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Genotoxic Effects of Electromagnetic Fields from High Voltage Power Lines on Some Plants

Aksoy, H.[1*], Unal, F.[2] and Ozcan, S.[3]

[1]Sakarya University, Science Faculty, Department of Biology, Sakarya, Turkey

[2]Gazi University, Science Faculty, Department of Biology, Ankara, Turkey

[3]Ankara University, Faculty of Agriculture, Department of Field Crops, Ankara, Turkey

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ABSTRACT: *Allium cepa* bulbs were germinated in pots for three days on treatment area on which 380 kV high voltage power lines are passing. Ten bulbs were set up for each treatment area (0 m (meter), 10 m, 25 m, 50 m and 100+ m for control from power lines). *Triticum baeoticum* Boiss. subsp. *baeoticum* seeds were collected at same distance from power lines on planted field. Ten seeds from each area were germinated in Petri dishes for three days in laboratory. The treatment groups were compared with the control group for mitotic index and chromosome aberrations. Data obtained showed that electromagnetic fields from high voltage power lines increased the mitotic index and chromosome aberrations.

Keywords: Electromagnetic Fields, High Voltage Power Lines, Chromosome aberrations

INTRODUCTION

Industrial development has widely affected the environment during recent decades (Nabi Bidhendi et al., 2007; Abduli et al., 2007; Mehrdadi et al., 2007; Motesaddi Zarandi et al., 2008; Ahmad et al., 2009; Sadashiva Murthy et al., 2009; Javid and Lak, 2007). It is a modern fact of life that we are all exposed to EMFs (electromagnetic fields) produced by generation, transmission, and use of electricity. EMFs are produced by power lines, electrical wiring, and electrical equipments. EMFs are invisible lines of force that surround any electrical device. As various chemicals effects living organisms in different ways, various forms of electromagnetic energy can have very different biological effects. However, the mechanism leading to changes in the biosynthesis has been elusive. Low-frequency electric fields do not penetrate cells very effectively, but low-frequency magnetic fields do penetrate (Blank and Goodman, 1997).

The possible effects of EMFs on health, especially, were begun discussed after the Wertheimer and Leeper's (1979) publication. They reported that an association was found between living near high voltage power lines and childhood cancer. Current researches on EMFs are divided into two general categories; epidemiological and laboratory studies. While a majority of the epidemiological studies have focused to reveal that relation between EMFs exposure and cancer (Floderus et al., 1993; Coogan et al., 1996; Kheifets et al., 1997; Feychting et al., 1997; McElroy et al.,2001; Draper et al., 2005), laboratory studies has focused on chromosomal aberration in human blood cells which exposed to EMFs (Khalil and Qassem, 1991; Garcia-Sagredo and Monteagudo, 1991; Valjus et al., 1993; Skyberg et al., 1993; Antonopoulos et al., 1995; Erdal et al., 1998; Cho and Chung, 2003). On the other hand, cellular damage (Veiga et al., 2000; Belyavskaya, 2001), plant chromosome aberrations (Rapley et al., 1998) and plant grow up (Kocacaliskan, 1990; Soja et al., 2003; Kobayashi et al., 2004; Fischer et al., 2004) have been investigated in the same condition.

According to some epidemiologic studies, while there is a relationship between EMFs and various cancer types (Floderus et al., 1993; Dockerty et al., 1998; Zhu et al., 2003), according to some other studies, there is no relationship (Zheng et al., 2000; McElroy et al., 2001; Forssen et al., 2005). Even though some researchers reported that EMFs increased frequency of chromosomal aberrations in cultured human lymphocytes (Khalil and Qassem, 1991; Erdal et al., 1998; Erdal et al., 1999), some of them reported that EMFs did not induce any cytogenetic damage in cultured human lymphocytes (Rosenthal and Obe, 1989; Garcia-Sagredo et al., 1990; Skyberg et al., 1993; Scarfi et al., 1994).

*Corresponding author E-mail: haksoy@sakarya.edu.tr

The aim of this study was to investigate possible cytogenetic effects of EMFs produced by high voltage power lines in plant root tip mitotic cells.

MATERIALS & METHODS

In this study as a live materials, *Allium cepa* L. and *Triticum baeoticum* Boiss. subsp. *baeoticum* root tips meristems, also as a physical agents, electromagnetic fields from high voltage power lines that are 380 kV/m and 50 Hz were used. The geometry of the power lines are approximately 15 m height and 20 wires. Electromagnetic fields on the treatment areas are 4.5 kV/m and 1 G, 3.5 kV/m and 0.8 G, 1 kV/m and 0.25 G, 0.4 kV/m and 0.1 G, 0, 10, 25, 50 m respectively (Kinis 1999). For the control area, we chose the after 100 m distance from power lines. We did not use real negative controls in laboratory conditions because of the treatment areas and laboratory conditions are different.

