Effect of Electromagnetic Waves of Mobile Phone Tower on Colony Development and Performance of *Apis mellifera*

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(2015-A-1062-M)

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Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir

2017

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Syed Tazkiya Manzoor
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Thesis

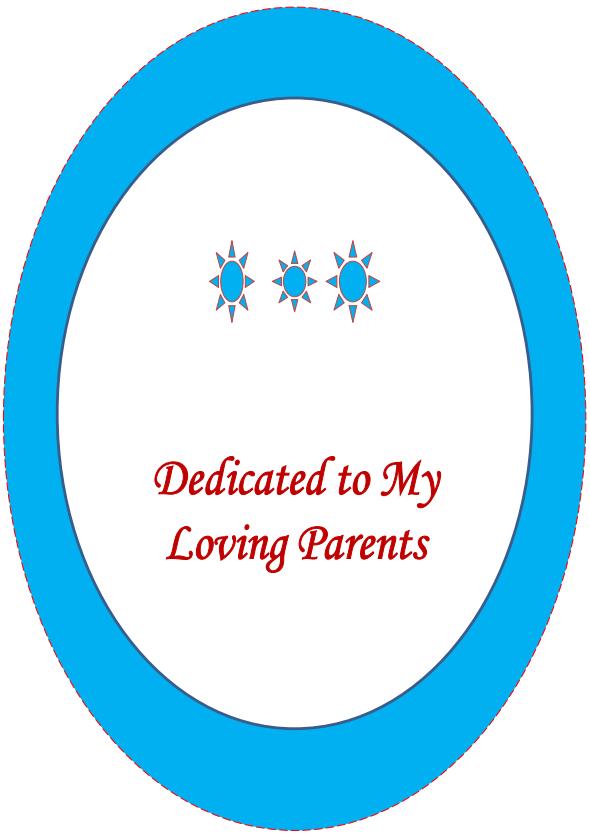
Submitted to

The Faculty of Agriculture
Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir

in partial fulfillment of requirements for the award of the degree of

Master of Science in Agriculture
(Entomology)

2017


Dedicated to My
Loving Parents

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Division of Entomology, Faculty of Agriculture, Wadura

Certificate – I

This is to certify that the thesis entitled, **"Effect of Electromagnetic Waves of Mobile Phone Tower on Colony Development and Performance of *Apis mellifera*"** submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science in Agriculture (Entomology),** to the **Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** is a record of bonafide research work carried out by **Ms. Syed Tazkiya Manzoor (Regd. No. 2015-A-1062-M)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that any help or information received during the course of investigation has duly been acknowledged.

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We, the members of the Advisory Committee of **Ms. Syed Tazkiya Manzoor (Regd. No. 2015-A-1062-M)** a candidate for the degree of **Master of Science in Agriculture (Entomology)** have gone through the manuscript of the thesis entitled, **"Effect of Electromagnetic Waves of Mobile Phone Tower on Colony Development and Performance of *Apis mellifera*"** and recommend that it may be submitted by the student in partial fulfilment of the requirements for the award of the degree.

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Certificate – III

This is to certify that the thesis entitled, **"Effect of Electromagnetic Waves of Mobile Phone Tower on Colony Development and Performance of *Apis mellifera*"** submitted by **Ms. Syed Tazkiya Manzoor (Regd. No. 2015-A-1062-M)** to the **Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** in partial fulfilment of the requirements for the award of the degree of **Master of Science in Agriculture (Entomology)** was examined and approved by the Advisory Committee and External Examiner on …….

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Title of the Thesis	:	**Effect of Electromagnetic Waves of Mobile Phone Tower on Colony Development and Performance of *Apis mellifera***

ABSTRACT

Focusing on the effects of electromagnetic radiations of mobile phone towers on honey bees (*Apis mellifera*) colonies present investigation was carried out at Faculty of Agriculture, Wadura to study the effect of electromagnetic waves (EMW) from cell phone tower on developmental and behavioural characteristics of *Apis mellifera.* The characteristics studied included bee strength, sealed brood area, unsealed brood area, pollen stores, sealed honey stores, unsealed honey stores initiation and cessation of foraging, number of incoming and outgoing foragers. The bee strength (5.3-9.3 bee frames) and honey stores-sealed (5.7 to 8.8 kg), unsealed (4.6 to 6.6 kg) of *Apis mellifera* colonies significantly increased from 14 to 70 days after placement (DAP) at all the distances from cell phone tower. There were significant increase in brood area from 14 to 56 DAP then decreased at 70 DAP in both the sealed (1118.80cm^2) and unsealed brood (643.9 cm^2). Significant increase in pollen stores (199-263.2 cm^2) from 14 to 42 DAP and then decrease at 56 DAP (217. 9 cm^2) followed again by increase at 70 DAP (329.1 cm^2) was recorded. The bees started earlier and ceased foraging later during this period. Number of incoming foragers/5 minute increased significantly from 14 to 56 DAP and reduced at 70 DAP while as number of outgoing foragers per 5 minute increased significantly from 14 to 70 DAP. The investigations

showed no significant effect of EMW emitted from cell phone tower on bee strength, brood area, pollen stores, honey stores, initiation and cessation of foraging, number of incoming and outgoing foragers when only one mobile phone tower is present in a locality within 800m distance range, therefore, there is no threat of any negative impact on the apiaries which are close to the mobile phone tower.

Keywords: Electromagnetic Waves, Days after placement

Signature of Student
Dated: _____

Signature of Major Advisor
Dated: _____

ACKNOWLEDGEMENT

In the name of Great Almighty, "ALLAH" The most Beneficent and Merciful To start with I bow in reverence to "Almighty Allah, The most Merciful, Beneficent, Omnipresent, Magnificent creator of creations, Cherisher and Sustainer of the Worlds" by whose grace I was able to complete my work. I testify that nothing deserves worship except Allah alone, with no partner and I testify that Muhammad (S. A. W) is his Messenger-may Allah send prayers upon him, his family and his companions

The dream begins with a teacher, who believes in you,

Who tugs and pushes and leads you to the next plateau,

Sometimes poking you with the sharp stick called 'truth'

Dan Rather

MY first debit of gratitude must go to the chairman of my advisory committee, Dr. Manzoor Ahamad Paray, Associate Professor and I/c Research and Training Centre for Pollinators, Pollinizers and Pollination Management, SKUAST-K, whose utmost co-operation, consistent encouragement, constructive criticism, meticulous suggestions and keen interest were instrumental during the tenure of my study and proved to be a wonderful guide helping out every instance of difficulty during the preparation of this manuscript. I appreciate all your contributions time, ideas, and funding to make my P. G experience productive and stimulating. I thank Almighty for blessing me with a mentor like u.

I greatly rejoice to express empathetically, with profound sense of gratitude, highest veneration and sincere thanks to Dr. S. S Pathania, Assistant Professor, Division of Entomology, SKUAST-K, Shalimar and co-chairman of my advisory committee for his constant and painstaking guidance, persuasion, sustained interest, relentless efforts, untiring help, incessant encouragement and enabling me to accomplish this hustling task.

It is my privilege to place on records my profound gratitude and thanks to the other members of my advisory committee viz; Dr. Khalid Rasool, (Associate Professor Division of Fruit science SKUAST-K Wadura), Dr. S. A Saraf (Associate Professor, Division of Agriculture Economics, SKUAST-K) and Dr. Showkat Maqbool (Associate Professor, Division of Agri-statistics, SKUAST-K) for their valuable and learned suggestions, keen interest, exorbitant help during the entire course of investigation and review of this manuscript.

With highest degree of veneration, I express my profound gratitude to Professor and Head, Division of Entomology, Dr. Sheikh Bilal Ahmad, whom I

shall ever remain indebted for his painstaking guidance and sparking his precious time for going through this manuscript with patience and utmost care.

I profoundly acknowledge my sincere thanks to teaching/research staff Division of Entomology Dr. Shaheen Gull (Associate Professor), Dr. Munaza Yaqoob (Assistant Professor), Dr. Ishtiyaq Ahad (Assistant Professor), Dr G. M Lone (Assistant Professor) for their help rendered during the course of studies.

My Sincere gratitude and thanks to scientific staff namely Dr. Parveena Banoo, Dr. Rizwanan Khurshid Research and Training Centre for Pollinators, Pollinizers and Pollination Management SKUAST-K Shalimar. I specially convey my thanks to Dr Sajad Hussain Paray for his help rendered during the research work.

I am also thankful to all the non-teaching staff of Division Entomology for their help and cooperation during the research work and also the library staff of SKUAST-K for their cordial and timely help during the research work.

Completion of this work was only possible due to cooperation and help many people. I shall be failing in my duty if I do not record my indebtedness to my express my friends and colleagues Ms. Aoufa Mushtaq, Ms. Kawser Rasool, Mr. Retaish Kumar, M. s Rozy Rasool, Ms. Uzma Arifie, Ms. Uzma Rashid for their moral support from time to time.

I unfeignedly owe my parents a tremendous filial respect and gratitude for their unending love and affection. They have been instrumental in every success that I have achieved hitherto. In fact, words, are insufficient to convey the veneration and a highly sense of gratitude to all the sacrifices, heartfelt pious blessings and encouraging moral support from them. I I would like to voice my deep admiration and deeper love to my adorable brother Syed Ubaid Manzoor and sister Syed Mehroo-un-Nisa for their affection and encouragement, which give me constant strength to go on who have been the bliss of my life. Their presence in my life has been a solace of my eyes bestowed on me by my Lord, Allah, and the Almighty. My love increases for them with every passing day.

Above all I bow my head to Almighty "Allah" for his blessings in this life and the life hereafter.

Syed Tazkiya Manzoor

Place: Shalimar, Srinagar
Dated:

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Chapter-1

INTRODUCTION

Apiculture has developed into an important industry in India as honey and bee wax have become common products. Besides honey bees do great environmental services by providing pollination services. Bee keeping proves worthwhile from a monetary point of view as honey and wax command rewarding profits (Pattazhy, 2011). Honey bees (members of the family Apidae; order Hymenoptera) are the best known and most useful insects, known not only for the production of honey and other valued hive products (wax, royal jelly, propolis, pollen, venom etc), but also for their more important ecological role as the most dependable and efficient pollinators of flowering plants/trees; which leads to enhanced crop productivity (quantitatively as well as qualitatively), besides contributing to maintenance of plant diversity(Kejriwal, 2012).

Pollinators are very important in global crop production point of view as 85 per cent of the crops are pollinated by insects for setting of fruits and seeds (Klein *et al.*, 2007). Among all pollinators bees are important for both natural vegetation and for crops (Castro, 2001). Pollination in nature is also very important, especially for biodiversity as 15 per cent of all wild plant species in Europe are visited by honey bees (Kwak *et al.*, 1998). The economical role of honeybees in worldwide pollination has been valued to be around 153 billion euro's in the year 2005 (Gallai *et al.,* 2009). The annual economic valve of insect pollinators to agricultural productivity for the major crops cultivated in the study areas in the HKH region was USD 2.7 billion: USD 53.8 million for the Chittagong hill track of Bangladesh,USD17.9 million for Bhutan USD676.8 million for the Chinese Himalayan provinces, USD 365 million for Himachal Pradesh and USD 426.8 million for Kashmir in north-western Indian Himalayan, USD 166.8 million for Uttarakhand in the central Indian Himalayas, and USD 954.6 million for the Himalayan region of Pakistan (Partap *et al.*, 2012).

