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Effect of magnetic field on germination, seedling growth and cytogenetic of onion (*Allium cepa* L.)

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Magnetic field is considered a simple and cheap method for stimulation of germination process compared to traditional chemical processes. In this research, laboratory experiment was conducted at Seed Technology Unit, Mansoura, Egypt to evaluate the effect of magnetic field on germination, seedling growth and cytogenetic characters of fresh and carry over (old) onion seeds (c.v.Giza Red). Seeds were magnetically pretreated by different magnetic field (0.03 or 0.06 T) using static magnetic device for different periods time (30, 60 and 90 mint). The obtained results indicated that magnetic field treatment increased all germination and seedling growth characters compared with control. Exposed fresh and carry over seeds to 0.06 T with 30 mint gave the heights values of germination percentage, germination rate, speed germination index and seedling growth parameters, that is, seedling length, seedling dry weight, seedling vigor I and seedling vigor II. Whereas, mean germination time was decreased using 0.03 T with 60 mint gave maximum values in carry over seeds and with 60 min in new seeds. Also, the results showed significant increase in mitotic activity and chromosomal aberration after 30 min treatments for both doses of fresh seeds and with 0.06 T of carry over seeds, while relative division rate (RDR) gave positive values and little disturbance in mitotic phase index. However, the percentage of mitotic abnormalities increased after all exposure treatments. It could be concluded that utilization of magnetic field could enhancement of germination of onion seeds but we need to be carry out more experiments to make magnetic map for all varieties of onion.

Key words: Magnetic field, germination, mitotic activity, phase index, relative division rate, mitotic aberrations.

INTRODUCTION

Onions are an important food crop worldwide. Since many years one has been observing problems with storing onion seeds. Seeds generally have a relatively short storage life and viability decreases rapidly. The main reasons of low quality of onion seed listed: Long

flowering period resulted in different stages of seed maturity in the umbel and suboptimal storage conditions as high temperature and relative humidity (Brocklehurst, et al., 1985).

For this reason, for many years there have been

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research works to improve seed germination and to prolong their use for sowing (Kelly, 1998). The improvement in seed germination have been achieved by different pre-sowing treatments including various physical factors such as electric field, magnetic field, laser radiation and microwave radiation (Pietruszewski and Kania, 2010). Over the years, the effects of magnetic fields on plant life have been the subject of different research studies. The first studies were conducted by Savostin (1930) who reported 100% increase in the rate of elongation of seedlings under the influence of magnetic condition. Recently, many authors have reported that magnetic field was affective on seed germination, seedling growth, reproduction and growth of meristem cells and chlorophyll quantities (Namba et al., 1995; Atak et al., 1997; Reina et al., 2001; Amera and Hozayn, 2010a, b; Hozayn et al., 2014). Magnetic field had a positive effect on photochemical activity, respiration ratio and enzyme activity (Martinez et al., 2000; Phirke et al., 1996; Carbonell et al., 2002). The reason of this effect can be searched in the presence of paramagnetic properties in chloroplast which can cause an acceleration of seeds metabolism by magnetic treatment (Aladjadjiyan and Ylieva, 2003). Physiological mechanisms of magnetic field on germination and seedling growth are not completely understood. Magnetic field treatment of seeds leads to acceleration of plants growth, proteins biosynthesis and root development (Kordas, 2002). Racuciu et al. (2008) reported that the activities of some enzymes were increased by exposure to magnetic field. Copeland and Donald (1995) reported that the effectiveness of the magnetic field stimulation is evaluated based on two parameters. These are: Energy of germination and capacity of germination. A result of higher energy of germination is often, stronger development of a radicle, increased fresh mass of the whole seedling and thereafter a plant. This, usually, results in better plant useful characters, e.g. yield of roots, bulbs or leaves (Kubisz et al., 2012) found that exposure onion seeds to magnetic field (20 mT) for 60 min increased their germination % from 4.6 control to 22%.

Recently some magnetic devices have been developed by Magnetic technologies L.L.C., Box 27559, Dubai, UAE with the claim that after passing seed through these devices get bio-stimulated. This magnetized seed exhibits better results in terms of germination and plant growth. Keeping in view their claim, the current study was undertaken to determine the influence of magnetic treatment on germination, seedling growth rate and cytogenetic in onion.

MATERIALS AND METHODS

This study was conducted at Seed Technology Unit, Mansoura, Egypt to evaluate the effect of magnetic field on germination characters of fresh and carry over (old) onion seeds. Onion seeds (c.v.Giza Red) production of season 2012 (carry over seed) and

2013 (fresh seed) were obtained from Onion Research Department, Field Crops Institute, Agriculture Research Centre, Giza, Egypt. Seeds immersed in 5% NaOCl (Sodium hypochloride solution) for 5 min to avoid fungal invasion. Seeds were exposed to magnetic field through rimming it in static magnetic device (Magnetic Technologies L.L.C) (Figure 1) with 0.03 or 0.06 T for different periods time (30, 60 and 90 min). Germination tests were performed according to ISTA (1999), while 300 seed of onion were sown in 3 replicates in 20±1°C in sterilized Petri dishes covered at the bottom with two sheets of Whitman filter paper that had been autoclaved and germination was performed daily to study the following characters:

1. Germination percentage defined as the total number of normal seedlings at the end of the test after twelve days.
2. Germination rate (GR): It was defined according to the following formula of Bartlet (1937):

$$GR = \frac{a + (a + b) + (a + b + c) + \dots + (a + b + c + m)}{n(a + b + c + m)}$$

Where a, b, c are No. of seedlings in the first, second and third count, m is No. of seedlings in final count, n is the number of counts.