Equal sized *A. cepa* bulbs were chosen and germinated in pots for three days on treatment area which the 380 kV high voltage power lines are passing. Ten bulbs were set up at each treatment area (These are 0 m, 10 m, 25 m, 50 m and 100+ m (control) distance from power lines). *Triticum baeoticum* Boiss. subsp. *baeoticum* seeds were collected at the same distance from planted field. Ten different plant's seeds from each area were germinated in Petri dishes for three days in laboratory. Following the treatments, the roots were fixed directly in absolute alcohol: glacial acetic acid (3:1) for 24 h and stored in 70 % alcohol in refrigerator until use. Cytological preparations were made from ten different bulbs and seeds (for each treatment area). The root tips were stained according to the conventional Feulgen technique. Permanent microscope slides were prepared by depex and analyzed.

Each slide was prepared from different bulbs and seeds. 1000 cells were screened from each slide, and, in total, it was reached to 10000 cells for each treatment area. Mitotic index (MI), the frequency of mitotic phases and types of chromosomal abnormalities were found by observing 10000 cells for each treatment groups. In anaphase-telophase test, 500 cells in anaphase or early telophase were examined for aberrations for each treatment groups.

The data obtained for the mitotic index, frequency of mitotic phases and chromosomal abnormalities stastically analyzed using z-test. Dose-response relationships were determined from correlation and regression coefficients for the percentage of mitotic index and aberrations.

RESULTS & DISCUSSION

In *Allium cepa* L., 380 kV high voltage power lines significantly increased the mitotic index (MI) at 0, 10 and 25 m treatments compared with control group. Only 50 m treatment group was not significantly different from the control. On the other hand, there was no significant difference in the MI between 0 and 10 m, and 25 and 50 m distances (Table 1). In *Triticum baeoticum* Boiss. subsp. b*aeoticum*, as in *Allium cepa*, mitotic index significantly increased at 0, 10 and 25 m treatments compared with control. However, MI at 50 m distance showed no significant difference from the control (Table 2). MI analysis showed that high voltage power lines significantly increased the cell division a dose dependent manner in *Allium cepa* L. and in *Triticum baeoticum* Boiss. subsp. B*aeoticum* (r=0.98, r=0.88 respectively).

The percentages of the mitotic phases in *Allium cepa* L. was also illustrated in Table 1. At 0 m group,

Table 1. Mitotic index and phase rates in *Allium cepa* L. and *Triticum baeoticum* Boiss. subsp. *baeoticum* exposed 380 kV high voltage power line

Test Materials	Distance (m)	Stages				Mitotic index (%)*
		Prophase (%)*	Metaphase (%)*	Anaphase (%)*	Telophase (%)*	
A. cepa L.	Control	58.60^{a}	9.88^{a}	7.33^{ab}	24.19^{ab}	5.87±0.24^{a}
	50	63.22^{ab}	8.39^{ab}	4.68^{a}	23.71^{ab}	6.20±0.24^{ab}
	25	67.27^{b}	6.46^{b}	2.10^{c}	24.17^{ab}	6.66±0.25^{b}
	10	61.11^{a}	10.43^{a}	7.59^{b}	20.87^{b}	7.38±0.26^{c}
	0	41.38^{c}	18.87^{c}	13.61^{d}	26.15^{a}	7.42±0.26^{c}
T. baeoticum Boiss. subsp. *baeoticum*	Control	51.57^{a}	23.48^{a}	7.39^{ab}	17.56^{a}	11.50±0.32^{a}
	50	60.70^{bc}	17.18^{b}	8.43^{a}	13.69^{b}	12.34±0.33^{a}
	25	60.01^{b}	15.26^{b}	8.82^{a}	15.91^{ab}	13.83±0.35^{b}
	10	62.59^{bc}	16.55^{b}	5.47^{b}	15.39^{ab}	14.62±0.35^{b}
	0	63.96^{c}	16.40^{b}	6.04^{b}	13.60^{b}	13.90±0.35^{b}

Mitotic index: represent the dividing cells in total cells

*Values with different letters in columns intra species are significantly different (at least at P<0.05)

Table 2. Types and rates of abnormalities in *Allium cepa* L. and *Triticum baeoticum* Boiss. subsp. *baeoticum* exposed 380 kV high voltage power lines

Test Materials	Distance (m)	Dividing cells	Abnormalities (%)								AC / DC (%)*	AC / TC (%)*
			Mn	St	F	Cm	Im	M	B	Lc		
A. cepa L.	Control	587	-	-	-	-	-	0.17	0.34	0.17	0.68±0.34[a]	0.04±0.02[a]
	50	620	0.01	-	-	0.16	-	-	0.32	0.16	0.64±0.32[a]	0.05±0.02[a]
	25	666	0.02	-	-	0.30	-	-	-	0.30	0.60±0.30[a]	0.06±0.02[a]
	10	738	0.02	-	0.41	-	-	0.14	0.41	0.27	1.23±0.41[a]	0.11±0.03[a]
	0	742	0.08	0.94	0.54	0.67	0.27	0.94	1.08	1.08	5.52±0.84[b]	0.48±0.07[b]
T. baeoticum Boiss. subsp. *baeoticum*	Control	1150	-	0.09	-	-	-	-	-	-	0.09±0.09[a]	0.01±0.01[a]
	50	1234	0.01	-	0.16	-	-	-	-	-	0.16±0.11[a]	0.03±0.02[a]
	25	1383	0.01	-	0.07	0.07	-	-	0.07	0.15	0.36±0.16[ab]	0.06±0.02[a]
	10	1462	0.07	-	0.21	-	-	0.21	0.27	0.21	0.90±0.25[b]	0.19±0.04[b]
	0	1390	0.01	0.29	0.86	0.22	0.07	0.14	0.14	0.22	1.94±0.37[c]	0.28±0.05[b]