About 50 million bee colonies mostly of *Apis mellifera* are maintained all over the world. According to United Nations Conference on Trade and Development (UNCTAD)/ General Agreement on Tariff and Trade (GATT) 1986 report (ITC, 1986) world production of honey was estimated to be at about 1 million metric tonnes. There are 15 countries in the world which account for 90 per cent of the world honey production. China is the only Asian country, among these, producing nearly 305,000 metric tonnes in 2012. It ranked first in the world, followed by the United States of America 82,000 metric tonnes (Apeda, 2013). There are about 16 lakh bee colonies in beehives, maintained by more than 2.6 lakh beekeepers in the country with estimated annual production of around 70,000 tonnes of honey and provide employment to around 1.75 lakh persons (Sarswat, 2012).

India has about 1 million *Apis cerana* and about 0.2 million *Apis mellifera* colonies. However, during past decade, hardly a few lakh bee colonies have been added to the basic stock. Therefore, our country's production of honey was low in 2012 in comparison of last few years. India exported honey (26089 metric tonnes) to 48 countries in 2011-12, and earned Rs.321.24 crores (Apeda, 2013). The most important honey producing states in India are Bihar, Maharashtra, Punjab, Uttar Pradesh, Himachal Pradesh etc. The production of honey was maximum in Uttar Pradesh followed by Bihar in 2012-13.In Jammu and Kashmir, beekeeping is mainly forest based and the state of J&K offers great potential, having (6,58000) hectare of net forest area (Annonymous,1999).

A great loss of honey bees have been recorded for more than a century due to diseases and unknown reasons (Hart, 1893; Aikin, 1897; Beuhne, 1910; Wilson and Manepace, 1979). In recent years, many factors have been reported that affect the development of honey bees such as diseases, natural enemies, pesticides, adverse climate etc. (Favre, 2010). At present human being (Leszezynski *et al.*, 2002; Gandhi and Singh, 2005; Hardell and Sage, 2008), rabbit/rats (Lai and Singh, 1996; Moorhouse and Macdonald, 2005), bats (Nicholls and Racey, 2007;

Nicholis and Paul, 2007), birds (Everaert and Bauwens, 2007;Balmori, 2009; Grigoriev, 2003), frogs (Balmori, 2006;Balmori, 2010), nematode (Daniells *et al.,* 1998), Drosophila (Ghamdi, 2012), plants (Belyavskaya, 2001; Haggerty, 2010) and honey bees (Warnke, 1976; Greenberg *et al.*,1981; Martin, 1988; Harst *et al.*, 2006; Sharma and Kumar, 2010; Favre, 2011) are also reportedto be affected by electromagnetic field.

Monarch butterflies and locusts migrate great distances using their antennae to sense air currents and earths electromagnetic fields. Moths are drawn to light frequencies. Ants, with the help of their antennae are adept at electrical transmission and found to respond to frequencies as low as 9 MHz. Flying ants are very sensitive to electromagnetic fields (Warnke, 2007). Insects and other small animals would naturally be the first to obviously be affected by this increase in ambient radiation since naturally they have smaller bodies and hence less flesh to be penetrated by exposure to microwaves (Aday, 1975).

A study by the University of Athens on fruit flies exposed to 6 minutes of 900 MHz pulsed radiation for 5 days showed reduction in reproductive capacity (Panagopoulos *et al.*, 2004). Scientists suspect a multiple of factors responsible for the loss of bees, of which *Varroa* mite, pesticides, viruses, farming practices, monoculture, hygiene in the hive and climatic factors are the most widely cited possibilities and the influence of electromagnetic waves and cell phone use near the bees colonies (Anonymous, 2007).

EMFs are considered as a cause of sudden disappearance of honey bees which is a huge problem in the field of beekeeping (Van Engelsdorp *et al.*, 2009). The losses of honey bees are problematic both from the ecological and human point of view with regard to production of bee products, crop pollination, biodiversity etc. (Blacquiere *et al.*, 2009). Bees and other insects have survived and evolved complex immune system on this planet over a span of millions of years. It is not logical that they would now suddenly die out due to diseases and natural parasites. This suggests another factor has been introduced to their

environment that disrupts their immune system and the scientists suspect use of mobile towers and mobile phones (Sahib, 2011).

Apis mellifera is considered to be a bioindicator of electromagnetic radiations because its brain anatomy and the learning region are well known for associative learning capabilities (Manzel and Muller, 1996; Zhang *et al.*, 1999; Schwarzel and Muller, 2006).Since the brain structure of the honey bee is comparable to those of vertebrates (Bliss and Collinridge, 1993; Eichenbaum, 2004; Giurfa, 2003) hence could help in determining the effect of electromagnetic radiations on them.

The electromagnetic radiations are extensively used in modern communication and technology era (Cleveland *et al.*, 1999). In India, during the last sixteen years there has been exponential growth of mobile telephoning. At present nearly 800 million people have mobile phones, making it the second largest mobile subscribers in the world after China (Anonymous, 2010). India has adopted International Commission on Non-Ionizing Radiation (ICNIRP) guidelines as the standard for safety limits of exposure to radiofrequency energy produced by mobile handsets for general public. In the country as per the guide lines of ICNIRP, the safe frequency is between 400 and 2000 MHz, 22.5 W/m^2 power density for occupational exposure and 4.5 W/m^2 for general public (ICNIRP,1998). According to Sivani and Sudarsanam (2013) the value of various radiations of radio frequency electromagnetic field (RF-EMF) emitted from cell phone technology is ranged from 800 MHz to 3 GHz and for cell tower antenna from 900 or 1800 MHz.

However, Blacquiere and Hoofwijk (2010) have observed that the influences of EMF on honey bees have not been studied thoroughly as enough scientific data is not available on the impact of mobile phone towers. According to different investigators the thermal impacts of EMR exposure on biological systems have neither succeeded to detect any statistically significant changes in the biological processes nor could have proved any acute change in health

conditions at the ground levels (Zach and Mayoh, 1984; Zach and Mayoh, 1986; Hanowski *et al.*, 1996; Brent, 1999; Lonn *et al.*, 2005; Hoskote *et al.*, 2008). Similarly, Mixson *et al.*, (2009) have reported that exposure of honey bee to 900to 1800 MHz from Global System for Mobile Telecommunications (GSM) radiations does not influence the antennal response to sucrose feeding in harnessed foragers of *Apis mellifera*. They also found that these radiations do not affect the returning of foragers to the foraging site. Hence, did not affect communication in *Apis mellifera* within the hive.

Keeping in view the controversial reports on effect of electromagnetic waves emitted from the cell phone towers and on the important potential pollinator *Apis mellifera,* the studies were carried out with the following objectives:

- To study the effect of electromagnetic waves of cell phone towers on colony development.
- To study the effect of electromagnetic waves of cell phone towers on bee behavior.

Chapter-2

REVIEW OF LITERATURE

A critical and comprehensive review of literature is inevitable for any scientific investigation. *Apis mellifera*, a common honey bee is responsible for the 80% of the pollination among field crops and other flowering plants. Beekeeping is one of the oldest traditions in India, honey and bee products have great market demand. It makes the major income for most of our famers. The declining population of these species is a serious issue. Colony Collapse Disorder (CCD) is mainly due to electro-pollution by increasing mobile phone tower radiations (Paramanik and Paramanik, 2016) In India, sharp decline in population of honey bees thought to be due to unscientific proliferation of towers and mobile phones. This loss has been plunged up to 60 per cent in Kerela (Sahib, 2011).There are various reasons for the decline of the honey bee populations, the effects of electromagnetic radiations EMR can also be added into the list. Honey bees have crystals of magnetite in their fat body cells which produce magnetic reminisce under the influence of radiations (Gould *et al.*, 1978; Keim *et al.*, 2002).This indicates the presence of magnetoreception system in them (Hsu and Li,1994) is responsible for sensitivity to the electromagnetic radiations produced by the mobile towers, mobile phones (Hsu *et al.*, 2007).The effects of electromagnetic radiations on immune system automatically affect their working, behavior and physiology (Pattazhy, 2011). Many researches were conducted to suggest that cell phone radiations are affecting honey bees very badly and have revealed that there is direct relationship between decline in honey bee populations and electromagnetic radiations (Dalio, 2015).In the last few years, the use of products that produce electromagnetic fields has been increasing rapidly and is still increasing (Aldrich and Easterly, 1987). Examples of these products are mobile phones, Wi-Fi and high tension electric lines. In this thesis, an attempt has been made to collect and compile the literature on the effect of EMF on honey bees.

Like other insects, honey bees are also reported to be affected by

electromagnetic radiations Warnke (1976) observed that under the influence of an electric field, a bee and all electrolytic pathways in it (haemolymph, epidermal secretions) are affected. Bees in strong electric field became aggressive, stinging each other to death. At still higher electric field bees tour out brood from the cells and no new brood was produced. The bees left their hive, if they could or otherwise the sealed themselves inside it with propolis closing not only cervices and holes but also the entrance.

According to Ho (2007), bee colonies exposed to Digital Enhanced Cordless Telecommunication (DECT) weighed 21 per cent less than non-exposed colonies. In these colonies, total area of the honeycomb was also 18 per cent less than controls ones. Harst *et al.* (2006) also studied the effect of DECT on the returning behaviour and honey comb weight. They found that honey comb weight was 66.98 per cent less as compared to non-exposed hive where the weight of honey combs was found to be increased to189.4 per cent from initial weight. The life span of worker honey bee was found to be prolonged by 60-74 per cent. Area under honey and nectar stores before exposure during exposure and after exposure was i.e. 1800 1000 and 200cm^2 as compared to 1850, 1900 and 1970 cm^2 in control colonies (Dalio, 2015).

The average total weights of the honeycombs, which were built by non-exposed bees, came to 1326 g while the average honeycomb weight of the exposed bees amount 1045 g. The difference of 281g corresponds to 21.1%. (Harst *et al.*, 2006). According to Girish (2010) when honey bee colonies were exposed with radiation, the honeycomb weight and area were reduced and returning time of honey bees increased compared to similar non-exposed colonies. Mall and Kumar (2014) observed that under the influence of cell phone radiations the average honey production was found to be highest 14.43 kg/hive in the colonies placed near the tower followed by cell phone equipped colonies 13.76 kg/hive while control colonies produce 12.80 kg/hive honey in first harvesting.

It was shown that the total bee strength was significantly higher in the

control colonies being nine comb frames as compared to one in the test colony at the end of the experiment. The thriving hives suddenly left with only queens, eggs and hive bound immature worker bees. The queens in the test colonies produced fewer eggs/day (100) compared to the control (350) (Sahib, 2011). Similarly Sharma and Kumar (2010) have also studied the effect of cell phone (GSM 900 MHz) frequency radiations (power density- 8.549 uW/cm^2) on *Apis mellifera* colonies by exposing them for 15 minutes, twice a day at Panjab University (Chandigarh). They observed reduction in colony strength. It was observed that the total bee strength was significantly higher in the control colony being nine comb frames as compared to only five in the treated colony at the end of the experiment. The queen exposed to cell phone radiations produced fewer eggs/day (144.8) compared to the control (376.2) eggs/day. Brood area, egg laying rate of the queen, honey store was even very severely reduced. Pattazhy (2011) have concluded that once operating mobile phones of 900 MHz frequency were kept10for 10 minutes in the bee hives, the worker bees stopped coming to the hives after ten days. He has also noticed drastic decrease in the egg laying capacity of queen bees.

Dalio (2015) similarly studied the effects of electromagnetic radiations on *Apis mellifera* colonies revealed that such exposure cause significant decrease in colony strength, pollen reserves, brood area and egg laying capacity of queens in test colonies as compared to normal colonies (control) and test colonies before exposure Brandes and Frish (1986) have reported that under the influence of cell phone radiations honeybee queen produced only drones with abnormal wings, antenna and legs. The radiations lead to low egg laying capacity in queens. Pattazhy (2011) similarly observed that due to the effect of electromagnetic radiation the thriving hives suddenly left with only queens, eggs and hive bound immature worker bees.

