

1 **Effect of Electromagnetic Field (EMF) and Electric Field (EF) on Some Behavior of**
2 **Honeybees (*Apis mellifera* L.)**

3 **Effect Of Electromagnetic Field On Honeybees**

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9 **KEY WORDS: Apiculture, Detect food, Magnetoreception, Helmholtz coil equipment**

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28 **Summary**

29 Honeybees uses the magnetic field of the earth to to determine their direction.
30 Nowadays, the rapid spread of electrical devices and mobile towers leads to an increase in
31 man-made EMF. This causes honeybees to lose their orientation and thus lose their hives.

32 **ABSTRACT**

33 Geomagnetic field can be used by different magnetoreception mechanisms, for
34 navigation and orientation by honeybees. The present study analyzed the effects of magnetic
35 field on honeybees. This study was carried out in 2017 at the Bayburt University Beekeeping
36 Application Station. In this study, the effect of Electro Magnetic field (EMF) and electric field
37 (EF) on the time of finding the source of food of honeybees and the time of staying there were
38 determined. The honeybees behaviors were analyzed in the presence of external magnetic
39 fields generated by Helmholtz coils equipment. The Electro Magnetic field values of the coils
40 were fixed to 0 μ T (90mV/m), 50 μ T (118 mV/m), 100 μ T (151 mV/m), 150 μ T (211 mV/m),
41 200 μ T (264 mV/m). Petri dishes filled with sugar syrup were placed in the center of the coils.
42 According to the study, honeybees visited at most U1 (mean =21.0 \pm 17.89 bees) and at least
43 U5 (mean =10.82 \pm 11.77 bees). Honeybees waited for the longest time in U1 (mean =35.27 \pm
44 6.97 seconds) and at least in U5 (mean =12.28 \pm 5.58 seconds). According to the results
45 obtained from this first study showed that honeybees are highly affected by electromagnetic
46 radiation and electric field.

47 **INTRODUCTION**

48 Living things have been adapted to the magnetic field of the Earth they were exposed to
49 as a result of millions of years of natural selection. Many organisms use the magnetic field of
50 the earth in space and time orientation (Wiltschko and Wiltschko, 2005). There is a scientific
51 discipline called Magnetobiology, which investigates the effects of magnetic fields on living
52 things.

53 Magnetobiology was formed by the unification of many scientific principles around
54 biophysics. Magnetic fields are important ecological factors that can affect living things
55 (Binhi and Savin, 2003; Rosen, 2003). Many studies have examined the possible effects of
56 EMF and EF on animals. Magnetic fields and electric fields can have an impact on the daily
57 activities, behaviors and spatial orientations of living things (Klotz and Jander, 2003; Vacha,
58 2006; Vacha et al., 2008). Studies have shown that ELF and EMF cause some physiological
59 and behavioral changes on insects and increase stress protein levels. (Wyszkowska et al.2006;

60 Wyszowska et al. 2016). In another study carried out by Rooder (1999), they found that
61 there was a significant increase in the motor activity of insects as EMF increased octopamine
62 levels in insects. Honeybees are one of the most important insect affected by the
63 electromagnetic field.

64 Many studies have been conducted on the response of honeybees to the electromagnetic
65 field. They can be summarized as follows: When extra magnetic field was applied, comb
66 building behavior and hive orientation were changed (Collett and Baron, 1994; Frier et
67 al.1996). Free-flying honey bees can detect weak magnetic field fluctuations as much as 26
68 nT. It has emerged in T-labyrinth experiments where honey bees are affected by short
69 magnetic pulses (Kirschvink, and Kobayashi-Kirschvink,1991). The magnetic remanence was
70 detected in the abdomen of honeybees (Gould et al. 1978). Iron granules (IGs), 0.560.1 mm
71 diameter were found in trophocytes surrounding the abdomen (Hsu and Li, 1993). Four IGs
72 trophocyte super paramagnetic magnetite was detected under high resolution transmission
73 electron microscopy (Hsu and Li, 1999). Fe_3O_4 and $FeOOH$ were found in the honey bees (El-
74 Jaick et al. 2001).