Mn: Micronuclei, St: Stickiness, F: Fragment, Cm: C-mitosis, Im: Irregular metaphase, M: Multipolarity, B: Bridge, Lc: Lagging chromosome, AC: Abnormal cells, DC: Dividing cells, TC: Total cells

*Values with different letters in columns intra species are significantly different (at least at P<0.05)

high voltage power lines significantly decreased the percentage of prophase and increased the percentage of metaphase and telophase stage when compared to the control group. Decrease at prophase and increase at metaphase and anaphase was also significantly different from the other treatment groups. At 10 m treatments, cells at anaphase stages were increased and at telophase stages were decreased as compared to the control. On the other hand, at 25 m treatment groups, there were a significantly increase in the percentage at prophase and a significantly decrease in the percentage of metaphase and anaphase. The percentage of cells at different stages, at the 50 m treatments, was not different from the control.

The percentages of the mitotic phases of *Triticum baeoticum* Boiss. subsp. b*aeoticum* was illustrated in Table 2. The results showed a significant increase in all treatment groups from the control for prophase stages and a significant decrease for metaphase stages. At anaphase, while 0 and 10 m treatments showed a significant decrease from the control, 25 and 50 m treatments did not. At telophase stage, 0 and 50 m treatments showed a significant decrease but 10 and 25 m. High voltage power lines at 380 kV were induced some abnormalities in mitotic cells in both *Allium cepa* L. and *Triticum baeoticum* Boiss. subsp. b*aeoticum* (Table 3 and 4).The abnormalities observed at mitotic stage were bridges, multipolarity, fragment, lagging chromosome, c-mitosis, stickiness, irregular metaphase and micronuclei at interphase (Fig. 1 & 2).

In *Allium cepa*, lagging chromosome was present in all treatment groups as well as control. Bridge was observed in all treatment groups and control but 25 m. Again, multipolarity was detected at 0 and 10 m treatment and in control roots. C-mitosis was observed at 0, 25 and 50 m treatment groups. Fragment was detected in 0 and 10 m treatment groups. Stickiness and irregular metaphase were present at only 0 m treatment root tips. At interphase, all treatment groups had micronuclei. Abnormal cells/dividing cells and abnormal cells/total cells ratios in *Allium cepa* were significantly different from the control at only 0 m treatment group. This ratio was not significantly different from the control in all the other treatments (Table 3). On the other hand, the increases are dose dependent manner in abnormal cells/dividing cells and abnormal cells/total cells ratios (r=0.76, r=0.79 respectively).

In *Triticum baeoticum* Boiss. subsp. b*aeoticum*, fragment was observed in all treatment groups. Lagging chromosome and bridge were detected in all treatment groups except 50 m. Multipolarity was present at 0 and 10 m treatment groups. While irregular metaphase was observed at only 0 m treatment group, c-mitosis was observed at 0 and 25 m treatment groups. On the other hand, stickiness was present at 0 m treatment group as well as control. All treatment groups had micronuclei at interphase. Abnormal cells/dividing cells ratio in *Triticum baeoticum* Boiss. subsp. b*aeoticum*, was significantly different from the control at 0 and 10 m treatment groups. Similarly, abnormal cells/total cells ratio was also significantly different from the control at 0 and 10 m treatments (Table 4). In abnormal cells/ dividing cells and abnormal cells/total cells ratios the increases are dose dependent manner (r=0.92, r=0.95 respectively).

In anaphase-telophase test, the most common abnormalities were bridges. Fragment was observed in all treatment groups and control in both species. Lagging chromosome was detected in all treatment groups but control. Multipolarity was

present in all groups in both species but control in *Triticum baeoticum* Boiss. subsp. b*aeoticum*. The total abnormalities at anaphase or early telophase were significantly increased at 0 and 10 m treatment groups with compared to the control in both species (Table 5 and 6). In anaphase-telophase test, significantly increases are dose dependent manner in *Allium cepa* L. and in *Triticum baeoticum* Boiss. subsp. B*aeoticum* (r=0.96, r=0.96 respectively).