Mall and Kumar (2014) conducted experiment with three treatments by placing colonies bellow the tower by equipping colonies with and without cell

phone were taken into consideration. To quantify the effect of electromagnetic radiations EMR, all treatments have different radiation levels were maintained. It was observed that the maximum brood area was found in control colonies560.36cm, followed by the colonies kept near the tower 537.85 and lowest brood area was observed in the colonies equipped with cell phone 534.81cm was observed in the colonies equipped with cell phone. Similarly Sharma and Kumar (2010) reported that under the influence of electromagnetic radiations the area under brood declined to 760.19 cm^2 which was significantly less than the control 1975.44 cm^2.

Sangwan (2009) studied the overall increase in total carbohydrates in the haemolymph of EMR exposed drones. Similarly Kumar *et al.* (2011) have noticed the effects of cell phone radiations on various biomolecules in the adult workers of *Apis mellifera.* Initially, a rise in concentration of biomolecules including proteins, carbohydrates and lipids was observed due to stimulation of body mechanism to fight the stressful condition created by the radiations. But at later stages of exposure, a slight decline in the concentration of the biomolecules was recorded because the body had adapted to the stimulus. Studies were also made in drones of *Apis mellifera* exposed to cell phone radiations for 30 minutes, with respect to various biochemical and physiological aspects of semen. The results indicate the increased concentration of various biomolecules viz., carbohydrates, proteins and lipids and decreased activities of seminal enzymes was due to reduced utilization of the biomolecules and hence increase in their concentration (Kumar *et al.*, 2012).

Kumar *et al.* (2013) conducted an experiment in which drone was exposed for 30 minutes to radiations using live cell phones kept in working mode with tape recorder at the speaker end and positive response at the receiver's end. The results of the treatment were analyzed and compared with the control. The concentration of various biomolecules increased from 1.65 to 2.75 mg/ml for carbohydrates, 3.74 to 4.85 mg/ml for proteins and from 0.325 to 1.33 mg/ml for lipids under the

influence of EMR. There was definite influence of cell phone radiations on the biomolecules as well as on the enzyme activities present in the haemolymph of drone. They also reported that these EMR radiations grossly interfered with the normal metabolic and physiological processes of *Apis mellifera.*

Radiation affects the pollinators, honeybees, whose numbers have recently been declining due to CCD by 60% at US West Coast apiaries and 70% along the East Coast (Cane and Tepedino, 2001). The electromagnetic radiation (EMR) exposure provides a better explanation for Colony Collapse Disorder (CCD) than other theories. The path of CCD in India has followed the rapid development of cell phone towers, which cause atmospheric EMR (Pattazhy, 2011). The declining population of these species is a serious issue. Colony Collapse Disorder (CCD) is mainly due to electro-pollution by increasing mobile phone tower radiations. The mobile phones have great benefits in spite of all the harmful effect and hence complete ban on their usage is not acceptable. But its usage has to be minimized in order to conserve the honey bees (Pramanik and Pramanik, 2016).

Cammaerts (2017) conducted two experimental protocols for bringing to the fore the potential adverse effect of electromagnetism on bees and to act consequently. The first one is the observation of bees avoidance of a wireless apparatus; the second one is the assessment of colonies strength and of the intensity of the electromagnetism field (EMF) surrounding them. He reported bees avoid a wireless apparatus, if hives in bad health are located in EMF of a rather high intensity, it can be presumed that bees are affected by manmade electromagnetism. If the impact of electromagnetism on bees' health is demonstrated then, beekeepers could take this impact into account and look for protective measures for their hives. For example, the hives could be located in places where the electromagnetism has a very low intensity, and/or the hives could be set inside a kind of Faraday cage or enclosure.

Greenberg *et al.* (1981) have conducted studies by keeping the honey bee colonies under 765 kV, 60-Hz. They recorded increased motor activity with

transient increase in the bee hive temperature, abnormal propolization, impaired hive weight gain, queen loss and abnormal production of queen cells, decreased sealed brood and poor winter survival. Studies have also indicated that honey bee hives exposed to extremely low frequency electric fields but higher than those projected for the CapX2020 transmission lines, exhibited bee behavioural changes such as increased motor activity, redistribution of honey comb material (propolis), lower foraging rates, and decreased winter survival (Valberg, 2010)

In India, Sivani and Sudarsanam (2012) have reported negative effect of radio-frequency electromagnetic field (RF-EMF) in honey bees and other organisms. According to them, it changes the neurotransmitter functions, blood-brain barrier, morphology, electrophysiology, cellular metabolism, calcium efflux, gene and protein expression in certain types of cells. Similarly, other researchers have also recorded negative effects of EMR on bees with regard to immunity, health, reproductive success, behavior, communication etc.(Fernie and Bird, 2001; Preece *et al.*, 2007; Hardell *et al.*, 2007; Hardell *et al.*, 2008;Levitt and Lai, 2010)

Electromagnetic field producing electromagnetic radiations (EMR) emitted from mobile towers and mobile phones alter the behavioral pattern of bees when they are in close proximity, leading to disappearance of bees (Van Engelsdrop *et al.*, 2009). Radiations of 900 MHz is highly bioactive, causing significant alternation in the physiological function of living organisms (Aday, 1975). If the number of towers and mobile phones increases, the honey bees might be wiped out in ten years (Pattazhy, 2011). If scientifically documented, honeybees could be used as indicator of EMF pollution. Therefore, possible effect on honey bees' navigation could be expected as these make use of magnetite and chemical reception system based on a radical pair mechanism for Magneto reception (Wiltschko and Wiltschko, 2005).

Harst *et al.* (2006) found that fewer bees returned when a Digital Enhanced Cordless Telecommunication (DECT) station was placed inside the hive and that generally took a longer time to return. Similarly, Kimmel *et al.*

(2007) found that only 49.2 per cent of the exposed bees were returned to the hives as compared to 63.0 per cent of the non-exposed foragers. Stever *et al.* (2007) also reported that honeybees were perturbed in their returning behavior to the hive after foraging by placing digitally enhanced cordless telephones located in the bottom of beehives, In a recent studies significant differences have been detected in returning of honey bees to their hives: 40 per cent of the non-irradiated bees came back as compared to 7.3 per cent of the irradiated ones (Stefan *et al.,* 2013). Similarly Sharma and Kumar (2010) have found that cell phone (GSM 900 MHz) frequency radiations have adverse effect on navigation system of *Apis mellifera.* There is a severe reduction in the number of returning foragers when the bees were exposed to these radiations. The result indicate a strong effect of the mobile phone radiations with about 30% decrease in number of worker bees leaving and returning to the hive during exposure compared to before exposure. EMFs from telecommunication infrastructure interfere with bees biological clocks that enable them to compensate properly for the sun's movements, as a result of which, may fly in the wrong direction when attempting to return to the hive (Rubin *et al.*, 2006). Sahib (2011) observed showed that after ten days the worker bees never returned hives in the test colonies and number of worker bees leaving the hive entrance/ minute) was also found negligible as compared to control.

The massive amount of radiation produced by towers and mobile phones is actually frying the navigational skills of the honey bees and preventing them from returning back to their hives and concluded that once a operating mobile phones of 900 MHz frequency were kept for 10 minutes in the bee hives, the worker bees stopped coming to the hives after ten days. (Pattazy, 2011). There was no remarkable change in nectar and pollen gathering behaviour of foragers in all the three treatments by placing colonies bellow the tower by equipping colonies with and without cell phone (Mall and Kumar, 2014).

The mobile phone radiations disturb the bees navigational system, leaving them unable to find their way back to the colony; this phenomenon will lead to

problems in their reproduction system and to their death eventually (Halabi *et al.*, 2013).The effects of electromagnetic radiations cell phone towers on *Apis mellifera* colonies revealed that such exposure caused disturbance, more aggressiveness disturb navigational skills of foragers, bees get irritate and degree of stinging behaviour was very high as compared to normal colonies (control) and test colonies before exposure Worker bees showed behaviour as they used to do just before swarming. Change in behavioural pattern of honeybees when they were very close to mobile phones or towers have also been observed. Number of returning foragers to their respective hives was much lesser as compared to outgoing bees. Number of outgoing bees was also lesser as compared to that of normal (control) colonies. At the end of experiment negligible number of bees were coming back to their hives (Dalio, 2015).

Schneider and Lewis (2004) studied that the induction of honeybee worker piping by the electromagnetic fields of mobile phones might have dramatic consequences in terms of colony losses due to unexpected swarming. The present study also reported that active mobile phone handsets in beehives noticeably induce the rate of worker piping. However, no evidence for piping of the laying queen was observed. Similarly Sharma and Kumar (2010) reported that the behaviour of exposed foragers was negatively influenced by the effect of electromagnetic radiations of cell phone towers. Dalio (2015) tested electromagnetic waves originating from mobile phone for potential effects on honey bee behavior. The audiograms and spectrograms revealed that active mobile phone handsets have a dramatic impact on the behavior of the bees, namely by inducing the worker piping signal which was regularly observed about 25 to 40 min after the onset of the mobile phone communication. In natural conditions, worker piping either announces the swarming process of the bee colony or is a signal of a disturbed bee colony (Favre, 2010).

The behaviour of honey bees (*Apis mellifera carnica*) was observed by exposing them to the radiation of DECT-phones. In this study four respectively

eight bee-colonies were used as experimental group and were irradiated, whereas the same numbers of comparable bee-colonies were field-free.The returning behaviour was found to be affected as the quantity of returning bees was bigger in case of non-exposed as compared to exposed as well as the returning time of the few returning exposed honey bees was distinctly longer (Harst *et al.*, 2006).

After keeping a mobile for a period of one month next to the hive, and by making a fifteen-minute call each day, it was realized that the number of bees inside the hive decreased and bee keeper estimated that 80% of the bees were lost. The eggs were also not transformed into larva. These results verify that mobile phones' radiations affect the honeybees life's system. The experiments performed also showed that honeybees in their normal case produced sounds at lower frequencies around 450 Hz, and with lower intensity 0.3 normalized amplitude. But, when they were disturbed by the presence of a mobile phone, they produced sounds with higher frequencies that reached 1.5 KHz, and with higher intensity that reached 0.7 normalized amplitude (Halabi *et al.,* 2013).

In an experiment of exposure of the bees to an electric field of 250Hz for 128 days resulted in spontaneous and continuous change of dance angles (Korall and Martin, 1988). Soares (1981) observed eye mutation in honey bee under the influence of electromagnetic radiations.

According to Vacchia *et al.* (2009) studies have not shown any consistent evidence of negative effects of non-thermal radio frequency exposure conditions on biological system of honey bees *in vitro* so far. Darney *et al.* (2015) conducted an experiment in which honeybees were individualized with radio frequency identification (RFID) tags glued onto their dorsal surface and detected at the hive entrance by readers emitting high-frequency (HF) radio waves. In this work they searched for a possible adverse effect of HF on honeybee's survival. Eight-day-old honeybees were exposed to HF (13.56MHz) or ultra-high-frequency (UHF, 868 MHz) radio waves for 2 h split into ON and OFF periods. Out of the five experimental conditions, they observed an increase in mortality in two conditions,

once after HF and once after UHF exposure, with OFF duration of 5 min or more. They then recommend limiting exposure of honeybees to radio waves to less than 2 h per day, and conclude that the RFID parameters, like those we used in the field for monitoring hive activity, present no adverse effects for honeybees.

Effects of radiations emitted from Global System for Mobile Telecommunications (GSM) cellular phones on the behaviour of forager honey bees (*Apis mellifera carnica, Apis mellifera caucasiaca* and *Apis mellifera syricaca*) were studied through a series of experiments by Mixson *et al.* (2009) at University of Texas, Brownsville. They reported that exposure to such radiations did not influence proboscis extension or feeding. In a second series of experiments, free-flying foragers were trained to visit a target. It was reported that a 45 minutes radiations exposure did not influence return to the target. While in the final series of experiments, no effect of the radiations on honey bees' aggression was recorded.