3. Speed germination index (SGI): It was calculated as described in the Association of Official Seed Analysis (AOSA, 1983) by following formula:

$$SGI = \frac{\text{No. of germinated seed}}{\text{Days of first count}} + \dots + \frac{\text{No. of germinated seed}}{\text{Days of final count}}$$

4. Mean germination time (MGT): It was calculated based on the equation of Ellis and Roberts (1981):

$$MGT = \frac{\sum Dn}{\sum n}$$

Where (n) is the number of seeds, which were newly germinated on day, D is number of days counted from the beginning of germination.

5. Seedlings length (cm): It was measured of ten normal seedling 12 days after planting.
6. Seedlings dry weight (gm): Ten normal seedlings 12 days after planting, the seedlings were dried in hot-air oven at 85°C for 12 h to obtain the seedlings dry weight (g).
7. Seedling vigor was calculated following Abdul Baki and Anderson (1973) as:

$$\text{Vigor index I} = \text{Germination (\%)} \times \text{Seedling length (Root + Shoot)}$$

$$\text{Vigor index II} = \text{Germination (\%)} \times \text{Seedling dry weight (Root + Shoot)}$$

Cytogenetic analysis

After both fresh and carry over germinating roots were grown until they reached about 1 to 1.5 cm in length. The root tips were then used for cytogenetic investigation and analysis. Roots were fixed in ethanol : acetic acid (3:1) for 24 h, hydrolysed in 1 M HCl for 10 min then stained with aceto-orcien for 24 h. Root tips were cut off in a drop of 45% acetic acid, macerated and squashed (Sharma and Sharma, 1980). Three replicates were performed for each mentioned treatments and scoring about 2000 cells was done from at least 5 roots of each replicate. Mitotic Index (MI), frequencies of mitotic phases (prophase, metaphase, anaphase and telophase), relative division rate (Relative division rate (RDR)) calculated by the formula (Hoda et al., 1991):

$$RDR\% = \frac{\text{\% of dividing cells in treated sample} - \text{\% of dividing cells in control sample}}{100 - \text{\% of dividing cells in control bulbs}} \times 100$$



Figure 1. Magnetic devices used to treat onion seed.

Mitotic abnormalities were used as endpoints for determination of cytogenetic effects. The MI was calculated as the ratio between the number of mitotic cells and the total number of scored cells and expressed as percentage. The frequency of mitotic abnormalities was expressed as a percentage in relation to the number of cells in mitosis. The most frequent abnormalities are shown in photomicrographs.

Statistical analysis

Data were statically analyzed using an analysis of variance (ANOVA) of completely randomized design (MSTAT-C v. 3.1., 1988). Least Significant Difference (LSD) was applied to compare mean values.

RESULTS

Germination traits

General results showed that magnetic field enhanced seed germination and seedling growth parameters comparing with untreated seeds.

Data presented in Table 1 showed that significant effect on Germination % (G), Germination Rate (GR) and Speed Germination Index (SGI) and Mean Germination Time (GMT) occurred by exposes carry over and new onion seeds for two magnetic field (0.03T and 0.06 T) at different time exposure (30, 60 and 90 min) compared to untreated seeds. Regarding germination percentage, the highest values achieved by exposing seeds to 0.06T for 30 min in new and carry over onion seeds where G (%) increased from 82 and 54% in control to 90 and 70% on new and carry over seed, respectively. Germination rate increased from 0.729 in control to 0.793 when exposed to 0.03 T at 30 or 60 min on new seeds and from 0.688 to 0.739 when exposed to 0.03 T at 30 min on carry over seed. SGI increased from 23.48 to 35.72 in new seed and from 18.44 to 22.96 in old seed. Whereas, using 0.03

T with 30 min gave the maximum increase in G%, GR and SGI on new seeds and with 60 min on old seeds. Data in the same table show that significant decrease in mean germination time in magnetically treated onion seeds. Whereas the minimum MGT 2.87 and 3.45 were occurred from treated seed with 0.06 T for 30 min in new and carry over seeds. MGT decreased (3.35 to 3.43) in 0.03T with 30 min in new seed and (3.32 to 3.80) with 60 min in carry over seed.

It could be concluded that, using 0.03T with 30 min gave the maximum increase regarding new seeds and with 60 min on carry over seeds in above mentioned characters compared to untreated treatment.

Seedling growth

Regarding to seedling growth characters, results clear that a positive effect of different magnetic treatments on seedling length and dry weight, seedling vigor and seedling vigor index compared with untreated treatment (Table 2). The maximum increases were resulted from using 0.06T for 30 min in new and carry over seeds in all mentioned parameters. These increases reached to 58.50, 46.66, 49.13 and 74.15% in new seed and to 109.52, 72.72, 78.54 and 115.90% in carry over seed at the above parameters, respectively compared with control treatment. On the other hand, exposing seeds to 0.03 T gave the highest values with 30 min on new seeds and with 60 min on carry over seeds.

Cytogenetic analysis

Mitotic index (MI) results showed significant increase after all magnetic treatments for both fresh and carry over seeds as shown in Table 3. For fresh seeds, exposed for 30 min gave the highest values in both doses 0.03T and

Table 1. Effect of magnetic field treatments on germination traits of fresh and carry over onion seeds.