Table 3. Types and rates of abnormalities in anaphase and early telophase stages in *Allium cepa* L. and *Triticum baeoticum* Boiss. subsp. *baeoticum* exposed 380 kV high voltage power line

Test Materials	Distance (m)	Cells scored	Abnormalities (%)				AC (%)*
			B	M	Lc	F	
A. cepa L.	Control	500	0.40	0.80	-	0.40	1.60^{a}
	50	500	1.20	0.60	0.40	0.20	2.40^{ab}
	25	500	1.40	0.80	0.60	0.40	3.20^{ab}
	10	500	1.60	0.80	1.20	0.80	4.40^{bc}
	0	500	3.40	1.60	1.20	0.80	7.00^{c}
T. baeoticum Boiss. subsp. *baeoticum*	Control	500	0.60	-	-	0.80	1.40^{a}
	50	500	1.00	0.20	0.20	0.40	1.80^{a}
	25	500	1.00	0.20	0.40	0.60	2.20^{ab}
	10	500	2.00	1.20	0.40	0.60	4.20^{bc}
	0	500	1.40	1.60	0.60	1.60	5.20^{c}

B: Bridge M: Multipolarity, Lc: Lagging chromosome F: Fragment, AC: Abnormal cells
* Values with different letters in columns intra species are significantly different (at least at P<0.05)

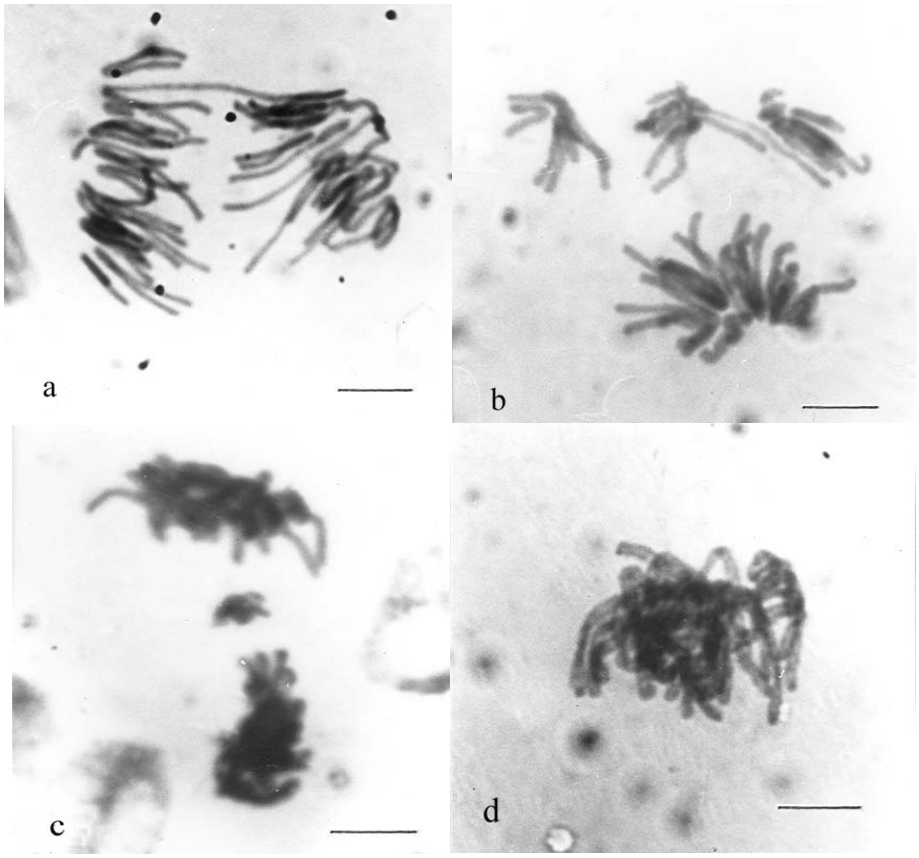

Fig. 1. Different types of aberrations induced by electromagnetic fields from high voltage power lines in Allium cepa L. root tips. a) Bridge b) multipolarity c) lagging chromosome d) Stickiness (bar= 5 µm)