Blacquiere and Hoofwijk (2010) do not expect EMF to be a direct nor a major cause of colony losses. If EMF plays a role in colony losses, it will most likely to be contribution between EMF and other factors. They have observed that the influences of EMF on honey bees have not been studied thoroughly as enough proper scientific data is not available on the impact of mobile phone towers.

According to different investigators, the thermal impacts of EMR exposure on biological systems have neither succeeded to detect any statistically significant changes in the biological processes nor could have proved any acute change in health conditions at the ground levels (Zach andMayoh, 1984; Zach and Mayoh, 1986; Hanowski *et al.*, 1996; Brent, 1999; Lonn*et al.*, 2005; Hoskote *et al.*, 2008).

Chapter-3

MATERIALS AND METHODS

The present study entitled "Effect of electromagnetic waves of mobile phone tower on colony development and performance of *Apis mellifera* L." were carried out at Faculty of Agriculture SKUAST-K Wadura Sopore. The details of the experiments conducted are given as under:

3. 1 Period of study

The experiment was conducted from 2015-2017 at fortnight intervals at SKUAST-Kashmir, Wadura.

3.2 Experimental setup

Before starting the experiment, Fifteen *Apis mellifera* colonies were equalized in terms of strength, brood area pollen stores and honey stores. Empty hives were pre-stocked with equal amounts of brood, empty combs, feeders. These colonies were headed by newly mated queens. The selected colonies were used in conducting present studies. The worker bees were transferred to the hives and the bee frames were distributed equally among the hives and bee strength was measured as total number of bee frames per colony. Status of *Apis mellifera* colonies at the time of equalization is presented in Table 1.

Table 1: Status of *Apis mellifera* colonies at the time of equalization

Colony type* (BF)	Bee strength (BF)	Pollen stores (cm^2)	Sealed brood ($cm^{2)}$	Unsealed brood (cm^2)	Sealed honey store (kg)	Unsealed honey store (kg)
10	5.0	219-228	1005 -1015	475-480	4-4.7	3.5-4

Plate 1: Colony equalization

Plate 2: Radio frequency meter

Plate 3: Mobile phone tower

3.3 Selection of site

In the University campus of FoA, mobile phone tower is affixed near the administrative block. This site was selected for conducting present studies on the effect of electromagnetic radiations (EMR) emitted from the tower on *Apis mellifera.* Location where the maximum radiations were recorded was considered as zero meter distance. Whereas, other distances i.e. 200 m, 400m, 600 m and 800 m (control) were selected away from zero m distance in such a manner that they lie in same area and have similar floral and environmental conditions. Three selected colonies of *Apis mellifera* were kept at each distance during last week of April, 2016.

3.4 Measurement of radiations

The strength of EMR emitted from cell phone tower and was measured in terms of mV/m (Electrical field strength), µA/m (Magnetic field strength), and mW/m^2 power density with the help of RF meter (Model 480836). The strength of radiations recorded was (294.23 mV/m, 420.12 µA/m, 291.910 mW/m^2), (12.663 mV/m, 26.083 µA/m, 0.274 mW/m^2), (19.826mV/m100.54µA/m, 3.215 mW/m^2), (6.198 mV/m, 21.338 µA/m, 0.0971mW/m^2), (5.088 mV/m, 21.12 µA/m, 0.152mW/m^2) at 0,200,400,600 and800 m distance from mobile phone tower.

3.5 Measurement of different parameters

Data on different colony development parameters such as bee strength, sealed and unsealed brood area, pollen stores, sealed and unsealed honey stores, initiation of foraging, cessation of foraging, number of incoming foragers, number of outgoing foragers, were collected at fortnight intervals. The detail of each parameter/experiment is as follows.

3.5.1 Bee strength (No. of bee frames)

Bee strength was measured by the transparent grid pre-marked in (cm^2). For measurement of bee strength, help of an assistant was taken. The colony was opened and comb of bees sequentially removed and the percentage of the comb

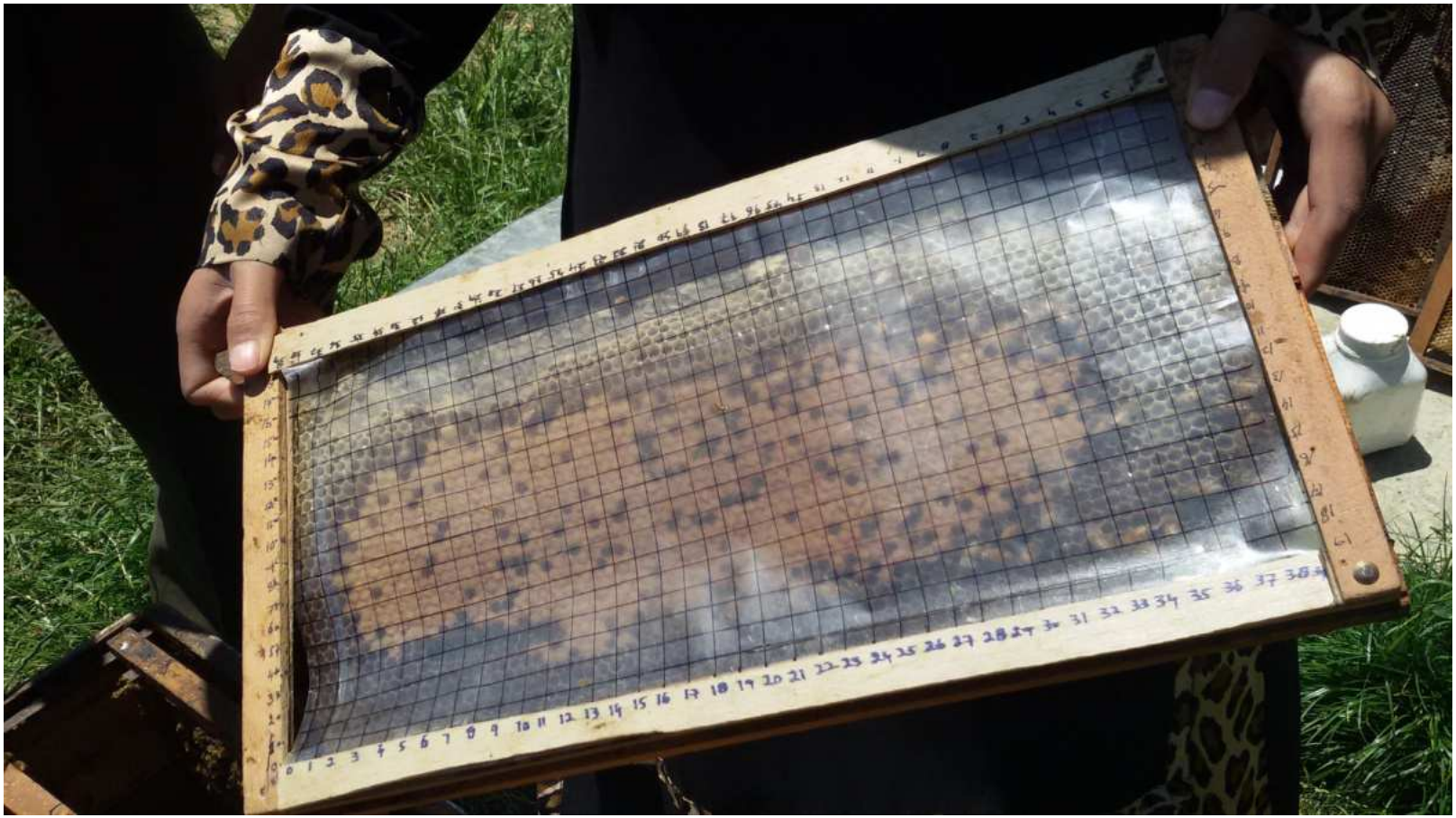

Plate 4: Use of transparent grid

covered by bees was recorded. The frames of every colony were labelled at the start of the experiment as 1,2,3,4,5.....10 and the sides of frames as A1,A2,B1,B2 and so on. The percentage comb surface was converted into colony bee population. The mean of the estimate as percentage comb surface for individual frames was converted into area cm^2.The area in $cm^2$of bees was converted into number of bees with appropriate bee density using the below mentioned formula. Finally the colony bee population was obtained by summing up bee of each frame and side.

Number of bees =Area covered (cm^2) × bee density

[Bee density =1.23/cm^2]

3.5.2 Sealed and unsealed brood area (cm^2)

The quantity of sealed and unsealed worker brood was measured by overlaying on each side of every brood comb through a transparent grid pre marked in $cm^2$and the area brood underlying the grid was visually summed up. The total brood area was obtained by summing up the brood area on individual frames.

3.5.3 Pollen stores

The pollen store was measured with the help of a transparent grid pre marked in cm^2. The grid was placed on comb frame containing the pollen. The area of the pollen underlying the grid was summed up visually and the data was recorded. The total area of pollen was obtained by summing up the pollen area present on individual frames.

3.5.4 Sealed and unsealed honey store

The honey store was measured by removing the frames sequentially, brushing the bees back into the hive and separating 10 cm^2 area. Each of empty wax comb and honey filled wax comb and weighing them on electronic balance.

Weight of honey filled comb in 10 cm^2.

Weight of the honey in 10 cm^2 area (g) = area - Weight of empty comb in 10 cm^2 area

The total honey in one frame on its both sides was calculated by summing up the individual weights 10 cm^2 at all the spots containing honey. The total honey store of the colony was obtained by summing up the individual weight of all the frames of the colony.

3.5.5 Bee behaviour

The bee activity at the hive entrance was recorded at two different times of day at fortnight intervals.

3.5.5.1 Initiating of foraging and cessation of foraging

The observations were recorded by recording the time of initiation and cessation of outgoing and incoming bees at hive entrance at early morning and evening time.

3.5.5.2 Incoming foragers and outgoing foragers

The observations were recorded by counting number of bees coming in and going-out of the hive by two observers simultaneously with the help of a recording device and a stop-watch. The mean of the counts of two observers at a particular time was taken as the actual number of bees going in or coming out at a particular time for a colony.

The experimental colonies were observed regularly and data was recorded at fortnight intervals on colony development. Colonies were judged on the basis of following parameters.

1. Brood rearing based on area of sealed and unsealed broad.
2. Food stores based on area of pollen.
3. Sealed and unsealed honey stored.
4. Data was recorded on initiation and cessation of foraging activity by honey bee foragers.

5. Data was also recorded on foraging rate in which bees coming in and going out of bee hive will be counted for 5 minutes.
6. Bee strength based on number of bee frames was also recorded.
7. Data analysis: Data was statistically analysed by using standard protocol for factorial RBD.

Chapter-4

EXPERIMENTAL FINDINGS

Various research workers across the globe have reported the negative effect of electromagnetic radiations (EMR) emitted from cell phone towers and on honey bees with regard to strength, navigation, behaviour, honey store, pollen store and brood area, etc. (Greenberg *et al.*, 1981; Kimmel *et al.*, 2007; Korall and Martin, 1988; Harst *et al.,* 2006; Stefan *et al.*, 2013; Sharma and Kumar, 2010). However, other groups of investigators have not noticed the effect of EMR on honey bees (Mixson *et al.*, 2009; Blacquiere and Hoofwijk, 2010; Chhuneja *et al.*, 2013; Patel *et al.,* 2016). Keeping in view such controversy in mind, present investigations on "Effect of electromagnetic waves on the performance of *Apis mellifera*." were carried out at fortnight intervals from 1st of May to 14th of July 2016 at SKUST-K, Wadura, Sopore which is the first kind of such research work carried out on honeybees in Kashmir conditions. The results obtained from the experiments conducted have been presented below.

