatment. The results mentioned to the better role of irrigation with magnetize water on transplant growth in the first season, whereas in general the magnetic seed and water treatment surpassed the control treatment in both seasons. This is in corresponding with **Gurusamy and Kalavathi (1998),** they observed that the dry weight of seedling derived from magnetically treated seeds were greater than those in control treatment in cowpea. Also **ozdemir *et al* (2005)** found that electromagnetic treated water increased the root dry weight by 11% comparing with control**.**

Transplant Leaf area

Transplant leaf area was significantly motivated by magnetic treatments as compared with control treatment (Table 5). Concerning the magnetic seed treatment the increase was not significant in first season but in the second the increase in leaf area was significant. The magnetically water treatment lead to significant increment in leaf area in both studying seasons as presented in Table (5). The highest leaf area value was found in seedling grown from seeds treated grown by magnetized water irrigation. The same results was found by **Novitsky *et al* (2001),** they observed the increase in the length of leaf at seedling onion that raised by magnetically treated seeds. The same results were detected by **Souza *et al* (2005)** and **khattab *et al* (2000).**

The acting mechanism of the magnetic field in plants and other living systems are not well known yet**, (Florez *et al*, 2007),** but some theories explain this phenomenon as the hypothesis of **Balouchi *et al* (2007)** confirmed that MF influences the structures of cell membrane, and increases their permeability and ion transport**,** which then affects some metabolic pathways. **Moon and change (2000)** reported that magnetic field treatments influencing the biochemical processes involve free radicals by stimulating the activity of proteins and enzymes**.** Also **Reina *et al* (2001)** attributed the increase in the germination speed of the seeds treated with stationary magnetic fields to the increase in water uptake rate in treated seeds. **Florez *et al* (2007)** ratified that magnetic field treatment led to biochemical changes or altered enzyme activities and increase water uptake rate.

Authors concluded that irrigation with magnetically water is an ecological and harmless

technology and should be recommended for applying in agriculture, **Carbonell *et al* (2004)** confirmed that the magnetic water treatment showed higher values for mobile forms of nitrogen, phosphorus and potassium and improved the dissolve of fertilizers in the soil irrigated with magnetized water**.** The studies revealed that irrigation with magnetically treated water increase nutrient uptake as mentioned by **Diaz *et al* (1997)** on tomato and **khattab *et al* (2000)** on gladiolus cormels**.** Magnetic field also improved the properties of water but the mechanisms of action for the effect of seeds or water exposed to the magnetic field are not well known yet**.**

Table 5. the effect of seed and water magnetic treatments on height , stem diameter, fresh weight, dry weight and leaf area of tomato seedling in (2005 and 2006) seasons

Seed Treatment	2005			2006		
	Water treatment		Mean	Water treatment		Mean
	Magnetic	Tap		Magnetic	Tap	
			Seedling height (cm)			
Magnetic	20.38 a	16.96 ab	18.67 A	21.48 a	20.69 a	21.08 A
Untreated	20.25 a	15.56 b	17.90 A	20.98 a	16.26 b	18.62 B
Mean	20.32 A	16.26 B		21.23 A	18.48 B	
			Stem diameter (mm)			
Magnetic	3.29 a	2.98 ab	3.13 A	3.49 a	3.37 a	3.43 A
Untreated	3.31 a	2.64 b	2.97 A	3.44 a	2.75 b	3.09 B
Mean	3.30 A	2.81 B		3.47 A	3.06 B	
			Fresh weight (g)			
Magnetic	4.64 a	3.75 ab	4.20 A	4.91 a	4.52 a	4.71 A
Untreated	4.69 a	3.06 b	3.88 A	4.86 a	3.26 b	4.06 B
Mean	4.67 A	3.41 B		4.88 A	3.88 B	
			Dry weight (g)			
Magnetic	0.32 a	0.28 b	0.30 A	0.35 a	0.34 a	0.34 A
Untreated	0.31 a	0.21 c	0.26 B	0.33 a	0.22 b	0.27 B
Mean	0.32 A	0.24 B		0.34 A	0.28 B	
			Leaf area (cm2)			
Magnetic	21.46 a	17.96 ab	19.71 A	22.51 a	21.09 a	21.80 A
Untreated	20.65 a	16.51 b	18.58 A	21.71 a	17.06 b	19.39 B
Mean	21.06 A	17.24 B		22.11 A	19.08 B	

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