75 These results suggest that in addition to behavioral evidence, honeybees have
76 biomagnetites necessary for magnetoreception. That is to say, honeybees have the capacity of
77 magnetoreceptics. However, no evidence has been found to explain this capacity so far (Hsu
78 et al. 2007).

79 Honeybees are of great importance for humanity and nature for many reasons.
80 Honeybees make a great contribution to nature by providing pollination of plants other than
81 producing beekeeping products. Therefore, bees are important pollinators for both natural
82 vegetation and for crops (Castro, 2001). According to the studies conducted, the economic
83 value of honeybees was about 153 billion euros in 2005 (Gallai et al., 2009). The European
84 honeybees (*Apis mellifera* L.) is one of the most effective pollinator insects (Garibaldi et al.,
85 2011, Garibaldi et al., 2014). In addition, *Apis mellifera* L. is the most widely used bees in the
86 world for beekeeping.

87 Honeybees carry honey, pollen, propolis, and water from the outside to their hives.
88 Honeybees are talented insects who can find plants in the field and return to the hive. Worker
89 honeybees are rare social insects that collect foods from distances of up to 8-12 km and return
90 to their hives without losing direction.

91 Honeybees use the position of the sun (Rossel and Wehner, 1984), polarized light
92 (Rossel and Wehner, 1986; Evangelista et al., 2014) and landmarks (Dyer and Gould, 1981)
93 to determine their direction.

94 The ability of the bees to feel the Electromagnetic field of the Earth is one of the most
95 important factors that honeybees use in finding direction. Although it is thought that the most
96 important factor that honeybees use in finding direction is the sun; they can also use **cues** such
97 as smell, polarized light, compass of the sky, signs around the hive, chemicals, acoustic
98 instruments and magnetic field.

99 The state of the sky (cloudy sky or clear blue sky) and the time of day determine which
100 of these elements will be used by honeybees. Today, the use of devices that produce the
101 Electro Magnetic field such as mobile towers, mobile phones, Wi-Fi, Bluetooth, electric
102 appliances and high voltage lines has increased considerably.

103 The increase in these devices has led to debates that the ability of the honeybee to
104 navigate has disappeared when the magnetic field causes negativity on human and other living
105 things. Depending on the intensity of the magnetic field and the duration of exposure, the risk
106 of developing cancer (Wertheimer and Leeper 1979) leukemia (Greenland et al., 2000; Draper
107 et al., 2005), lymphoblastic leukaemia (Hatch et al., 1998), acute lymphoblastic leukaemia
108 (Kabuto et al. 2006) and alzheimer's (Huss et al., 2006) are increased.

109 According to the results of the studies, it was found that humans (Leszczynski et al.,
110 2002; Gandi and Singh, 2005; Hardell and Sage, 2008), rabbits, rats (Moorhouse and
111 Macdonald, 2005), bats (Nicholls and Racey, 2007; Nicholis and Paul, 2007), birds (Everaert
112 and Bauwens, 2007; Balmori, 2009; Grigoriev, 2003), frogs (Balmori, 2006; Balmori, 2010),
113 nematodes, Drosophila (Ghamdi, 2012), plants (Belyavskaya, 2001; Haggerty, 2010), Paper
114 wasp (Pereira-Bomfim et al. 2015), and honey bees (Harst et al., 2006; Sharma and Kumar,
115 2010; Favre, 2011) have been reported to be influenced by electromagnetic fields (EMF).

116 Pereira-Bomfim et al. (2015) showed that the social wasp *Polybia paulista* is sensitive
117 to modifications in the local geomagnetic field. This study, which was made with magnets
118 and Helmholtz coils equipment, showed that the change of the magnetic field affects the flight
119 activity of *Polybia paulista* (Ihering) .

120 Recently there have been reports of many factors affecting the development of
121 honeybees, such as disease, natural enemies, pesticides and adverse climatic conditions
122 (Favre, 2011).

123 The increase in losses in bee colonies all over the world has caused a phenomenon in
124 which the number of bees in the hive decrease very rapidly, without showing the symptom of
125 an illness. Scientists believe that these phenomena, called the Colony Collapse Disorder
126 (CCD) (Gallai et al., 2009), are caused by viruses, unscientific farm applications,
127 monoculture, no hygienic farming conditions, sudden changes in the climate, pesticides, air
128 pollution, and even GMO crops.