Character	Germination (G) (%)		Germination rate (GR)		Speed germination index (GRI)		Mean germination time (MGT) (day)	
	Fresh	Carry over	Fresh	Carry over	Fresh	Carry over	Fresh	Carry over
Control	82.00	46.00	0.70	0.69	23.48	18.44	3.43	3.80
0.03 T 30 min	90.00	64.00	0.74	0.70	28.56	19.60	3.35	3.50
0.03 T 60 min	90.00	66.00	0.78	0.73	28.56	20.60	3.86	3.32
0.03 T 90 min	90.00	56.00	0.70	0.68	26.32	18.44	4.38	3.85
0.06 T 30 min	90.00	70.00	0.79	0.74	35.72	22.96	2.87	3.45
0.06 T 60 min	90.00	58.00	0.79	0.72	34.12	22.72	2.87	3.48
0.06 T 90 min	88.00	56.00	0.72	0.68	28.92	21.40	3.57	3.88
F significant	**		**		**		**	
LSD_{5%}	12.19		0.04		0.81		0.28	
CV (%)	9.85		2.56		7.6		4.66	

LSD_{5%}= Least significance difference at probability 5% level; CV= coefficient of variation; T = Tesla.

Table 2. Effect of magnetic field treatments on seedling traits of fresh and carry over onion seeds.

Character	Seedling length (cm)		Seedling dry wt. (g)		Seedling Vigor		Seedling vigor index	
	Fresh	Carry over	Fresh	Carry over	Fresh	Carry over	Fresh	Carry over
Control	10.00	6.30	0.016	0.011	1.32	0.62	821.00	352.80
0.03 T 30 min	10.65	6.65	0.015	0.018	1.34	1.13	958.20	428.40
0.03 T 60 min	9.55	6.45	0.012	0.016	1.09	1.05	845.40	424.60
0.03 T 90 min	7.90	7.65	0.010	0.019	0.93	0.88	701.40	346.40
0.06 T 30 min	15.85	13.20	0.022	0.019	1.97	1.11	1429.80	762.00
0.06 T 60 min	13.65	8.70	0.019	0.016	1.68	0.91	1230.60	487.20
0.06 T 90 min	11.80	9.05	0.017	0.013	1.53	0.89	1036.80	631.60
F significant	**		**		**		**	
LSD_{5%}	1.76		0.002		0.26		155.45	
CV (%)	10.7		6.37		13.64		12.44	

LSD_{5%}= Least significance difference at probability 5% level; CV= coefficient of variation; T = Tesla.

0.06T which recorded values (13.30 and 14.13), respectively compared to control (10.42), while exposing carry over seed for 30 and 60 min gave the highest values at 0.03T (11.15) and 0.06T (10.68). Relative division rate (Relative division rate (RDR)) gave positive values after all magnetic treatments for both seeds coordinate with the increase in mitotic index and germination (Table 3). In the same table, phase index showed little disturbance decreasing or increasing in their values. Where in fresh seeds (0.03 T for 60 min) treatment found to have the pronounced change in prophase which decreased about 9.52% compared to control as well as in carry over seeds (0.06 T for 90 min) treatment was increased about 25.71% compared to control.

Relative division rate (Relative division rate (RDR)) had positive values after all magnetic treatments (Table

4), where the maximum increase was recorded in fresh seed which exposed to 0.06 T for 30 min. Data in the same table show significant increases in Aberrations index (AI) (chromosomal aberrations) under magnetic treatments compared to control. Where, exposing fresh seeds to 0.06T for 90 min treatment had the highest aberration with (3.05) compared to control (0.27) as well as for carry over seeds at 0.06 T with 90 min treatment (2.50) value compared to control (1.20). Generally, the recorded aberration percentage in this study found to be not lethal. Stickiness and micronucleus were the most recorded chromosomal aberration types; more pronounced were observed when both fresh and carry over seeds exposed to 0.06 T for 90 min, laggard chromosome and binucleolate cell also recorded (Table 4 and Plate).

Magnetic field treatments improved germination

Table 3. Effect of magnetic field treatments on mitotic index (MI), aberration index (AI), relative division rate (RDR) and phase index (P=Prophase, M=Metaphase, A=Anaphase and T=Telophase) of fresh and carry over onion seeds.

Treatment			MI	AI (%)	RDR	Phase index				
Age	Dose	Time				Pro	M	A	T	
Fresh	Control		10.42	0.27	--	18.58	32.04	27.84	21.55	
		30 min	13.13	0.63	3.02	17.31	34.29	29.29	19.10	
		60 min	12.57	0.90	2.40	16.81	35.21	30.10	17.87	
	0.03 T	90 min	11.05	1.15	0.70	19.64	34.56	26.91	18.89	
		30 min	14.13	1.91	4.14	20.77	33.52	25.05	20.66	
		60 min	13.04	2.38	2.92	19.58	34.64	26.68	19.10	
	0.06 T	90 min	12.15	3.05	1.93	16.56	36.80	27.65	18.99	
		Control		8.52	1.25	--	19.85	33.80	26.13	20.22
			30 min	9.88	1.24	1.49	18.74	33.61	28.05	19.60
60 min	10.68		1.54	2.36	18.83	34.49	29.79	16.97		
Carry over	0.03 T	90 min	9.01	1.57	0.53	19.53	34.22	28.96	16.90	
		30 min	11.15	1.77	2.87	21.62	34.15	24.71	19.53	
		60 min	9.99	1.95	1.61	17.55	35.89	28.71	17.85	
	90 min	9.61	2.50	1.19	15.75	37.03	29.45	17.77		
F significant			**	**		**	**	**	**	
LSD_{5%}			1.15	0.86		0.27	0.61	1.04	0.89	
CV (%)			3.63	1.85		1.45	23.85	3.32	1.54	

LSD_{5%}= Least significance difference at probability 5% level; CV= coefficient of variation; T = Tesla.

