







Table 1. Experimental results of mitotic division.

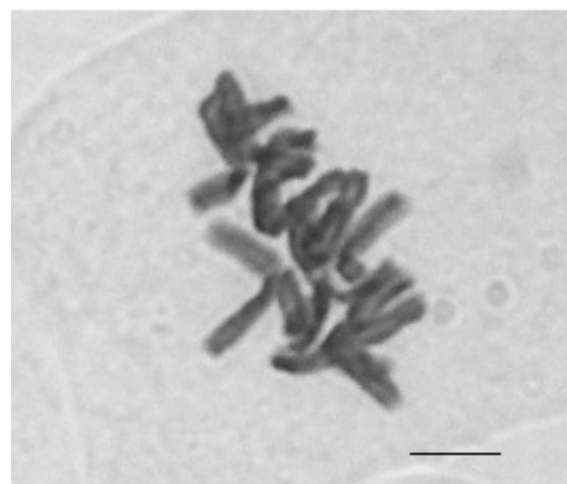
Experiment	Cells analyzed	Divided cells		Mitotic index	Division increase compared to control (%)	Abnormal division rate (%)	Abnormal division increase compared to control (%)
		Normal	Abnormal				
Electromagnetic waves applied for 48 hours prior to 48 hours germination (state of dormancy)	2000	177	12	8.85	<b>-12.50</b>	6.35	<b>52.38</b>
Electromagnetic waves applied for 48 hours while germinating (state of division)	2000	281	12	14.05	<b>35.65</b>	4.10	<b>-1.71</b>
Control	2000	207	9	10.35	-	4.17	-

of the control seedlings. This supports the idea that root growth can depend on mitotic activity [20]. This positive correlation confirms our findings that mobile phone EMFs may have an effect on the root growth process. Effects of 900 MHz cell phone EMFr were investigated on the root growth of *Vigna radiata* (mung bean). It was found that

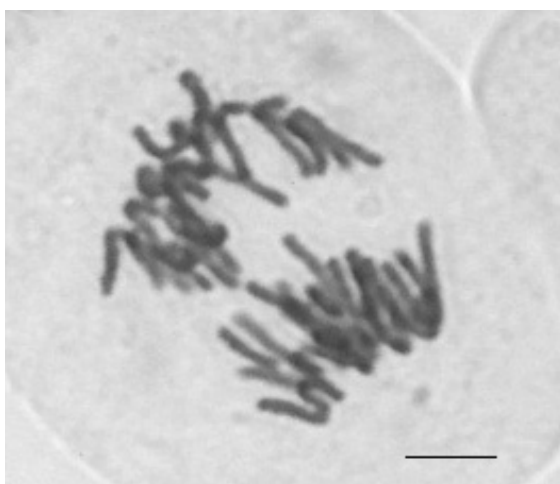
application of cell phone EMFr has an inhibitory effect on the root growth of mung bean by inducing reactive oxygen species-generated oxidative stress, despite increased activities of antioxidant enzymes [19]. This may explain our results obtained on the dormancy state seeds that root growth was reduced by 59.55% compared to the control



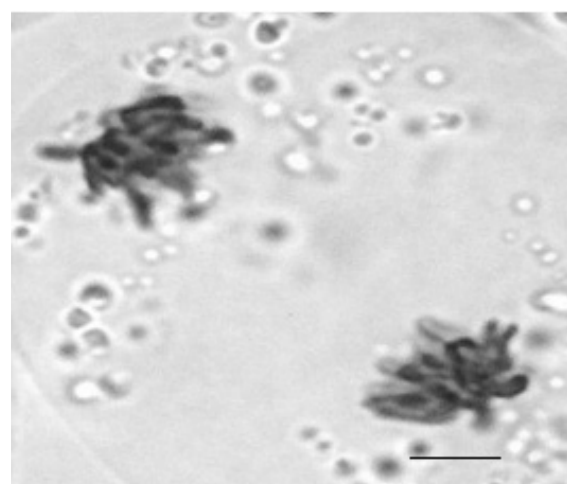
Prophase



Metaphase



Anaphase



Telophase

Fig. 3. Normal mitosis stages in the root tip cells of control *L. culinaris* seeds (scale bars: 10  $\mu$ m).