129 At present, it is argued that the most important cause of CCD is electromagnetic
130 pollution (Kumar, 2018; Taye et al., 2017; Cammaerts, 2017). Due to increased
131 electromagnetic pollution, it is suggested that the honeybees come out from the hive for
132 honey, pollen, propolis or water collect but they do not return to the hive.

133 Honeybees have magnetite crystal structures in body fat cells. These magnetite
134 structures are the active components of the magneto-reception system. Thanks to these
135 structures, honeybees can feel even slight changes in the magnetic field lines of the earth.
136 These delicate structures are affected by the slightest magnetic pollution to occur and cause
137 the honeybees to lose their direction. The bee dances that honeybees use to communicate with
138 each other are distorted (Favre, 2011).

139 The electromagnetic field consists of electromagnetic waves. Electromagnetic waves
140 consist of Electric Field and Magnetic Field components. These waves move at the speed of
141 light.

142 Electromagnetic fields are physical fields produced by an Electro Magnetic field source.
143 Electromagnetic waves are found in the continuous wavelength/frequency spectrum. The
144 shorter the wavelength, the higher the frequency (Hernandez et al., 2010).

145 The Electro Magnetic Field is measured as the magnetic flux density and the unit is
146 Tesla (T). The frequency of the electric magnetic fields is expressed in Hertz (Hz) (Vecchia et
147 al., 2009).

148 Electro Magnetic field measurements can be influenced by different factors such as
149 strength and distance of the source, the physical environment of the sites, the frequency of the
150 radiation and possible modulation, reflection or polarization (Vecchia et al., 2009).

151 According to many studies, it has been reported that radio frequency and
152 electromagnetic radiation (EMR) produce many misleading biological effects that disrupt the
153 functions of all biological systems and all organisms (Blank and Goodman, 2009; Rööslü et
154 al., 2008; Schuz and Ahlbom., 2008)

155 The electromagnetic field can affect the immune system, working behavior and
156 physiology of honeybees and ultimately cause them to disappear (Pattazhy, 2011). According
157 to Sharma and Kumar (2010), a large amount of radiation also disturbs the bee's ability to
158 navigate and prevents them from returning to their hives. Honeybees are like a bioindicator of
159 electromagnetic radiation because brain anatomies and learning regions are well known for
160 associative learning abilities (Schwarzal and Muller, 2006). According to Pattazhy (2011), if
161 the number of towers and mobile phones increases, honeybee may disappear within a decade.

162 According to the study, significant differences were found in returning to the hives of
163 honeybees: 40 percent of the non- irradiated bees and 7.3 percent of the irradiated ones
164 returned to their hives (Stefan et al., 2013). In this study, it was aimed to detect the effect of
165 electromagnetic field intensity on the honeybees and waiting time of the bees in the area of
166 the experiment.

167 MATERIALS AND METHODS

168 The study was conducted on Caucasian honeybees (*Apis mellifera caucasica*).
169 Caucasian bees are dark bees with gray hairs. They originated from the Caucasus mountains.

170 These bees are fairly gentle and have a longer language than other honeybee subspecies.
171 They winter well in cold climates and raise strong colonies in the spring. Honey and Propolis
172 production is more than other bee species and they are quite plundering but they are sensitive
173 to *Nosema apis* and *Nosema ceranae*.

174 This study was carried out in 2017 at the Bayburt University Beekeeping Application
175 and Research Station (40° 10' 09" N, 39° 50' 53 26" E). This Study was conducted in
176 order to determine the effects of the electromagnetic field on honeybees' time to locate food
177 and their waiting time in the area.

178 In order to identify the numbers of bees that came to the Petri dishes for feeding, the
179 experimental setup was placed at a distance of 100 m from the 50 caucasian hybrid bee
180 colonies in the bee yard. Helmholtz coil equipment were placed in the rear of the bee yard,
181 with a distance of 1.5m between them. In order to prevent chaos between the beehives and to
182 make it easier to work, the back part of bee yard was preferred (Fig. 1).