Table 4. Effect of magnetic field treatments on chromosomal aberrations (CA) of fresh and carry over onion seeds.

Treatment			Total cell count	Miotic cell count	Type of aberration					Total	
Age	Dose	Time			Sticky	Lag	Bi-nucleus	Micro-nucleus	Other		
Fresh	Control		6010	626	-	-	-	1	1	2	
		30 min	6072	797	1	-	-	1	1	3	
		60 min	6056	761	2	1	1	1	2	7	
	0.03 T	90 min	6001	663	1	1	-	2	3	7	
		30 min	6100	862	4	2	3	3	5	17	
		60 min	6031	786	5	2	3	5	4	19	
	0.06 T	90 min	6028	732	7	4	3	5	3	22	
		Control		6011	512	2	-	1	2	2	7
			30 min	6034	596	2	-	2	1	2	7
60 min	6082		650	3	1	2	2	2	10		
Carry over	0.03 T	90 min	6100	550	3	1	1	1	3	9	
		30 min	6051	675	4	2	2	1	3	12	
		60 min	6038	603	3	2	2	2	3	12	
	90 min	6075	584	5	3	3	2	2	15		

parameters of fresh and carry over onion seeds (Table 1). Studies made on various plants have shown that positive effects of magnetic field on seed germination. Kubisz et al. (2012) showed that low frequency of

magnetic field (20 mT) can be successfully used to improve germination of onion (4.6 to 22%). Also, they recorded that treated onion seeds (cultivar Eureka) with 20 mT for 60 min increased their energy of germination

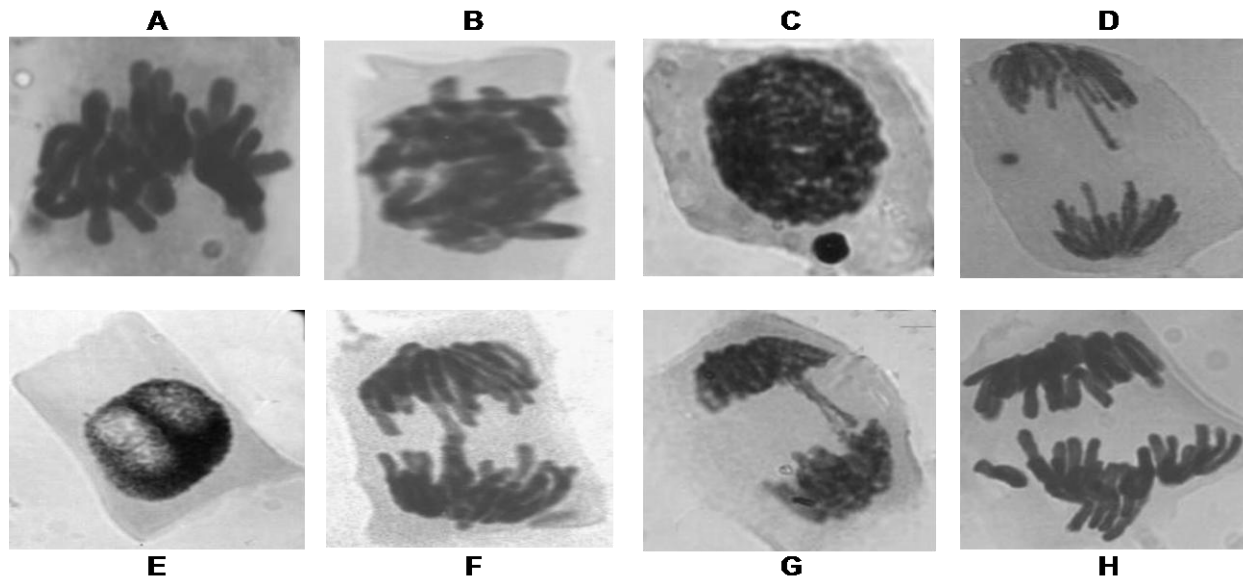


Plate 1. Types of chromosomal aberrations resulted from the treatment of *Allium cepa* seeds (fresh and carry over) with magnetic field, (a-b) stickiness, (c-d) micronucleus, (e) binucleolate nucleus, (f-g) bridge and (h) laggard chromosome.

from 40% to 63%, which improves evenness of plants emergences in the field and has a significant importance for horticultural practice. Celestino et al. (2000) observed that germination was faster for seeds exposed to the magnetic field than those in the control group, and germination percentage increased. Alexander and Dojode (1995) reported that pre-germination treatment improved the germination and seedling vigor of low viability onion and rice seeds. In treated wheat seeds germination was raised from 45.3 to 49.3% (Ijaz et al., 2012). Flórez 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. Magnetic field treatment of seeds leads to acceleration of plants growth, proteins biosynthesis and root development (Kordas, 2002). Carbonell et al. (2002, 2004). found that magnetic treatment produced a biostimulation of the germination. The activities of some enzymes were increased by exposure to magnetic field (Racuciu et al., 2008). Stress enzyme like APX and SOD increased in seedling which was grown from pretreated seeds, these stress enzymes have antioxidant mechanism they scavenge free radicals and decrease oxidative stress (Azita and Ahmad, 2009). Ahmad et al. (2010) showed that Mean germination time (MGT) significantly increased when the time of seed exposed at magnetic field treatments increased, about 3 and 2 h respectively for Omid and BCR wheat cultivars.