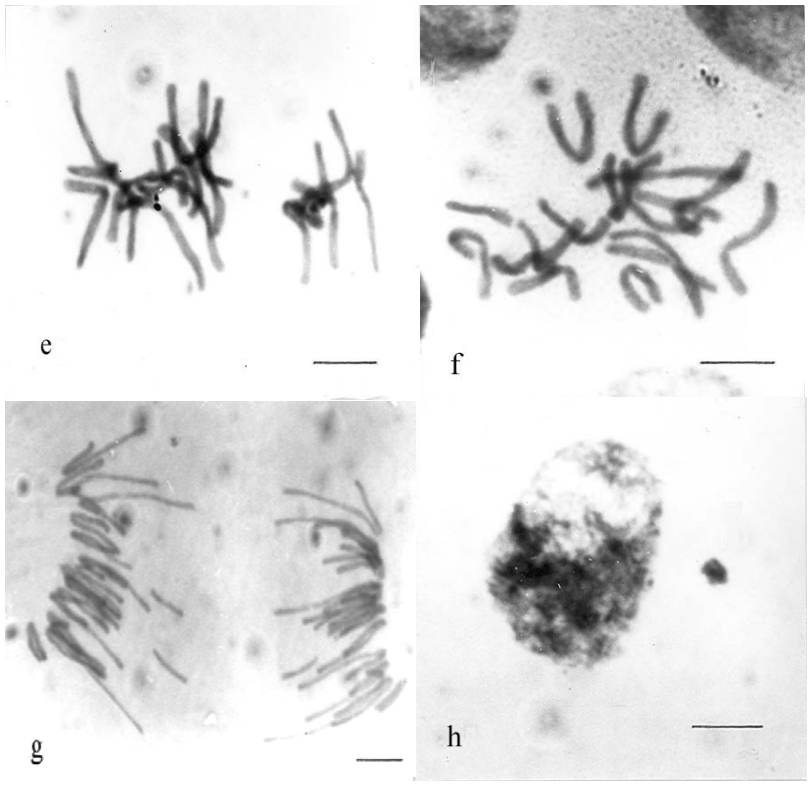

Fig. 1. (continue) Different types of aberrations induced by electromagnetic fields from high voltage power lines in Allium cepa L. root tips. e) Irregular metaphase f) C-mitosis g) Fragment h) Micronucleus (bar= 5 µm)

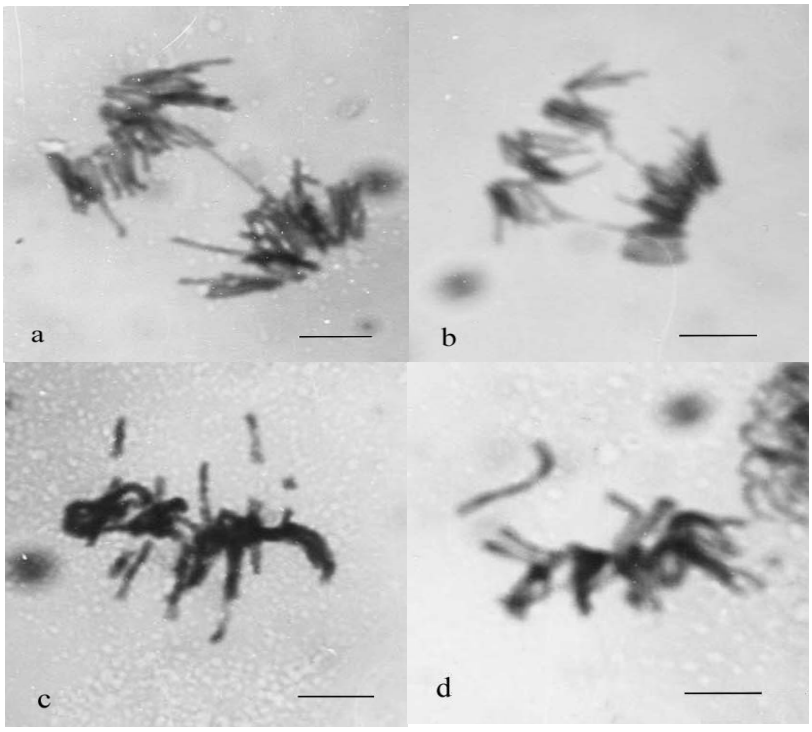

Fig. 2. Different types of aberrations induced by electromagnetic fields from high voltage power lines in *Triticum baeoticum* Boiss. subsp. *baeoticum* root tips. a) Bridge b) Multipolarity c) Fragment d) Lagging chromosome (bar= 5 µm)

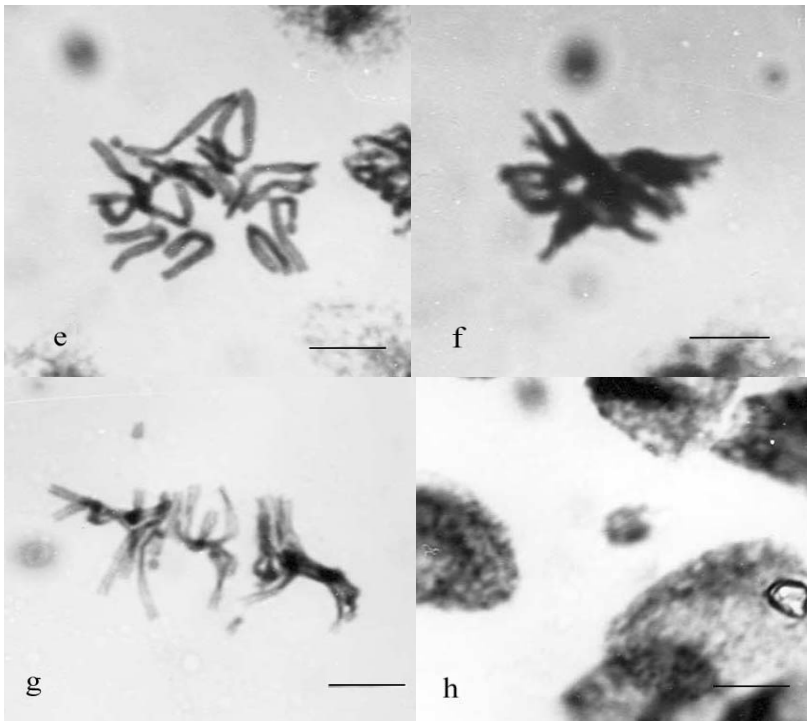

Fig. 2. Different types of aberrations induced by electromagnetic fields from high voltage power lines in *Triticum baeoticum* Boiss. subsp. *baeoticum* root tips. e) C-mitosis f) Stickiness g) Irregular metaphase h) Micronucleus (bar= 5 µm) - continuation