183 Helmholtz coil equipment was used to create electric and magnetic fields. Five
184 Helmholtz bobbins and five different magnetic field levels were used in the study (Table: 1).
185 The magnetic field strength produced by the Helmholtz coil equipment is adjusted by

186 changing the voltage of the electricity applied to the coils. In this study, 50 Hz AC electricity
187 was used.

188 The Electromagnetic Field generated by the Helmholtz coil equipment was measured in
189 terms of μT with the help of a TES Magnetic Field Meter model 1393. A diagram of the
190 experimental setup is shown in Fig. 2. When the electromagnetic field is generated, the
191 electric field also occurs at the same time. Both have an impact on living things. The strength
192 of Electro Magnetic Radiation generated by Helmholtz coils equipment is measured in terms
193 of mV / m with the help of TES Electrosmog meter brand, model 593.

194 Petri dishes containing 25 cc 1: 1 syrup was placed in the center of Helmholtz bobbins
195 and the experimental setup was prepared. The study began in the second week of June. Count
196 down of honey bees were made between 14-16 o'clock. Because in the region where the study
197 was conducted, the most intense nectar in this time range is carried. All of the helmotz coils
198 equipment were energized at 14 o'clock at the same time and power was cut off at 16 o'clock.

199 The honeybees from the Petri dish were observed one by one, the period of time spent
200 on the Petri dish was determined and recorded as the waiting period. This process was
201 repeated 3 times with at least at 15 day intervals. I took care to make the honeybees count
202 down on rainless and windless days. The juxtaposition of the Helmholtz coils equipment was
203 done every time by draw lots.

204 The number of honeybees that came to feed in Petri dishes was detected, by counting
205 with a minute interval. The counting process was continued until the syrup in the Petri dish
206 was finished. All statistical analyses were performed using SPSS statistical software (IBM
207 SPSS Statistics 22).

208 **RESULTS**

209 As a first observation at the beginning of the study, honeybees began to circulate around
210 petri dishes, but they did not alight on in Petri dishes. The first honeybee alight on Petri dish
211 U1 (control (0 μT , 90 mV/m) after 5 minutes, followed by U2 (50 μT , 118 mV/m), U3 (100
212 μT , 151 mV/m), U4 (150 μT , 211 mV/m), and U5 (200 μT , 264 mV/m). The most visited,
213 application was U1 (0 μT , 90 mV/m) (mean 21.07 ± 17.89 bees) and the least visited
214 application was U5 (200 μT , 264 mV/m) (mean 10.82 ± 11 , 77 bees) (Table 2). Honeybees
215 have passed intensely on Petri dishes with a magnetic field at the top after finishing the feed
216 in the Petri dish. As the magnetic field intensity increases, the demand for honeybees
217 decreases and reluctance is seen (Table 1). Although the bees placed in the U1 (0 μT , 90

218 mV/m) Petri dish where no magnetic field was present stayed here for longer (mean 37.88 s)
219 (Table 1), the bees placed in U5 (200 μ T, 264 mV/m) Petri dishes with high magnetic field
220 abandoned Petri dishes in much shorter time (mean 12.61 Sec).

221 From the multiple comparison tests conducted, it was found that the application groups
222 were located in different groups (Table 2).

223 Analyzes of variance were made for bee numbers in Petri dishes (Table 3) and for the
224 time they spent in Petri dishes of honey bees (Table 4).

225 According to these results, while the highest number of bees and the waiting time were
226 0 μ T magnetic fields applied Petri dishes, the number of bees that alight on and the duration
227 of stay was the lowest of 200 μ T magnetic fields applied Petri dish (Table 2).

228 **DISCUSSION**

229 Different studies from different regions of the world have reported the negative effect of
230 EMF emitted from cell phone towers, high voltage wires and various electronic devices on
231 honey bees with regard to strength, navigation, behavior, honey store, pollen store and brood
232 area, etc. (Harst et al., 2006; Stefan et al., 2013; Sharma and Kumar, 2010; Pereira-Bomfim et
233 al. 2015).