Regarding to seedling growth, our results clear that a positive effect on testing parameters seedling length, seedling dry weight, seedling vigor and seedling vigor index (Table 2). Similar results were obtained by Kubisz et al. (2012), they observed that clear differences in the

length of radicals and fresh mass of seedling, longer radicals and bigger seedling than the ones from the control on the onion seeds exposed to magnetic field. Waleed et al. (2013) showed that root length, length of radical, dry weight of root and radical increased by 18, 12, 0.52 and 43%, respectively when exposed wheat seeds to (50 mT/30 min). Azita and Majd (2009) showed that the Lentil seedlings from seeds magnetically pretreated grew taller and heavier than untreated controls, they showed greatly improved root characteristics. Magnetic field treatment of seeds led to acceleration of plants' growth, protein biosynthesis and root development (Hirota et al., 1999; Pe-uelas et al., 2004; Amera and Hozayn, 2010a, b; Hozayn et al., 2014). Aladjaadjiyan (2005) concluded that magnetic field increased the shoot and root regeneration rate and their fresh weight in soybean and paulownia organ cultures. Azita and Ahmad (2009) suggested that pretreated plants by magnetic fields are more resistant against harmful environmental factors. Regarding cytogenetic parameters, magnetic treatment at low frequencies exerts significant increase the mitotic index in meristematic cells of *Allium cepa* and induces chromosomal aberration (Tables 3 and 4 and Plate 1). Similar results were recorded by Tkalec et al. (2009); they showed a significant increase of mitotic index in *A. cepa* roots after 900 MHz electromagnetic field exposure as well as mitotic abnormalities increased. Aksoy et al. (2010) found that mitotic index of *A. cepa* was significantly increased at 0, 10 and 25 m distance from magnetic field treatments compared with control, MI analysis showed significantly increased the cell division a dose dependent manner in *A. cepa* L. and in *Triticum baeticum* Boiss. As

well as they found differences in mitotic phases in both plants. Marcano et al. (2004) considered mitotic index a parameter that allows one to estimate the frequency of cellular division. Root growth depends on mitotic activity and cell elongation (Evseeva et al., 2005); these processes could be influenced by magnetic field. Moreover, Marcano et al. (2004) considered mitotic index a parameter that allows one to estimate the frequency of cellular division. Root growth depends on mitotic activity and cell elongation (Evseeva et al., 2005); these processes could be influenced by magnetic field.

Aberration percentage in this study is found to be not lethal. The chromosomal aberrations resulting from magnetic exposure might be due to the direct interaction with moving electrons within DNA (Blank and Goodman, 1998). Eren et al. (2010) found various types of mitotic defects in MF-exposed lentil roots, such as stickiness, c-mitosis, micronuclei, double nuclei. Induction of chromosome aberrations, such as stickiness, has long been known to occur in response to many environmental agents, including chemical mutagens (Yumurtacı et al., 2007; Türkoğlu, 2009) and certain kinds of magnetic or electric fields (Rapley et al., 1988). Chromosomal aberrations (CA) occur due to lesions in both DNA and chromosomal spindle protein causing genetic damage (Amin, 2002), and may be induced by other factors, such as DNA breaks, inhibition of DNA synthesis and replication of altered DNA. Cell metabolism is sensitive to a range of nonspecific weak treatments that do not directly affect receptors or any other specialized cell structures (Racuciu, 2011). While Tkalec et al. (2009) found exposure of *A. cepa* to magnetic field under most of the test conditions induced a significant increase of mitotic activity in root tips of *A. cepa* compared with control. This study may prove that MFs altered rates of DNA, RNA, and protein synthesis as other previous studies (Goodman et al., 1993; Greene et al., 1993; Zhao et al., 1999). Magnetic fields affect the synthesis of DNA and RNA as well as the cellular proliferation. EMFs in both extremely low frequencies activate the cellular stress response, a protective mechanism that induces the expression of stress response genes (Ruediger, 2009). Consequently, MFs alters gene expression, protein biosynthesis, enzyme activity, cell reproduction and cellular metabolism (Nirmala and Rao, 1996). Studies on the meristematic cells of plants have shown that magnetic field effects normal metabolisms and has impact on cellular division (Belyavskaya et al., 1992; Dhawi et al., 2009).