4.1 Effect of electromagnetic radiations on *Apis mellifera* colonies at different distances from cell phone tower

All honeybee colonies were observed regularly and data was recorded on fortnight intervals on various characteristics such as bee strength, Sealed and unsealed brood area, pollen store, Sealed and unsealed honey store, initiation of foraging, cessation of foraging, incoming foragers and outgoing foragers in *Apis mellifera*, at different distances from cell phone tower at Wadura are as follows:

4.1.1 Effect on bee strength

Experiments conducted on the effect of electromagnetic radiations emitted from cell phone tower on the strength of *Apis mellifera* colonies revealed that there was a continuous significant increase at fortnight intervals from 1st of May to 14th of July 2016 Table 2. The average valves of bee strength i.e. 5.3, 6.5, 8.3, 8.7 and 9.3 was found at fortnight intervals. Statistically the average strengths i.e. 7.9, 7.5, 7.7, 7.1 and 7.8 combs per colony at all the distances from the tower were

non-significant Table 2. Studies further indicate that the variations in strength in each respective month at all distances was significant, indicating no effect of electromagnetic waves on number of combs/colony.

4.1.2 Effect on sealed brood area

The perusal of the data presented in Table 3 on the status of brood per colony during experiment period revealed that there was increases in brood rearing from 14 days after placement to 56 days after placement at fortnight intervals from 1st of May to June ending and then decrease at 70 days after placement up to 14th of July at every distance from the cell phone tower. The mean sealed brood area varied between1103.00-1217.30 cm^2 in colonies placed at fortnight intervals from 1st of May to 14th of July 2016, respectively. Statistically, the mean sealed brood values varied between 1139.50-1169.00 cm^2 at 0, 200, 400, 600 and 800 m distances, respectively were non-significant. The data further showed that the variations in brood rearing at all the distances in each respective month were significant. Thus studies indicated no effect of the EMR on the area of sealed brood in the colonies kept at all distances from the tower.

4.1.3 Effect on unsealed brood area

Present data revealed that there was increases in unsealed brood area from 14 days after placement to 56 days after placement fortnight intervals from 1st of May to June ending and then decrease at 70 days after placement up to 14th of July 2016 at every distance from the cell phone tower Table 4. The average values of unsealed brood area were: 519.7, 548, 670.9, 722.7 and 643.9 cm^2 respectively at fortnight intervals. Statistically, the mean unsealed brood varied between of 604.9-632.5 cm^2 brood at 0,200, 400,600 and 800 m distances, were non-significant. The data further showed that the variations in brood rearing at all the distances in each respective month were significant. Thus studies indicated no effect of the EMR on the area of unsealed brood in the colonies kept at all distances from the tower.

Table 2: Effect of electromagnetic radiations on strength of *Apis mellifera* at different distances from cell phone tower

Distance from mobile phone tower (m)	Bee strength (No. of bee frames) at fortnight intervals					Mean
	14 DAP*	28 DAP	42 DAP	56 DAP	70 DAP	
0	5.2	7	8.9	8.6	9.8	**7.9**
200	5.5	6.3	7.9	8.5	9.5	**7.5**
400	5.2	6.7	8.6	9.1	9.1	**7.7**
600	5.1	6.2	7.9	7.6	8.8	**7.1**
800	5.5	6.4	8.3	9.5	9.4	**7.8**
Mean	**5.3**	**6.5**	**8.3**	**8.7**	**9.3**	

CD (p≤0.05)

Distance : NS
Days : 0.82
Distance ´ Days : NS

*DAP=Days after placement

Table 3: Effect of electromagnetic waves on sealed brood of *Apis mellifera* colonies at different distances from mobile phone tower

Distance from mobile phone tower (m)	Sealed brood $(cm)^2$ at fortnight intervals					Mean
	14 DAP*	28 DAP	42 DAP	56 DAP	70 DAP	
0	1,099.60	1,133.20	1,201.90	1,253.10	1,157.20	**1,169.00**
200	1,099.40	1,139.20	1,164.70	1,215.70	1,095.30	**1,142.90**
400	1,089.60	1,125.80	1,170.70	1,264.20	1,112.60	**1,152.60**
600	1,146.60	1,185.90	1,181.80	1,152.80	1,098.40	**1,153.10**
800	1,099.40	1,118.60	1,168.30	1,200.60	1,130.50	**1,139.50**
Mean	**1,103.00**	**1,140.50**	**1,177.50**	**1,217.30**	**1,118.80**	

CD (p≤0.05)

Distance : NS
Days : 21.04
Distance ´ Days : NS

*DAP=Days after placement

4.1.4 Effect on pollen stores

Data recorded on effect on pollen stores were tabulated in Table 5. It was found that under the effect of electromagnetic waves on the pollen stores in *Apis mellifera* colonies revealed a significant increase at 14 days after placement to 42 days after placement at fortnight intervals starting from 1st of May to 14th of July and then significant decrease at 56 days after placement then again increases at70 days after placement at all the distances from cell phone tower Table 5. The average values of pollen store were: 199, 230.5, 263.2, 217.9, and 329.1 cm^2 fortnight intervals starting from 1st of May to 14th of July 2016, respectively. Statistically, the variations in pollen stores at all distances in each respective month were significant. The mean pollen stores varied between 227.2-271.4 cm^2 at 0,200, 400, 600, 800m from mobile phone tower. Further, data also showed that the average variations in pollen stores at all the distances were non-significant during the period of experimentation. Thus pollen stores were not affected by the electromagnetic radiations.

4.1.5 Effect on sealed honey store

The studies conducted on the effect of electromagnetic radiations on the honey stores of experimental *Apis mellifera* showed that there was continuous significant increase in honey stores from 14 days after placement to 70 days after placement at fortnight intervals from 1st of May to 14th of July at all distances from the tower Table 6. The average values of honey store were: 5.7, 6.6, 7.7, 8.5 and 8.8 kg during, fortnight intervals. Statistically, the average values of honey store among all the distances were non-significant i.e. 7.6, 7.5, 7.4, 7.4 and 7.4 kg. Present studies further indicate that the variations in honey stores in all the respective months at all the distances were significant (Table.6) showed no effect of the radiations on the store.

Table 4: Effect of electromagnetic waves on unsealed brood area of *Apis mellifera* colonies at different distances from the mobile phone tower

Distance from mobile phone tower (m)	Unsealed brood (cm^2) during fortnight intervals					Mean
	14 DAP*	28 DAP	42 DAP	56 DAP	70 DAP	
0	525.5	536	672.8	715.9	645.9	**619.2**
200	511.3	513.4	674.6	770.8	648.2	**623.6**
400	512.1	597.7	676.0	728.8	647.8	**632.5**
600	528.3	547.2	678.5	719.2	651.4	**624.9**
800	521.5	545.7	652.4	678.5	626.3	**604.9**
Mean	**519.7**	**548**	**670.9**	**722.7**	**643.9**	

CD (p≤0.05)

Distance : NS
Days : 43.17
Distance ´ Days : NS

*DAP=Days after placement

Table 5: Effect of electromagnetic waves on Pollen stores of *Apis mellifera* at different distances from the mobile phone tower

Distance from mobile phone tower (m)	Pollen store (cm^2) at fortnight intervals					Mean
	14 DAP*	28 DAP	42 DAP	56 DAP	70 DAP	
0	247.6	289.3	236.5	243.1	340.4	**271.4**
200	168.5	245.7	246.5	198.8	421.4	**256.2**
400	201.7	232.5	269.2	231.7	293.2	**245.7**
600	194.7	194.8	282	193.1	331.6	**239.2**
800	182.4	190.2	281.8	222.6	258.9	**227.2**
Mean	**199**	**230.5**	**263.2**	**217.9**	**329.1**	

CD (p≤0.05)

Distance : NS
Days : 53.19
Distance ´ Days : NS

*DAP=Days after placement

4.1.6 Effect on unsealed honey stores

Studies conducted on the effect of electromagnetic radiations on the unsealed honey stores of experimental *Apis mellifera* showed that there was a significant increase in honey stores from 14 days after placement to 70 days after placement at fortnight intervals from 1st of May to 14th of July at all distances from the tower Table 7. The average values of honey store were i.e. 4.6, 5.5, 6.3, 6.5 and 6.6 kg during, fortnight intervals. Mean unsealed honey varied between 5.8-5.9 kg at different distances from mobile tower. Statistically, the average values of honey store among all the distances were non-significant. Present studies further indicate that the variations in honey stores in all the respective months at all the distances were significant Table 7, showed no effect of the radiations on the store.

4.1.7 Effect on initiation of activity

Data collected on foraging behaviour with regard to initiation of foraging revealed a trend of early initiation of *Apis mellifera* activity from 14 days after placement to 70 days after placement at fortnight intervals from 1st of May to 14th of July at all the distances from the tower Table 8. The average values of initiation activity are; 6.08, 5.56, 5.51, 5.52, and 5.53 am during fortnight intervals. Observations recorded on the initiation of bee activity during these months showed that it was started at 6.08, 5.54, 5.52, 5.54 and 5.53 am at zero meter; 6.09, 5.58, 5.52,5.55 and 5.51 am at 200 m, and 6.07, 5.57,5,51,5.51, and 5.54 am at 400 m distances from the tower, respectively. Similarly, the bees started their flight activity at 6.09, 5.58, 5.5, 5.51, and 5.54 am, and 6.08, 6 5.56, 5.51, 5.52 and 5.53 am at 600 and 800 m distances, respectively during the period of observations. Significant differences were found in the initiation of activity during the morning hours among all the distances from the cell phone tower during respective months Table 8 indicating no effect of EMR on the activity.

Table 6: Effect of electromagnetic waves on sealed honey stores of *Apis mellifera* colonies at different distances from the mobile phone tower

Distance from mobile phone tower (m)	Sealed honey (kg) at fortnight intervals					Mean
	14 DAP*	28 DAP	42 DAP	56 DAP	70 DAP	
0	5.5	6.8	8.2	8.3	9.0	**7.6**
200	5.7	6.4	7.7	8.9	8.8	**7.5**
400	5.9	6.8	7.4	8.4	8.7	**7.4**
600	5.8	6.4	7.7	8.3	8.9	**7.4**
800	5.5	6.6	7.7	8.5	8.7	**7.4**
Mean	**5.7**	**6.6**	**7.7**	**8.5**	**8.8**	

CD (p≤0.05)

Distance : NS
Days : 0.176
Distance ´ Days : NS

*DAP=Days after placement

Table 7: Effect of electromagnetic waves on unsealed honey stores of *Apis mellifera* colonies at different distances from the mobile phone tower

Distance from mobile phone tower (m)	Unsealed honey (kg) at fortnight intervals					Mean
	14 DAP*	28 DAP	42 DAP	56 DAP	70 DAP	
0	4.8	5.4	6.3	6.4	6.7	**5.9**
200	4.7	5.5	6.4	6.5	6.4	**5.9**
400	4.4	5.5	6.5	6.3	6.7	**5.9**
600	4.5	5.5	6.4	6.7	6.3	**5.9**
800	4.5	5.4	6.1	6.5	6.7	**5.8**
Mean	**4.6**	**5.5**	**6.3**	**6.5**	**6.6**	

CD (p≤0.05)

Distance : NS
Days : 0.194
Distance ´ Days : NS

*DAP=Days after placement

4.1.8 Effect on cessation of activity

Studies conducted on foraging activity of the experimental colonies indicate a trend of significant increase in cessation time of *Apis mellifera* activity at hive entrance from 14 days after placement to 70 days after placement at fortnight intervals from 1st of May to 14th of July at all the distances from the tower Table 9. Data showed that during these respective months, on an average bee activity stopped at 6.53, 7.02, 7.13, 7.19 and7.19 pm, respectively. Further, a non-significant difference was noticed in the cessation of activity during the evening hours at all distances i.e. 7.01, 7.02, 7.01, 7.01 and 7.00 pm at zero, 200, 400, 600 and 800 m, respectively, reflecting no effect of the radiations.