234 However, some other researchers have reported that EMF has no effect on honeybees
235 (Mixson et al., 2009; Blacquiere and Hoofwijk, 2010).

236 According to a study conducted by Mall and Kumar, the bee colonies were not affected
237 by EMF but reported that they could damage honeybees in the long term (Mall and Kumar,
238 2014).

239 Studies on the effects of electromagnetic fields on honey bees have shown that initiation
240 of foraging, cessation of foraging and number of incoming foragers are negatively affected
241 (Harst et al., 2006; Kimmel et al., 2007; Stefan et al., 2013; Sharma and Kumar, 2010;
242 Pattazhy, 2011; Darney et al., 2016; Taye et al. 2017) the number of outgoing foragers
243 (Valberg, 2010; Sharma and Kumar, 2010), the successful return of marked feeders (Harst et
244 al., 2006; Stefan et al., 2013)

245 On the contrary, a few researchers have argued that the EMF does not have a negative
246 effect on honeybees (Mixson et al., 2009; Blacquiere and Hoofwijk, 2010; Singh, 2014).

247 Considering these studies, a study entitled "The Effect of Electromagnetic Field (EMF)
248 on Nutritional Behavior of Honey Bees (*Apis mellifera* L.)" was conducted at Bayburt during
249 2017.

250 The study on the number of incoming bees increased from U1 (control 0 μ T, 90 mV/m,
251 10.82 \pm 11.77 bees) to U5 (200 μ T, 264 mV/m, 21.07 \pm 17.89 bees). It was observed that when
252 the EMF or electric field intensity increases the number of bees that arrived in the Petri dishes
253 and the waiting time of them decreases (Table 2).

254 That is, the EMF or electric field intensity increases, the number of bees from petri
255 dishes and the waiting time of Petri dishes decreases.

256 **Conclusion**

257 The present results showed that honeybees are sensitive to the modification of EMF or
258 electric field intensity.

259 Recently, Valkova and Vacha (2012) discussed the possibility of using honeybees for
260 both magnetic nanoparticles and the magnetic field of the earth to detect the geomagnetic
261 field.

262 In conclusion, Honeybees have been observed for the first time under the influence of
263 electric and electromagnetic fields. Firstly, honeybees have been added to the list of animals
264 that have been studied on magnetoreception and electroreception.

265 It can be deduced from our results that areas where the electromagnetic field is dense
266 will be less visited by bees, resulting in the fact that plants and fruit trees in these regions will
267 not be sufficiently pollinated. This will cause a decrease in the quality of fruits and other plant
268 products.

269 The development of technology increased by electromagnetic pollution will effect
270 honeybees and crop production negatively. The apiaries should be installed away from high-
271 voltage lines, base stations, industrial zones and residential areas in order to reduce the
272 negative impact of the electromagnetic field or the electric field on honeybees.

273 **Acknowledgments**

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275 **Competing interests**

276 There is no conflict of interest.

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460 Table:1 Application groups.

| Helmholtz equipment | coils | U1 | U2 | U3 | U4 | U5 |
|--|------------|-------------|--------------|--------------|--------------|----|
| Magnetic Field Levels | 0 μ T. | 50 μ T. | 100 μ T. | 150 μ T. | 200 μ T. | |
| (Strength Electromagnetic Radiations) | 90 mV/m | (118 mV/m) | (151 mV/m) | (211 mV/m) | (264 mV/m) | |

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462 **Table 2. Average values of the number of honeybees from Petri dishes and waiting**
 463 **periods in Petri dishes.**

| Applications | n | The number of honey bees from Petri dishes $\bar{x} \pm S\bar{x}$ | n | waiting periods (Sec.) $\bar{x} \pm S\bar{x}$ |
|------------------------|----|--|----|--|
| Control (90mV/m) | 29 | 21.07 \pm 17.89 ^a | 75 | 35.27 \pm 6.97 ^a |
| 50 μ T (118 mV/m) | 46 | 14.00 \pm 17.58 ^b | 75 | 24.81 \pm 4.98 ^b |
| 100 μ T (151 mV/m) | 57 | 13.51 \pm 13.34 ^b | 75 | 21.00 \pm 4.52 ^c |
| 150 μ T (211 mV/m) | 51 | 12.47 \pm 10.35 ^c | 75 | 18.73 \pm 4.35 ^d |
| 200 μ T (264 mV/m) | 98 | 10.82 \pm 11.77 ^d | 75 | 12.28 \pm 5.58 ^e |