Different studies evident that MFs of different intensities causes certain genotoxic effects in plants. During mitosis and meiosis both these fields are supposed to cause a number of chromosomal aberrations including stickiness, lagging chromosomes, micronuclei formation, bridges, multipolar division etc. (Racuciu et al., 2009; Aksoy et al., 2010; Zaidi et al., 2012; Zaidi et al., 2012), Induction of different types of chromosomal aberrations (Garcia-

Secrado and Monteagudo, 1991; Nordenson, et al., 1994). Stickiness may be due to degradation or polymerization of chromosomal DNA (Darlington and Mc-Leich, 1951) or may be due to defective functioning of one or two types of specific nonhistone proteins involving chromosome organization (Turkoglu, 2007). Some chromosomal aberrations induced by suitable MF exposure time of plant seeds may persist in the next generations so that some phenotypic characters may be modified (Racuciu, 2011) and these modifications could be observed following the plant development, some of them being benefit for the cultivation of this species (Attia et al., 2014). This way, the extremely low frequency MF could represent the molecular basis of a putative tool in the biotechnology of plant growth, an important species in the human life, with the advantages of being less toxic and most easy to manipulate in comparison to ionizing radiation for instance (Racuciu, 2011). Chromosomal aberrations that could cause delayed prophase and/or metaphase leading to an increased mitotic index (Evseeva et al., 2005).

Conclusion

The obtained results indicated that magnetic field exposure increased all germination characters compared with control. Exposed carry over and fresh onion seeds to 0.06 T with 30 min gave the greatest values of germination percentage, germination rate, germination energy, speed germination index and seedling vigor (seedling length (cm), seedling dry weight (g), seedling vigor I and seedling vigor II). Whereas, Mean germination time was decreased. Using 0.03T with 60 min gave maximum values in carry over seeds and with 60 min in new seeds. Significant increase in mitotic activity and chromosomal aberration after treatment with both doses for 30 min in fresh seeds and with 0.06 T in carry over seeds, while Relative division rate (RDR) gave positive values and little disturbance in mitotic phase index. However, the percentage of mitotic abnormalities increased after all exposure treatments. Hence, change in protein biosynthesis. The previous results indicate the change in cellular proliferation at low magnetic frequencies.

Conflict of Interest

The authors have not declared any conflict of interest.