Past studies demonstrate widely varying results concerning with the effects of EMFs on living organism. While a majority of the studies have focused on human and other animals, a few studies have conducted on plant. Therefore, in this study, the effects of EMFs from high voltage power lines on *Allium cepa* L. and *Triticum baeoticum* Boiss. subsp. *baeoticum* root tip cells were investigated. The Allium test has generally used to determine the genotoxic or cytotoxic activity of different chemicals and environmental agents. The results of this test permit an estimation of the cytotoxicity, genotoxicity and mutagenicity of various chemicals and environmental agents that have a direct or indirect influence on living organisms (Kovalchuk *et al.,* 1998). The Allium anaphase-telophase chromosome aberration assay is simpler and faster assay for detection of the genotoxicity of chemicals and environmental samples (Rank, 2003).

Some epidemiologic studies have explored the relation between EMFs exposure and cancer types (Floderus *et al.,* 1993; Dockerty *et al.,* 1998; Zhu *et al.,* 2003). Feychting et al. (1997) identified leukemia and central nervous system tumor cases and controls from a population living within 300 m of transmission lines in Sweden. Their results were provided support for an association between magnetic field exposure and leukemia. Relative risks for nervous system tumors were close to unity. Draper et al. (2005) were aimed to determine whether there is an association between distance of home address at birth from high voltage power lines and the incidence of leukemia and other cancer in children in England and Wales. They found a raised risk of childhood leukemia in children who lived within 200 m of high voltage lines at birth compared with those who lived beyond 600 m. There was also a slightly increased risk for those living 200-600 m from the lines at birth. There were no significant results for central nervous system/brain tumor or other tumors. In a study that is considered workers exposed to different levels of ELF fields, significant reduction of natural killer cells (NK) activity and of Lytic Units number were observed in workers exposed to above 1 ìT, with respect to those exposed to below 0.2 ìT. The authors conclude that their results suggest that occupational exposure to ELF levels exceeding 1 ìT may induce a reduction of NK activity (Gobba *et al.,* 2009). There is a hypothesis that NK cells play a major role in the control of cancer development and their results are in agreement with this hypothesis. On the other hands, several studies have explored the effects of EMFs no relation between EMFs and cancer

(Theriault et al., 1994; Laden et al., 2000; Zheng et al., 2000; McElroy et al., 2001; Minder and Pfluger, 2001). Tynes et al. (1994) were investigated the brain tumor and leukemia in railway workers that exposure to EMFs on Norwegian railways. Their results were no support an association between exposure to electric and magnetic fields and the risk for leukemia or brain tumors. Forssen et al. (2005) were found no evidence for an increased risk of breast cancer among women working in occupations with high magnetic field exposure.

EMFs do not act directly on the cell components (Blank and Goodman, 1997). The effects of EMFs on chemical reaction have caused to occurring the free radicals (Adey, 1993; Tuncel et al., 1999). Although the energy associated with environmental EMFs is too low to cause direct changes to the structure of DNA, EMFs might affect the production of agents such as free radicals, which themselves can react with DNA, or of other agents that cause chromosomal damage, instigating translocation by inducing DNA breaks or by formation of unnatural DNA structures. Interfering with the mechanisms of DNA repair or chromosomal replication and segregation can also cause DNA damage or increase the probability that a particular DNA sequence will be lost from the genome (Lacy-Hulbert et al., 1998). Another effective mechanism of EMFs is on ion flux in the cell membrane. The transmembrane ion flux is regulated by voltage-dependent changes in the conformation of channel proteins, and that perturb ion flux will cause profound changes in the metabolism and fate of effected cells. When the organism exposure to EMFs, EMFs can perturb the transmembrane movement of cations such as K^+, Na^+ or Ca^{+2} through their respective channels, thus producing biological effects (Balcavage et al., 1996; Stange et. al., 2002). Paksu et al. (1999) investigated the effects of EMFs on the erythrocyte membrane proteins of people working in and living near high voltage power lines. They pointed that there was significant difference between assay and control groups about proteins amount.

The rats in different groups were exposed to MF (B=5 mT) for 165 min every day for 30 days. Their results were revealed the exposure to modulation MF decreased the glucose levels in streptozotocin-induced diabetic rats. The authors were determined that the hypoglycemic effect of modulation MF was similar to that of insulin treatment. Also, the hypoglycemic effect of combined insulin treatment and exposure of modulation MF on the glucose levels was the lowest. The authors suggested that the hypoglycemic effect of MF on the function of â cells may be able to help increase insulin concentration and sensitivity to glucose metabolism. At the same time, in a streptozotocin-induced diabetic rat model, MF was increased the blood-brain barrier permeability (Gulturk et al., 2010). In another research, it was concluded that 50 Gauss EMF was raised the number of follicoles but the number of corpora lutei in rats (Solaeymanirad et al., 2003).