4.1.9 Effect on the number of incoming foragers

Experiments conducted on the number of incoming *Apis mellifera* bees/5 minute indicate that it significantly increased at fortnight intervals from 14 days after placement to 70 days after placement at fortnight intervals from 1st of May to 14th of July at all the distances from the tower Table 10. The data showed that the mean number of outgoing foragers/5 min during at fortnight intervals varied between 103-127 bees and was also found significant. Statistically, the average number of incoming bees varied between 111-116 bees at zero, 200, 400, 600 and 800 m distances, respectively from the tower, was non-significant. Further, data also showed non-significant differences in the number of incoming bees at all the distances in each respective month. Table 10 indicating no effect of electromagnetic radiations on foraging activity

4.1.10 Effect on the number of outgoing bees

Data collected on the effect of EMR on the number of outgoing bees/5 minute indicated that it increased significantly from 14 days after placement to 70 days after placement at fortnight intervals from 1st of May to 14th of July at all the distances from the tower Table 11. Statistically, variation in the average number of outgoing bees varied between 139-143 bees at 0, 200, 400, 600 and 800 m

distances, respectively from the tower, and data was non-significant. Further, the data showed that the average number of outgoing foragers/5 minute at fortnight intervals from 1st of May to 14th of July at all the distances from mobile phone tower varied between 88-165 bees. Data revealed that number of outgoing foragers at fortnight intervals was found significant. Thus the activity of outgoing bees was also not affected by the cell phone tower.

Table 8: Effect of electromagnetic waves on initiation activity of *Apis mellifera* colonies at different distances from the mobile phone tower

Distance from mobile phone tower (m)	Initiation of foraging (am) during fortnight intervals					Mean
	14 DAP*	28 DAP	42 DAP	56 DAP	70 DAP	
0	6.08	5.54	5.52	5.54	5.53	**5.64**
200	6.09	5.58	5.52	5.55	5.51	**5.65**
400	6.07	5.57	5.51	5.51	5.54	**5.67**
600	6.09	5.58	5.5	5.51	5.54	**5.64**
800	6.09	5.56	5.5	5.51	5.55	**5.64**
Mean	**6.08**	**5.56**	**5.51**	**5.52**	**5.53**	

CD (p≤0.05)

Distance : NS
Days : 0.057
Distance ´ Days : NS

*DAP=Days after placement

Table 9: Effect of electromagnetic waves on cessation activity of *Apis mellifera* colonies at different distances from the mobile phone tower

Distance from mobile phone tower (m)	Cessation of foraging (pm) during fortnight intervals					Mean
	14 DAP*	28 DAP	42 DAP	56 DAP	70 DAP	
0	6.54	7.00	7.12	7.21	7.18	**7.01**
200	6.54	7.02	7.15	7.21	7.18	**7.02**
400	6.56	7.01	7.1	7.21	7.19	**7.01**
600	6.52	7.05	7.12	7.18	7.21	**7.01**
800	6.50	7.01	7.13	7.16	7.20	**7.00**
Mean	**6.53**	**7.02**	**7.13**	**7.19**	**7.19**	

\CD (p≤0.05)

Distance : NS
Days : 0.017
Distance ´ Days : NS

*DAP=Days after placement

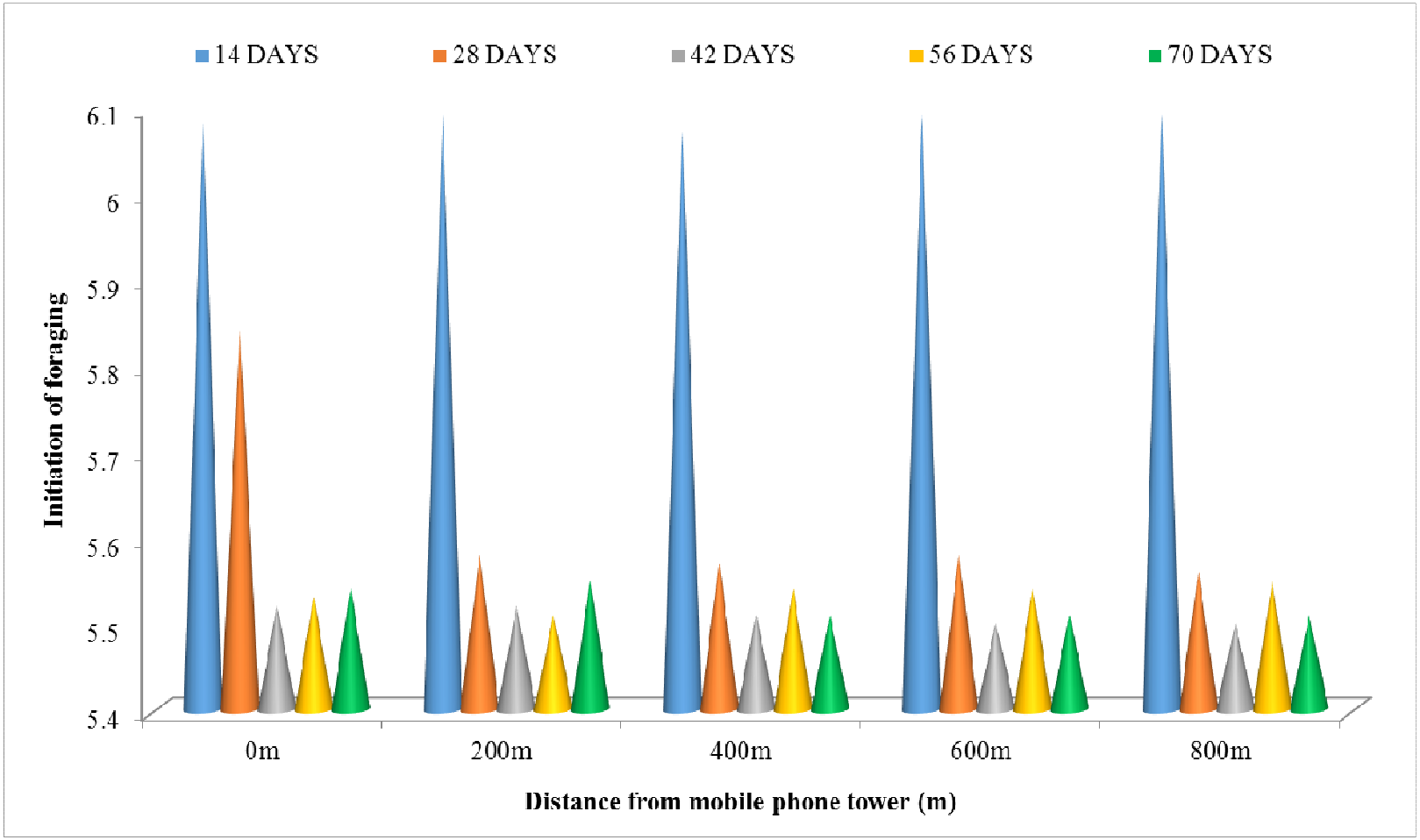

Fig. 1: Initiation activity of bees going out of the hive at different distances from mobile phone tower

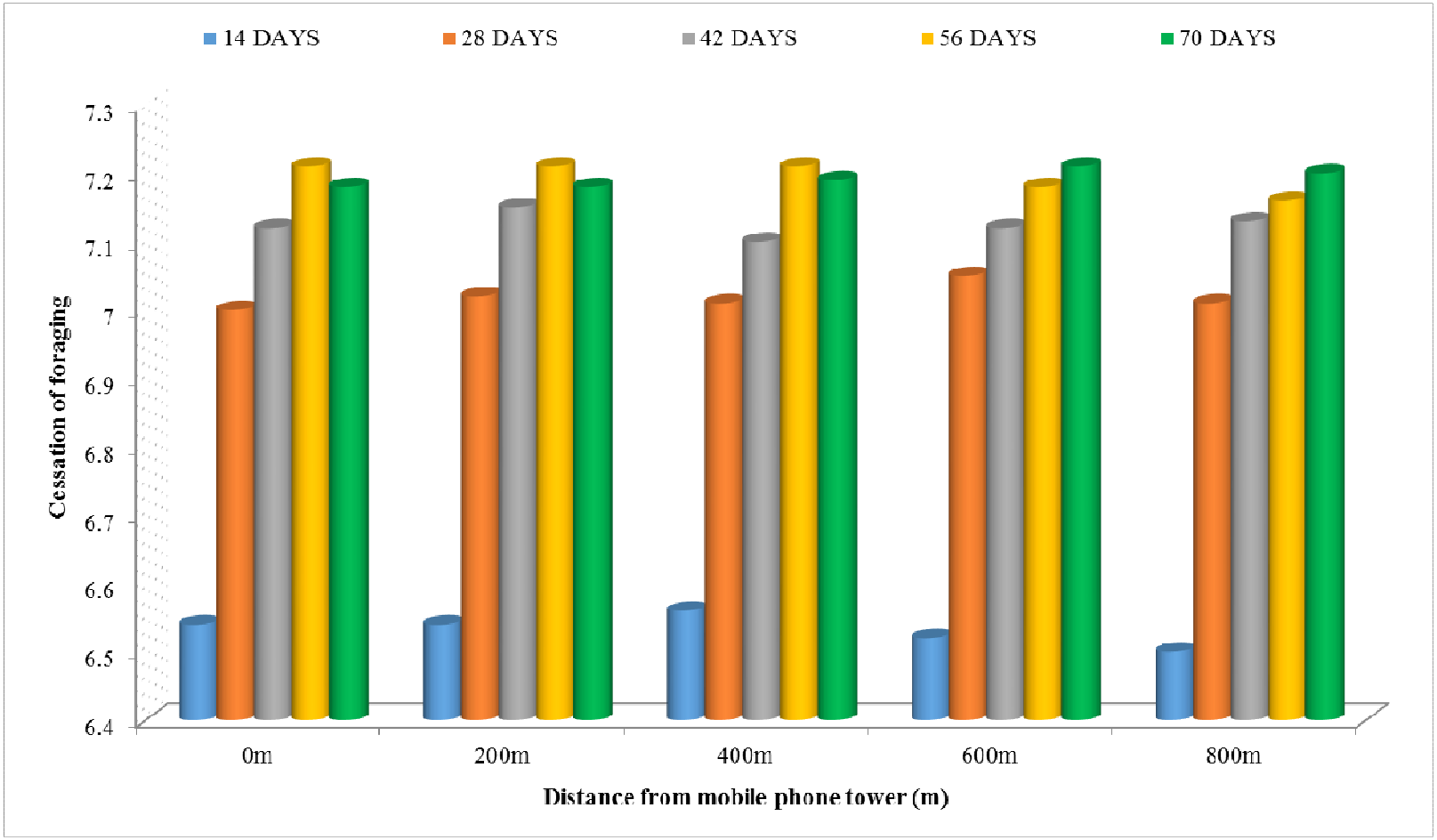

Fig. 2: Cessation activity of bees going out of the hive at different distances from mobile phone tower

Table 10: Effect of electromagnetic waves on incoming of *Apis mellifera* foragers at different distances from the mobile phone tower

Distance from mobile phone tower (m)	Incoming foragers during fortnight intervals					Mean
	14 DAP*	28 DAP	42 DAP	56 DAP	70 DAP	
0	99	105	129	133	113	**116**
200	103	106	122	128	110	**114**
400	101	104	121	125	109	**112**
600	108	104	121	124	107	**113**
800	103	102	118	126	105	**111**
Mean	**103**	**104**	**122**	**127**	**109**	

CD (p≤0.05)

Distance : NS
Days : 3.50
Distance ´ Days : NS

*DAP=Days after placement

Table 11: Effect of electromagnetic waves on outgoing of *Apis mellifera* foragers at different distances from the mobile phone tower