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REFERENCES

- Abdel Migid HM, Abdelrahman HHM (2013). Phyto-genotoxicity Assessment of Sewage Water for Agriculture Applications. *Res. J. Pharm. Biol. Chem. Sci.* 4(2):511-529.
- Abdul-Baki AA, Anderson JD (1973). Vigour determination in soybean by multiple criteria. *Crop Sci.* 10:31-34. <http://dx.doi.org/10.2135/cropsci1970.0011183X001000010012x>
- Ahmad G, Sharafi S, Abbasdokht H (2010). Effect of Magnetic Field on Seed Germination of Two Wheat Cultivars. *World Acad. Sci. Eng. Technol.* 44:8-23.
- Aksoy H, Unal F, Ozcan S (2010). Genotoxic Effects of Electromagnetic Fields from High Voltage Power Lines on Some Plants. *Int. J. Environ. Res.* 4(4):595-606.
- Aladjaadjiyan A (2010). Influence of stationary magnetic field on lentil seeds. *Int. Agro Phys.* 24:321-324.
- Aladjaadjiyan A, Ylieva T (2003). Influence of stationary magnetic field on the early stages of the development of tobacco seeds (*Nicotiana tabacum* L.). *J. Central. Europe. Agric.* 132,4(2):131-138.
- Alexander MP, Doijode SD (1995). Electromagnetic field, a novel tool to increase germination and seedling vigor of conserved onion (*Allium cepa* L.) and rice (*Oryza sativa* L.) seeds with low viability. *Plant Genet. Resour. Newsl.* 104:1-5.
- Amin AW (2002). Cytotoxicity testing of sewage water treatment Using *Allium cepa* chromosome aberrations assay Pak. *J. Biol. Sci.* 5(2):184-188. <http://dx.doi.org/10.3923/pjbs.2002.184.188>
- Amera AMS, Hozayn M (2010a). Magntic water technology, a novel tool to increase growth, yield, and chemical constituents of lentil (*Lens esculenta*) under greenhouse condition. *Amer.-Eurasian J. Agric. Environ. Sci.* 7(4):457-462.
- Amera AMS, Hozayn M (2010b). Response of growth, yield, yield components and some chemical constituent of flax for irrigation with magnetized and tap water. *World Appl. Sci. J.* 8(5):630-634.
- AOSA (Association of Official Seed Analysis) (1983). Seed Vigor Testing Handbook. Contribution to the Handbook on Seed Testing. P. 32.
- Atak C, Danilov V, Yurttas B, Yalçın S, Mutlu D, Rzakoulieva A (1997). Effects of magnetic field on soybean (*Glycine max* L.Merrill) seeds. *Com JINR. Dubna* pp. 1-13.
- Attia SAA, Gad N, Abdel-Rahman HM (2014). Effect of Cobalt on Growth, Yield and Production Quality with Mitotic and Meiotic Divisions in Two Onion Cultivars. *Current Sci. Int.* 3(2):122-131.
- Azita Sh, Ahmad M (2009). Effect of Magnetic Fields on Growth and Antioxidant Systems in Agricultural Plants PIERS Proceedings, Beijing, China, March 23-27.
- Bartlett MS (1937). Some samples of statistical method of research in agriculture and applied biology. *J. Roy. Soc.* 4:2.
- Belyavskaya NA, Fomicheva VM, Govorun RD, Danilov VI (1992). Structural Functional Organization of the Meristem Cells of pea, Lentil and Flax Roots in Conditions of Screening the Geomagnetic Field. *Biophysics* 37:657-666.
- Blank M, Goodman R (1998). Do electromagnetic fields interact directly with DNA? *Bioelectromagnetics*, 19:136-138. [http://dx.doi.org/10.1002/\(SICI\)1521-186X\(1998\)19:2<136::AID-BEM14>3.0.CO;2-O](http://dx.doi.org/10.1002/(SICI)1521-186X(1998)19:2<136::AID-BEM14>3.0.CO;2-O)
- Brocklehurst K, Salih E, McKee R, Smith H (1985). Fresh non-fruit latex of *Carica papaya* contains papain, multiple forms of chymopapain A and papaya proteinase omega. *Biochem. J.* 228(2):525-527.
- Carbonell MV, Martinez E, Amaya JM (2002). Stimulation of germination in rice (*Oryza sativa* L.) by a static magnetic field. *Electromagnet Biol.* 19(1):121-128. <http://dx.doi.org/10.1081/JBC-100100303>
- Carbonell MV, Martinez E, Díaz JE, Amaya M, Flórez M (2004). Influence of magnetically treated water on germination of signalgrass seed. *Seed Sci. Technol.* 32:617-619. <http://dx.doi.org/10.15258/sst.2004.32.2.30>
- Celestino C, Picazo ML, Toribio M (2000). Influence of chronic exposure to an electromagnetic field on germination and early growth of *quercus suber* seeds: preliminary study. *Electromagn. Biol. Med.* 19(1):115-120.
- Copeland LO, Donald MB, (1995). Principles of Seed Science and Technology. 2nd ed., Burgass Publ. Co., Minneapolis, Minnesota.
- Darlington CD, Mc-Leich L (1951). Action of maleic hydrazide on the cell. *Nature* 167:407-408. <http://dx.doi.org/10.1038/167407a0>
- Dhawi F, Al-Khayri JM, Hassan E (2009). Static magnetic field influence on elements composition in date palm (*Phoenix dactylifera* L.). *Res. J. Agric. Biol. Sci.* 5:161-166.
- Ellis HRA, Roberts EH (1981). The quantifications of ageing and survival in orthodox seed. *Seed Sci. Technol.* 9:373-407.
- Eren P, Vardar F, Birbir Y, İnan D, Ünal M (2010). Cytotoxic effect of an electromagnetic field on the meristematic root cells of lentils (*Lens clunaris* Medik.). *Fresen. Environ. Bull.* 19(3):481-488.
- Evseeva TI, Geras'kin SA, Shuktomova II, Taskaev AI (2005). Genotoxicity and cytotoxicity assay of water sampled from the underground nuclear explosion site in the north of the Perm region (Russia), *J. Environ. Radioact.* 80:59-74. <http://dx.doi.org/10.1016/j.jenvrad.2004.08.014>
- Flórez M, Carbonell MV, Martínez E (2007). Exposure of maize seeds to stationary magnetic field: effects on germination and early growth. *Environ. Exp. Bot.* 59:68-75 <http://dx.doi.org/10.1016/j.envexpbot.2005.10.006>
- Garcia-Secrado JM, Monteagudo JL (1991). Effect of low level pulsed electromagnetic fields on human chromosomes in vitro: Analysis of chromosomal aberrations. *Hereditas* 115:9-11. <http://dx.doi.org/10.1111/j.1601-5223.1991.tb00339.x>
- Goodman EM, Greenbaum B, Marron MT (1993). Altered protein synthesis in a cell free system exposed to a sinusoidal magnetic field. *Biochim. Biophys. Acta* 1202:107-112. [http://dx.doi.org/10.1016/0167-4838\(93\)90070-8](http://dx.doi.org/10.1016/0167-4838(93)90070-8)
- Greene JJ, Pearson SL, Skowronski WJ, Nardone RM, Mullins JM, Krause D (1993). Gene-specific modulation of rRNA synthesis and degradation by extremely low frequency electromagnetic fields. *Cell Mol. Biol.* 39:261-268.
- Hirota N, Nakagawa J, Kitazawa K (1999). Effects of a magnetic field on the germination of plants. *J. Appl. Phys.* 85(8):5717-5719. <http://dx.doi.org/10.1063/1.370262>
- Hoda Q, Bose S, Sinha SP (1991). Vitamin C mediated minimization of Malathion and Rogor induced mitoinhibition and clastogeny. *Cytologia*, 56:389-397. <http://dx.doi.org/10.1508/cytologia.56.389>
- Hozayn M, Abd El-Monem AM, Alwia TA, Abdallah MM (2014). Future of magnetic agriculture in arid and semi arid regions (case study). *Series A. Agron.* 57:197-204.
- Ijaz B, Shakeel AJ, Dawood A, Shahid MM, Sadar US (2012). Changes in germination behavior of wheat seeds exposed to magnetic field and magnetically structured water. *Afr. J. Biotechnol.* 11(15):3575-3582.
- ISTA (1999). International Seed Testing Association. International rules for seed testing. *Seed Sci. Technol. Proc. Int. Seed Test. Ass.* 31(1):1-152.
- Kelly AF (1998). *Encyclopaedia of Seed Production of World Crops*, Wiley, Chichester.
- Kordas L (2002). The Effect of Magnetic Field on Growth, Development and the Yield of Spring Wheat, *Polish J. Environ. Stud.* 11(5):527-530.
- Kubisz L, Holubowicz R, Gauza M, Li H, Hojan-Jeziarska D, Jaroszyk F (2012). Effect of low frequency magnetic field on germination of onion (*Allium cepa* L.) seeds. *Acta Physica Polonica A*, P. 121, No. 1-A.
- Marcano L, Carruyo I, Del Campo I, Montiel X (2004). Cytotoxicity and mode of action of maleic hydrazide in root tips of *Allium cepa* L. *Environ. Res.* 94:221-226.
- Martinez E, Carbonell MV, Amaya JM (2000). A static magnetic field of 125 mT stimulates the initial growth stages of barley (*Hordeum vulgare* L.). *Electr. Magnetobiol.* 19(3):271-277.
- MSTAT-C (1988). MSTAT-C, a microcomputer program for the design, arrangement and analysis of agronomic research. Michigan State University, East Lansing.
- Namba K, Sasao A, Shibusawa S (1995). Effect of magnetic field on germination and plant growth. *Acta Hort.* 399:143-147.
- Nirmala A, Rao PN (1996). Genetic of chromosome numerical mosaism in higher plants. *Nucleus* 39:151-175.