During the cell cycle, the order of events is maintained by controls termed checkpoints. Two checkpoints are sensitive to DNA damage, one act before mitosis and a second acts before DNA replication. The checkpoint mutants show genetic instability, and such instability is characteristic of many cancers. Studies of checkpoints in normal and cancer cells suggest a mechanistic relationship to the central cell cycle control p34CDC2 and its regulators. The researchers suggested that mutations in these genes and those with a role in DNA metabolism may affect the function at G_1-S checkpoint (Weinert and Lydall, 1993). Regard the literatures and present study, it says that the EMFs may effect the proteins which is activate the cell division and checkpoints in cell cycle because of increase not only chromosome aberrations, but also mitotic index in plant cells that exposed by EMFs.

The present study shows that a clear effects of EMFs from high voltage power lines on cell division and chromosomes. The mitotic index has risen in both plants as the distance gets decreased toward the power lines. These results are in agreement with previous report (Cossarizza et al., 1989; Scarfi et al., 1994). Tkalec et al. (2009) investigated that the effects of exposure to radiofrequency electromagnetic fields (RF-EMFs) on seed germination, primary root growth as well as mitotic activity and mitotic aberrations in root meristematic cells were examined in *Allium cepa* L. They reported that, exposures to EMFs of higher field strengths (41 and 120 V/m) showed a significant increase of the mitotic index compared with controls. Racuciu (2009), conclude that the low intensity 900 MHz electromagnetic radiation was increased the mitotic index for increasing exposure the electromagnetic field and the mitotic index is higher for all samples under the radiofrequency field compare to the control in *Zea mays* root tip. Also, it was provided a low percentage of chromosomal aberrations and the chromosomal aberrations are micronucleus, interchromatin bridges, retard chromosomes and chromosome fragments, combinations of retard chromosomes or chromosome fragments with inter-chromatin bridges. Ichim et al. (2007), were focused on cell proliferation in meristematic tissues of *Echinacea purpurea*'s young vegetal organism (in its very early ontogenetic stages) to exposure that the controlled electrostatic stress (10–17 V; (5, 10, 15, 20,

30, 40 pulses; 5s) and their results were revealed that the mitotic index was increased statistically significant for 20, 30, 40 pulses. In their research, higher changes were found in the metaphase and telophase percentages and the highest increase of metaphase cell number was recorded for 15 pulses while the lowest number of telophase cells were also found for 15 pulses. *Vicia faba* beans were germinated and grown in vermiculite granules in a controlled environment laboratory and seedlings were subjected to different magnetic fields. In particular, all treatments increased the length of prophase significantly in meristematic root tip cells compared with the controls (Rapley et al., 1998). Our results indicate that the duration of prophase is increased in the root meristem of all the experimental groups when compared with the control in both plants but 0 m treatment in *Allium cepa*. According to Rapley et al. (1998), during prophase, it may be possible that the EMFs play a role in the unwinding process, causing some slowing down of winding mechanism and resulting in a longer prophase. The durations of other stages also indicate variability in the effects of the EMFs. Researchers who observing the same results suggested that these are very difficult to interpret because of the apparent haphazard nature of the magnetic field effects and biological explanations for these differences remain elusive. At metaphase and anaphase, especially at 0 m treatment group, the phase ratio was increased a lot in *Allium cepa*. In *Triticum baeoticum* Boiss. subsp. B*aeoticum*, on the other hands, there was significantly decreased in all treatment groups compared with control at metaphase but anaphase. In this study, different results are shown both in stages and in two different plants. These differences might be resulted from the genetic composition, growing conditions and exposure period of these two species. At the same time, observing the differentiations in phase frequencies have been shown as an evidence of electromagnetic fields that effective on not only interphase stage but also during whole cell cycle.