Distance from mobile phone tower (m)	Outgoing foragers during fortnight intervals					Mean
	14 DAP*	28 DAP	42 DAP	56 DAP	70 DAP	
0	89	130	160	164	174	143
200	90	129	152	164	161	139
400	89	129	152	159	169	139
600	86	132	160	165	160	141
800	89	134	150	166	163	141
Mean	**88**	**131**	**155**	**164**	**165**	

CD (p≤0.05)

Distance : NS
Days : 6.52
Distance ´ Days : NS

*DAP=Days after placement

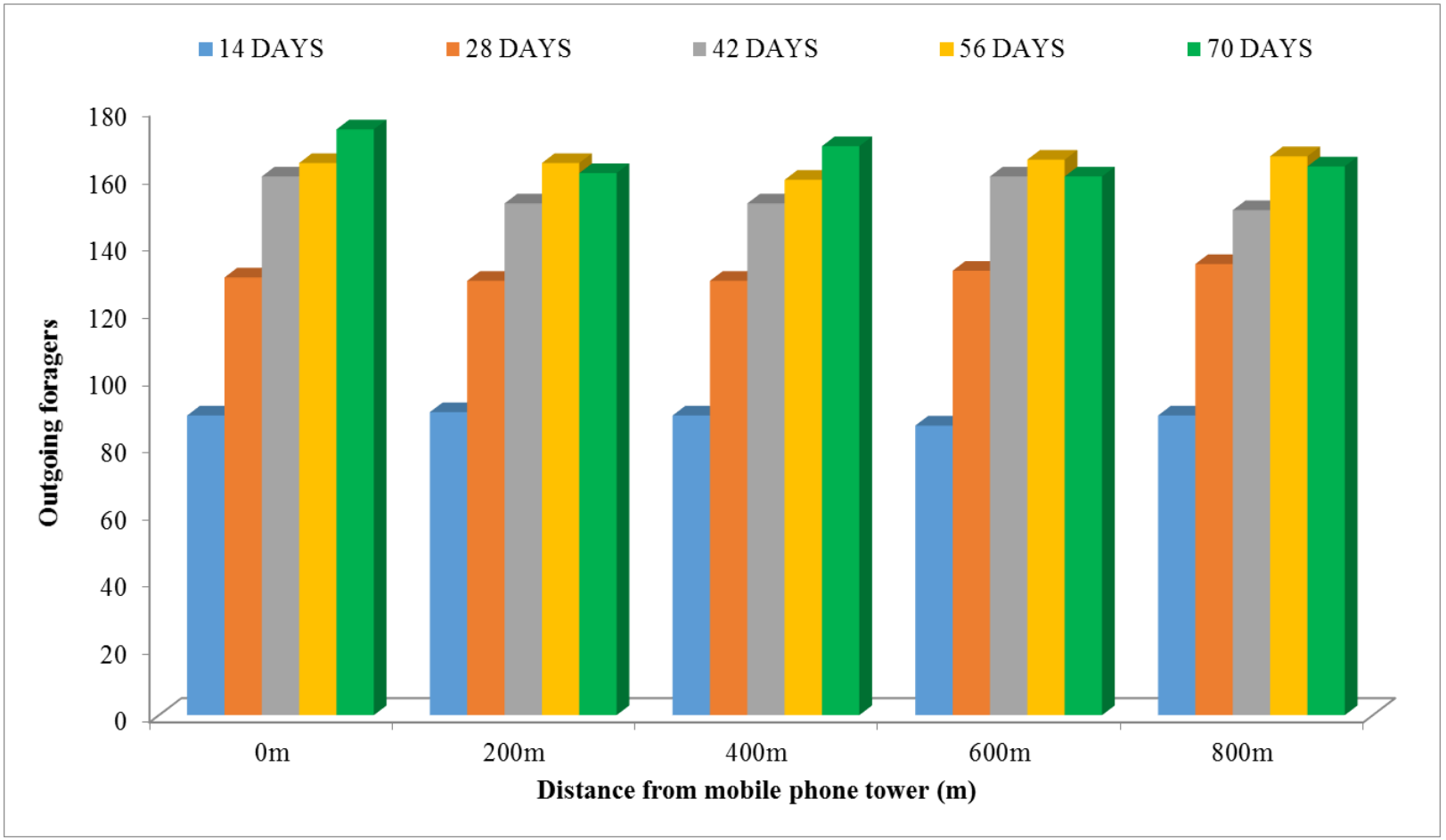

Fig. 3: Bees going out at different distances from mobile phone tower

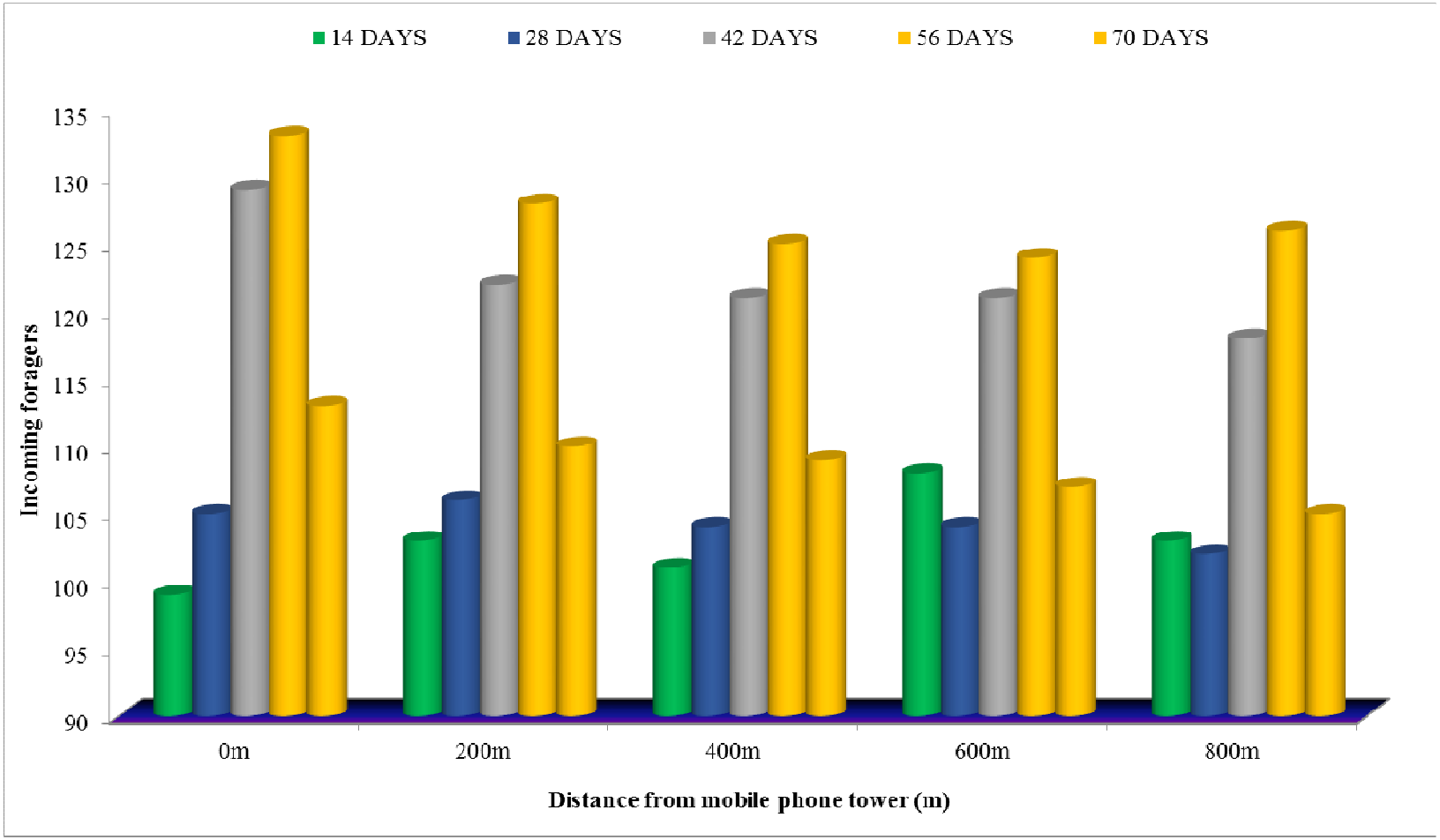

Fig. 4: Bees coming into the hive at different distances from mobile phone tower

Chapter-5

DISCUSSION

Studies conducted on the effect of electromagnetic radiations emitted from cell phone tower and on honey bees have indicated negative effect on colony strength (Sharma and Kumar, 2010), brood rearing (Sharma and Kumar, 2010), pollen stores (Sharma and Kumar, 2010), honey stores (Harst *et al.*, 2006; Sharma and Kumar, 2010; Ho, 2007), initiation of foraging, cessation of foraging, number of incoming foragers (Harst *et al.*, 2006; Kimmel *et al.*, 2007; Stefan *et al.*, 2013; Sharma and Kumar, 2010; Pattazhy, 2011), number of outgoing foragers (Valberg, 2010; Sharma and Kumar, 2010). On the contrary, few research workers who have conducted the investigation on the effect of such radiations have not found the negative effect on honey bees (Mixson *et al.*, 2009; Blacquiere and Hoofwijk, 2010, Chhuneja *et al.*, 2013, Patel *et al.*, 2016). According to Bindokas *et al.* (1988a, 1988b and 1989) when the honey bee colonies are kept at more than 29.2 m distance were not affected by the radiations. Keeping in view such confusions in mind present investigations were carried on "Effect of electromagnetic waves on colony development and performance of *Apis mellifera*". The outcome of the result studies have been discussed below.

5.1 Effect on bee strength

The number of bee frames starts increasing at fortnight intervals from 1st of May to 14th of July 2016 at all the distances from the cell phone tower Table 2. The respective average values being 5.3, 6.5, 8.3, 8.7 and 9.3 bee combs/colony. This trend is obvious because during this period there was a plenty of nectar and pollen yielding bee flora. Further, the data indicated that there was a non-significant variation in the increase in strength at zero, 200, 400, 600 and 800 m during this period i.e. 7.9, 7.5, 7.7, 7.1 and 7.8 bee combs per colony. Thus indicating no effect of radiations when the strength of the radiation was ranged between 294.23 (mV/m). Similar non-significant results were obtained by Patel *et*

al. (2016) with mean bee strength varied between 12444.25-32906.25 bees at 0,200,400,600 and 800 m. Chhuneja *et al.* (2013) also reported that radiations emitted by mobile phone tower did not pose any effect on bee strength. The mean bee strength varied between 6.7-8.8 frames at 0, 200, 400, 600 and 800 meters and was also found non- significant On the contrary, Sharma and Kumar (2010) have reported 28.57 per cent decline in the colony strength of *Apis mellifera* at Chandigarh where the electric field strength of the cell phones used in the experiment was 56.8 V/m (exposure for 60 minutes/week in four intervals from February to April at peak activity). This effect may possibly due to extremely higher radiation at Chandigarh than recorded in the present investigations at zero m distance 294.23 (mV/m).

5.2 Effect on sealed brood area

Data revealed that there was a significant increase in sealed brood area from 14 days after placement to 56 days after placement starting from 1st of May to June (1,103.00 to 1,217.30 cm^2) and then slightly decrease after 70 days of placement (1,118.80 cm^2) in July, 2016 Table 3. Possibly it was due to increase in pollen collection from the bee flora during May and June then decrease in July. Earlier, Rana and Goyal (1994) have also recorded similar observations in hive bee colonies. Present studies also indicated no variation in brood rearing at zero m (1169.00 cm^2), 200 m (1142.90 cm^2), 400 m (1152.60 cm^2), 600 m (1153,10 cm^2) and 800 m (139.50 cm^2). Chhuneja *et al.* (2013) has also reported that radiations emitted by mobile phone tower did not pose any effect on sealed brood area. The mean sealed brood area varied between 1822.1-2193.0 cm^2 at 0, 200, 400, 600 and 800 meters and was also found non-significant However, Sharma and Kumar (2010) recorded about 70 per cent decline in brood rearing when *Apis mellifera* colonies were exposed to EMR at Chandigarh. It may be due to the exposure of the colonies to very high electromagnetic field i.e. 56.8 V/m as compare to present exposure (294.23 mV/m).