464 *Means in each column followed by different letter are significantly different (P<0.01)

465 **Table 3: Results of variance analysis on honeybee numbers in Petri dishes**

| Variation Sources | df | Mean Square | F | Sig. |
|---------------------|----|-------------|-----------|------|
| Minutes | 32 | 884.793 | 3539.171 | .000 |
| Iteration | 2 | 34.722 | 138.888 | .007 |
| Applications | 4 | 3485.440 | 13941.762 | .000 |
| Minutes * Iteration | 64 | 11.250 | 45.001 | .022 |

| | | | | |
|------------------------------------|----|---------|---------|------|
| Minutes * Applications | 70 | 167.961 | 671.843 | .001 |
| Iteration * Applications | 8 | 75.340 | 301.361 | .003 |
| minutes * Iteration * Applications | 98 | 10.838 | 43.350 | .023 |
| Error | 2 | 0.250 | | |

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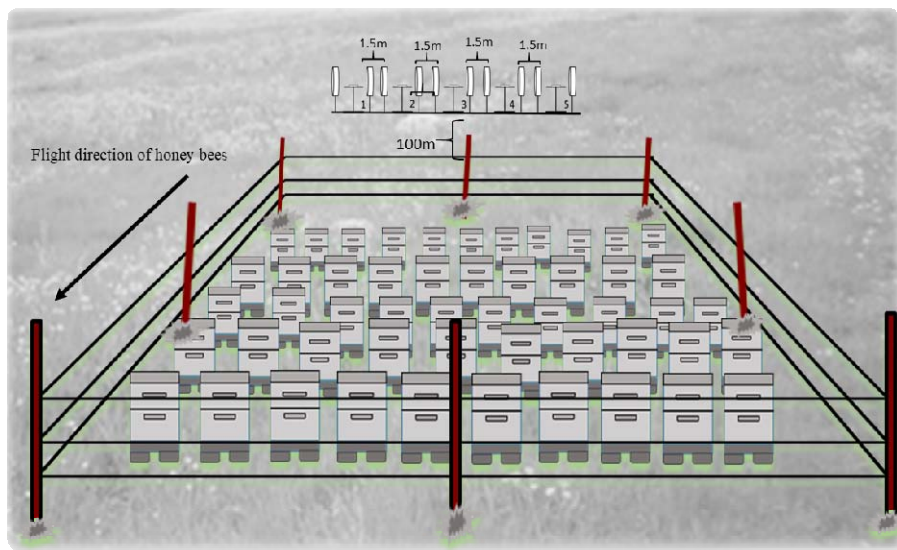
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470 **Table 4: Results of analysis of variance applied to the period in which honeybees**
471 **spend their Petri dishes.**

| Variation Resources | f | Mean Square | F | Sig. |
|-------------------------|----|-------------|---------|------|
| Applications | | 5422.357 | 222.250 | .000 |
| Iteration | | 3.523 | .144 | .866 |
| Iteration* Applications | | 7.959 | .326 | .956 |
| Error | 60 | 24.398 | | |

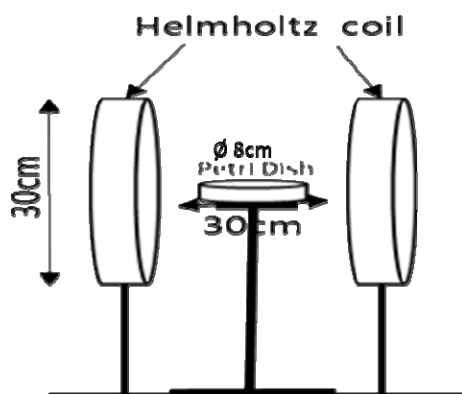
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474 **Figure 1. Positions of Helmholtz coil equipment according to apiary.**

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Figure 2. Representation of the Helmholtz coil equipment.

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