EMFs induced abnormalities in mitotic cells in both plant species investigated in this study. These are bridges, multipolarity, fragments, lagging chromosomes, c-mitosis, stickiness, irregular metaphase and micronuclei. Pavela and Creanga (2005), were studied the influence of a petroleum magnetic fluid upon the cell proliferation in young plants of agricultural interest and Zea mays plants, in their early ontogenetic stages were treated with magnetic fluid (10, 60 and 100 μL/L - ferrophase weight was of the order of magnitude of μg/L of culture medium) and root meristem was investigated by cytogenetical methods. In this study, they were found that the cell proliferation rate was significantly enhanced as well as the percentage of chromosomal aberrations and they explained that the petroleum magnetic fluid was able to stimulate the plant proliferation (up to 30%) and to induce various types of chromosomal aberrations: micronuclei, bridges, chromosome fragments. Hanafy et al., (2006) were used the two exposure systems of an extremely low frequency electric field, the first was an experimental model (50 Hz, 6 kV/m strength) and the second was the high voltage transmission lines passing through an open agricultural field (50 Hz, 66 kV/11 m = 6 kV/m). They were used for the controls that after 100 m distance in both systems. Their results indicated that the electric field of both systems showed a high frequency of chromosomal abnormalities. Each of the two systems induced a wide range of chromosomal abnormalities covering all mitotic stages. Among the mitotic irregularities induced by the applied electric field were stickiness, disturbed phases, laggards, bridges, fragment and micronuclei in interphase cells. The results also indicated that the molecular structure of the extracted water soluble protein changed the amount of protein in the bands of exposed grains decreased and their molecular weights changed. After these results, they suggested that the potentiality of the applied electric field to induce mitotic irregularities. Tkalec et al. (2009) pointed that higher numbers of mitotic abnormalities were found after exposure to modulated EMF as well as after exposure to EMFs of higher strengths (41 and 120 V/m) at 400 MHz, while the percentage of mitotic abnormalities increased after all exposure treatments at 900 MHz compared with the control in *Allium cepa*. Major abnormalities found after exposure at both frequencies were lagging chromosomes, vagrants, disturbed anaphases and chromosome stickiness. They suggested that mitotic effects of RF-EMF could be due to impairment of the mitotic spindle. Malfunction of the spindle mechanism could be connected with the effect of RFR on calcium-ion homeostasis in cells (Penafiel et al., 1997). The total percentage of aberrant cells was not considerably changed by the electrostatic exposure except for the two highest pulse numbers. The main types of chromosomal aberrations were retard and expulsed chromosomes, micronuclei and chromosome bridges. It was also been observed such as retard chromosomes combined with bridges. After these results, authors pointed that the young vegetal organisms are quite sensitive to external stress factors and therefore *E. purpurea* plantlets during their early ontogenetic stages can be influenced by electrostatic stress (up to 40 consecutive applied pulses) 15 kV amplitude, 4 ms duration, negative polarity, as the cytogenetic tests were revealed (Ichim et al., 2007). Ghotbi Kohan and Morgan (2007), the result of their research, have revealed the direct relation between increase of

pollution and the level of stress protein. They explained that stress proteins have high sensitivity to changes in the environment. Today, we know that electromagnetic field is also an environmental pollution. Maybe electromagnetic fields can increase the stress protein too and it can affect the living organism.

Haider et al. (1994) were used the *Tradescantia* micronucleus bioassay in an in situ experiment to find out whether short wave electromagnetic fields used for broadcasting and they were observed that the results at all exposure sites except one were statistically significant. Fatigoni et al. (2005) were investigated the possible genotoxicity of ELF-MF by *Tradescantia* micronucleus assay and their results indicated that a 50 Hz MF of 1 mT field strength is genotoxic. Feulgen stained chromosome spreads of colchicine treated root tips from control and experimental plants were examined in detail for structural aberrations, such as chromosome or chromatid breakage, anaphase bridges, or abnormal configurations. But, researchers were observed only chromosome and chromatid breakages and the results showed that no significant relationship between the frequency of chromosome and chromatid breaks compared with the control (Rapley et al., 1998). The reason of the no significant relation that compared the control of investigation results of researchers, it might be only study at metaphase for structural aberrations.

Some researchers explained that an association was found between cancer risks and increasing the chromosomal aberrations and micronucleus frequency (Bonassi, 2006; El-Zein et al., 2006). In this case, it must take into consideration the high voltage power lines that are important source that of EMFs caused the chromosomal aberrations.

Previous in vitro studies have indicated that unrepaired DNA lession exist in mutagen-treated cells until the cells enter mitosis. The repair of these lesions can be effectively inhibited in G_2 stage (Palitti et al., 1984). Kihlman and Andersson (1986) have suggested that chromosome aberration as such cause delay or block in the G_2 stage. Robison et al. (2002) were found that the rate of DNA repair for EMFs exposed HL-60 and HL-60R cultures were significantly decreased when compared to non-exposed cultures.

The reason of the some aberration such as multipolarity, lagging chromosome and fragment which are resulting micronuclei and then chromosome losing, and c-mitosis might be the damage to mitotic spindles which is caused by radicals. Because, mitotic spindles have important roles the chromosomes which are movement toward the poles during cell division. Ahmad and Yasmin (1992) reported that micronuclei may originate from lagging chromosomes and fragments occurred in mitotic stage. The physical adhesion of chromatin proteins may be cause the stickiness (Patil and Bhat, 1992). Fragments usually produce micronuclei and then genetic material is lost. Chromosomal stickiness and sister chromatid union are result in bridges.

CONCLUSION

Despite many epidemiological investigations, the association between high voltage power lines and some form of cancer or other some diseases is not clear, yet. However, from present and previous studies, it seems that EMFs may be capable of producing chromosome aberration and effecting mitotic index. We think that the main reason of increased number of chromosome aberrations and mitotic index are due to damaging in various proteins and DNA in interphase stage which is caused by free radicals and defect in the processing of the signals occurring because of EMFs from high voltage. In conclusion, in the literature and this study, it seems that EMFs may be effect the living organism and long exposure time must be avoided. More investigation is required to effectively understand the mechanisms associated with EMFs.

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