- Nordenson I, Mild KH, Andersson G, Sandstorm M (1994). Chromosomal aberrations in human amniotic cells after intermittent exposure to fifty Hertz magnetic fields. *Bioelectromagnetics* 15:293-301. <http://dx.doi.org/10.1002/bem.2250150404>
- Pe-uelas J, Llusia J, Martinez B, Fontcuberta J (2004). Diamagnetic susceptibility and root growth responses to magnetic fields in *Lens culinaris*, *Glycine soja* and *Triticum aestivum*. *Electromagn. Biol. Med.* 23(2):97-112. <http://dx.doi.org/10.1081/LEBM-200032772>
- Phirke PS, Kubde AB, Umbargar SP (1996). The influence of magnetic field on plant growth. *Seed Sci. Technol.* 24:375-392.
- Pietruszewski S, Kania K (2010). Effect of magnetic field on germination and yield of wheat. *Int. Agrophys.* 24:297-302.
- Racuciu M (2011). 50 Hz frequency magnetic field effects on mitotic activity in the maize root.. *Rom. J. Biophys.* 21(1):53–62.
- Racuciu M, Creanga DE, Galugaru CH (2008). The influence of extremely low frequency magnetic field on tree seedlings. *Rom. J. Phys.* 35:337-342.
- Racuciu M, Miclăuș S, Creangă DE (2009). The response of plant tissues to magnetic fluid and electromagnetic exposure, *Rom. J. Biophys.* 19:73–82.
- Rapley BI, Rowland RE, Page WH, Podd JV (1998). Influence of extremely low frequency magnetic fields on chromosomes and the mitotic cycle in *Vicia faba* L., the broad bean. *Bioelectromagnetics* 19:152-161. [http://dx.doi.org/10.1002/\(SICI\)1521-186X\(1998\)19:3<152::AID-BEM3>3.0.CO;2-0](http://dx.doi.org/10.1002/(SICI)1521-186X(1998)19:3<152::AID-BEM3>3.0.CO;2-0)
- Reina FG, Pascual LA, Fundora IA (2001). Influence of a Stationary Magnetic Field on water relations in lettuce Seeds. Part II: Experimental Results. *Bioelectromagnetics* 22:596-602. <http://dx.doi.org/10.1002/bem.89>
- Ruediger HWR (2009). Genotoxic effects of radiofrequency electromagnetic fields. *Pathophysiology* 16:89-102. <http://dx.doi.org/10.1016/j.pathophys.2008.11.004>
- Savostin PW (1930). Magnetic growth relations in plants. *Planta* 12:327.
- Sharma AK, Sharma A (1980). *Chromosome Techniques, Theory and Practice*, Butterworths, London P. 711.
- Tkalec M, Malaric K, Pavlica M, Pevalek-Kozlina B, Vidakovic-Cifrek Z (2009). Effects of radiofrequency electromagnetic fields on seed germination and root meristematic cells of *Allium cepa* L. *Mutat. Res.* 672:76-81. <http://dx.doi.org/10.1016/j.mrgentox.2008.09.022>
- Turkoglu S (2007). Genotoxicity of five food preservatives tested on root tips of *Allium cepa* L. *Mutation Research Genetic Toxicol. Environ. Mutagenesis* 626:4-14. <http://dx.doi.org/10.1016/j.mrgentox.2006.07.006>
- Türkoğlu Ş (2009). Evaluation of genotoxic effects of sodium sulphite, potassium sulphite and calcium sulphite on the root meristem cells of *Allium cepa*. *Fresen Environ. Bull.* 18:804-810.
- Waleed AJ, Riyadh CA, Hussein FH (2013). Effect of magnetic field on seed germination of *Triticum aestivum*. *World J. Agric. Sci.* 5:168-171.
- Yumurtacı A, Vardar F, Ünal M (2007). Inhibition of barley root growth by Actinomycin D: Effects on mitotic activity, protein content and peroxidase activity. *Fresen. Environ. Bull.* 16:917-921.
- Zaidi S, Khatoon S, Shaukat SS (2012). Effects of electromagnetic fields on some indigenous plant species-III, *Capparaceae* and *Chenopodiaceae*. *Pak. J. Bot.* 44(5):1733-1739.
- Zhao YL, Johnson PG, Jahreis GP, Hui SW (1999). Increased DNA synthesis in INIT/10T1/2 cells after exposure to a 60Hz magnetic field: a magnetic field or a thermal effect? *Radiat. Res.* 151:201–208. <http://dx.doi.org/10.2307/3579771>