Table 2. Numbers and rates of chromosome aberrations in experimental and control groups.

Experiment	c-mitosis		Laggard chromosomes in metaphase		Vagrant chromosomes in anaphase		Bridge in anaphase		Multipolar anaphase		Bridge in telophase		Vagrant chromosome in Telophase		Multipolar telophase	
	Rate (%)	Num.	Rate (%)	Num.	Rate (%)	Num.	Rate (%)	Num.	Rate (%)	Num.	Rate (%)	Num.	Rate (%)	Num.	Rate (%)	Num.
Electromagnetic waves applied for 48 hours prior to 48-hour germination (state of dormancy)	2.65	5	0.01	1	0.01	2	0.01	1	0.01	1	0.00	0	0.01	1	0.01	1
Electromagnetic waves applied for 48 hours during germination (state of germination)	1.71	5	0.01	3	0.01	2	0.00	0	0.00	1	0.00	1	0.00	0	0.00	0
Control	0.93	2	0.01	2	0.01	2	0.00	1	0.00	1	0.00	0	0.00	1	0.00	0

group. Reduced plant growth was also reported as a result of the application of EMF exposure at radio frequencies of 400, 600, and 1900 MHz on *Lemna minor* [22]. The increase in the root growth of state of division seeds could be explained as a result of thermal effect.

A literature research was performed on the genotoxic effects of radiofrequency electromagnetic fields [12]. Of 101 publications, 49 reported genotoxic effects while 42 did not. Numerical or structural anomalies of metaphase chromosomes were exploited by 21 studies that 9 of them report positive finding and 11 negative [12]. This part of the present study exploits cytogenetic effects of electromagnetic fields emitted by mobile phones on the root meristematic cells of *L. culinaris* seeds. Laggard chromosomes, c-mitosis, vagrant chromosomes, and bridges were investigated parameters (Fig. 4).

The *Allium* test is known to be a standard in monitoring environmental pollution [23]. This test provides information about environmental hazards caused by chemicals, pollutants and contaminants that observation of the adverse effects on chromosomes by this test provides an indication of toxicity [24]. In this present study, c-mitosis, laggard chromosomes in metaphase, multipolar anaphase, vagrant chromosomes in anaphase, bridge in anaphase, multipolar telophase, vagrant chromosomes, and bridge in telophase were observed aberrations (Fig. 4). In a recent study, observation of lagging chromosomes, vagrants, disturbed anaphases and chromosome sticknes in EMF-treated *Allium cepa* root meristematic cells were suggested to be a possible result of exposure to spindle function [20]. In our study, chromosome aberrations except the c-mitosis were found to be similar to the control group. The rate of c-mitosis was 2.64% in state of dormancy seeds, 1.71% in the state of division seeds, and 0.93% in the control group (Table 2). Observation of high rates of c-mitosis in the state of dormancy seeds is consistent with the rate of abnormal division rate results (Table 1). This rate was 4.17% in the control seeds, but 6.35% in the state of dormancy seeds. As suggested by [7, 25], that in the case of c-mitosis, the nuclear spindle is fully inactivated, meaning that no equatorial plate becomes organized and that the centromere division is [25]. Having an increased rate of c-mitosis on both state of division seeds and state of dormancy seeds may support the idea that electromagnetic exposure by mobile phones has a hazardous effect on spindle function of *Lens culinaris* root tip meristematic cells as in *Allium cepa* [20, 25].

As seen in our general results, dormant seeds exposed to an electromagnetic field emitted by a mobile phone was much more affected than the state of division seeds in terms of root growth and chromosome aberrations. Similar to the results of the dormant seeds in our study, fertile chicken eggs were exposed to a cell phone in the call position over the entire incubation period. A harmful effect was observed on embryo survival upon prolonged and permanent exposure of fertile chicken eggs to cell phone radiation [26]. Detection of negative effects on embryo is consistent with our findings that seeds in the dormant state were more affected.