5.3 Effect on unsealed brood area

Data revealed that there was a significant increase in sealed brood rearing from14 days after placement to 56 days after placement starting from 1st of May to June (519.7 to 722.7 cm^2) and then slightly decrease after 70 days of placement (643.9 cm^2) in July 2016, Table 4. Possibly it was due to increase in pollen collection from the bee flora during May June and then decrease in July. Earlier, Rana and Goyal (1994) have also recorded similar observations in hive bee colonies. Present studies also indicated no variation in brood rearing at zero m (619.2 cm^2), 200 m (623.6 cm^2), 400 m (632.5 cm^2), 600 m (624.9cm^2) and 800 m (604.9 cm^2). Chhuneja *et al.* (2013) has also reported that radiations emitted by mobile phone tower did not pose any effect on unsealed brood area. The mean unsealed brood area varied between 509- 667.6cm^2 at 0,200,400,600 and 800 meters and was also found non- significant. Similarly, Sharma and Kumar (2010) recorded about 70% per cent decline in brood rearing when *Apis mellifera* colonies were exposed to EMR at Chandigarh. It may be due to the exposure of the colonies to very high electromagnetic field i.e. 56.8 V/m as compare to present exposure (294.23 mV/m).

5.4 Effect on pollen stores

Present observations showed a significant increase in pollen stores from 1^4 days after placement 199,230.5, 263.2 then decrease at 56 days after placement 217.9 cm^2 and then again increase at 70 days after placement 329.1 in June 2016 when the *Apis mellifera* colonies were kept at 0 to 800 m distances from the cell phone tower Table 5. The period of pollen flow depends on the ecological and geographical conditions of areas. Investigations also revealed that there were no significant differences in pollen stores among 0, 200, 400, 600 and 800 m distances from the tower during the course of studies. The average respective values being: 271.4, 256.2, 245.7, 239.2 and 227.2 cm^2 Table 5. Chhuneja *et al.* (2013) also reported that radiations emitted by mobile phone tower did not pose any effect on pollen store. The mean pollen store varied between 193.5-325.7 cm^2

at 0,200,400,600 and 800 meters and was also found non- significant Similarly, Sharma and Kumar (2010) stated that the pollen stores of the treated colonies were reduced by about 30%. This effect may possibly be due to extremely higher radiations at Chandigarh than recorded in the present investigations at zero m distance (294.23 mV/m).

5.5 Effect on sealed honey store

Data collected on honey store of *Apis mellifera* kept at different distances from the tower revealed a trend of its increase from 5.7 to 8.8 Kg per colony at fortnight intervals from 1st of May to 14th of July 2016 (Table 6). Present studies also showed that there were no variations in honey stores of the experimental colonies kept at different distances during the period of studies i.e. 7.6, 7.5, 7.4, 7.4 and 7.4 kg at zero, 200, 400,600 and 800 m, respectively (Table 6) where the EMR ranged from 294.23.00 mV/m. Chhuneja *et al.* (2013) also reported that radiations emitted by mobile phone tower did not pose any effect on sealed honey store. The mean sealed honey 915.9-2902.5 cm^2 stores varied between 915-2902.5 cm^2 at 0, 200, 400, 600 and 800 meters and data was also found non- significant. Earlier investigators had recorded negative effect of radiations on the honey stores when *Apis mellifera* colonies were exposed to 56.8V/m (Sharma and Kumar, 2010). It may be due to the exposure of the colonies to very high electromagnetic field as compare to present exposure. Various research workers in different parts of the world had also reported the reduction in honey stores in exposed colonies i.e. 18% (Ho, 2007) to 66.98 per cent (Harst *et al.*, 2006).

5.6 Effect on unsealed honey store

Data collected on unsealed honey store of *Apis mellifera* kept at different distances from the tower revealed a trend of its increase from 4.6 to 6.6 kg per colony at fortnight intervals from 1st of May to 14th of July 2016 (Table 7). Present studies also showed that there were no variations in honey stores of the experimental colonies kept at different distances during the period of studies i.e.

5.9, 5.9, 5.9, 5.9 and 5.8 kg at zero, 200, 400, 600 and 800 m, respectively (Table 7) were the EMR ranged from 294.23 mV/m. Chhuneja *et al.* (2013) has also reported that radiations emitted by mobile phone tower did not pose any effect on unsealed honey store. The mean unsealed honey store varied between 1967.2-3612.0 cm^2 at 0, 200, 400, 600 and 800 meters and data was also found non-significant. Earlier investigators had recorded negative effect of radiations on the unsealed honey stores when *Apis mellifera* colonies were exposed to 56.8 V/m (Sharma and Kumar, 2010). It may be due to the exposure of the colonies to very high electromagnetic field as compare to present exposure i.e. 294.23 (mV/m). Various research workers in different parts of the world had also reported the reduction in honey stores in exposed colonies i.e. 18 per cent (Ho, 2007) to 66.98 per cent (Harst *et al.*, 2006).

5.7 Effect on initiation and cessation activities

The observations on the initiation and cessation of activities showed that *Apis mellifera* bees started their foraging early in the morning and stopped late in the evening at fortnight intervals from 1st of May to 14th of July 2016 (Tables 8 and 9). It is obvious due to increase in day length and ambient temperature along with favourable floral conditions during these months. According to Free (1993), time and duration of initiation and cessation activities also depend on floral, seasonal and geographical conditions. The data further revealed that there were no variations with regard to initiation and cessation of bee activities among zero, 200, 400, 600 and 800 m distances from the tower in the respective months of studies (Table 8 and 9).Thus no effect of EMR was recorded on such activities. No such report has been found in the literature.

5.8 Effect on the number of incoming foragers

The studies on the number of incoming foragers revealed that the number of incoming bees increased from 14 days after placement to 56 days after placement from1st of May to June and 103-127 bees/5 min. then decreased during

July (109 bees/5 minute) at all the distances from the cell phone tower Table 10. It is obvious that more pollen and nectar yielding bee flora was available fortnight intervals from1 of May to 14 July 2016. Earlier, Rana and Goyal (1994) also reported increasing trend of food stores in the colonies from May to June during 1991.There were no variations in the number of incoming *Apis mellifera* foragers at different distances from cell phone tower during the period of studies showing no effect of EMR (Table 10) as indicated by the data i.e. 116, 114, 112, 113 and 111 bees/5 min. at zero (294.23 V/m), 200, 400, 600 and 800 m, respectively. Chhuneja *et al.* (2013) also reported that radiations emitted by mobile phone tower did not pose any effect on the number of incoming bees. The mean number of incoming *Apis mellifera* foragers varied between 157.8-274.0 bees/5 minute at 1000 179.4-212.1.8 bees/5 minute at 1400h and 92.6-132.6 bee/5min at 1600 h at 0, 200, 400, 600 and 800 meters and data was also found non- significant. On the contrary, Sharma and Kumar (2010) observed about 30% decrease in the number of exposed (56.8 V/m) worker bees returning to the hive at Chandigarh. Similarly, different research workers had also reported negative effect of the EMR on the number of incoming bees (Harst *et al.*, 2006; Kimmel *et al.*, 2007; Stefan *et al.*, 2013; Pattazhy, 2011). The variation in the results may possibly be due to the exposure of honey bee foragers to very high strength of radiations as compare to present exposure.

5.9 Effect on the number of outgoing foragers

The data collected on the number of outgoing foragers indicated that the number of outgoing bees increased from 88to 165 bees/5 minute at fortnight intervals from 1st of May to 14th of July 2016 Table 11. It is obvious that more food yielding bee flora was available during April to May as compare to June 2013. Earlier, Rana and Goyal (1994) also reported increasing trend of food stores in the colonies May to June. Data also showed no effect of EMR (294.23 V/m) on outgoing bees from the colonies kept at different distances from cell phone tower during the period of studies at as is evident from (Table 11). The values being:

143,139,139,141 and 141 bees/5 min. at zero, 200, 400, 600 and 800 m, respectively. Chhuneja *et al.* (2013) has also reported that radiations emitted by mobile phone tower did not pose any effect on outgoing foragers. The mean outgoing foragers varied between 152.9-190.9 bees/5 minute at 1000h, 182.75-216.3 at 1400h and 147.88-179.8 bees/5 minute at1600h at 0, 200, 400, 600 and 800 meters and data was also found non- significant. However, Sharma and Kumar (2010) had reported strong effect of cell phone radiations (56.8 V/m) i.e. 30% decrease in number of exposed worker bees leaving the hive. Valberg (2010) had also noticed low foraging rates of bees when exposed to radiations. It may be due to the exposure of the colonies to very high electromagnetic field as compare to present exposure.

Chapter-6

SUMMARY AND CONCLUSION

The present investigations entitled "Effect of electromagnetic waves on the performance of *Apis mellifera*." were undertaken near cell phone tower at FoA, SKUAST-K, Wadura. The effect of the radiations on *Apis mellifera* colonies development and behavioural parameters such as bee strength, sealed and unsealed brood area, pollen stores, sealed and unsealed honey stores, initiation and cessation of foraging and number of incoming and outgoing foragers. The salient findings of the results are summarised as under:

- A continuous significant increase in strength of *Apis mellifera* colonies at fortnight intervals from 1st of May (5.3 bee combs) to 14th of July (9.3 bee combs) 2016 at all the distances from cell phone tower was recorded. Variations in the strength from (7.9 to 7.8 bee combs) were recorded in each respective month at all the distances, indicating no effect of EMR on number of combs/colony.
- Sealed brood area significantly increased at fortnight intervals from 14 days after placement (1140.50 cm^2) to (1217.30 cm^2) and then decreased after 70 days after placement (1118.80 cm^2) from 1st of May to 14th of July at every distance from the tower. However, it did not varied significantly (1169.00 to 1139.50 cm^2) among the distances in each respective month.
- Unsealed brood area significantly increased at fortnight intervals from 14 days after placement (519.7cm^2) to 56 days after placement (722.7 cm^2) and then decreased after 70 days after placement (643.9 cm^2) from 1st of May to 14th of July at every distance from the tower. However, it did not varied significantly (619.2 to 604.9 cm^2) among the distances in each respective month.
- Pollen stores significantly increase at fortnight intervals from 14 days after

placement (199 cm^2) to 42 days after placement (263 cm^2) and then decrease at56 days after placement (217.9 cm^2) and then again increase at 70 days after placement (329.1 cm^2) 1st of May to 14th of July at all the distances from cell phone tower. Statistically, no variation in pollen stores (217.4 to 227.2 cm^2) among the distances was recorded.

- A significant increase in sealed honey stores was observed at fortnight intervals from 1st of May from (5.7 kg) to 14th of July (8.8 kg) 2016 at all the distances in the experimental colonies. Non-significant differences in honey stores (7.6 to 7.4 kg) at all the distances were observed. A significant increase in unsealed honey stores was observed at fortnight intervals from 1st of May (4.6 kg) to 14th of July (6.6 kg) 2016 at all the distances in the experimental colonies. Non-significant differences in honey stores (5.9 to 5.8 kg) at all the distances were observed.
- No variations were found in the initiation and cessation activities of *Apis mellifera* foragers during the respective morning and evening hours at all the distances from the cell phone tower. However, the bee activities continuously initiated earlier and ceased later at fortnight intervals from 1st of May to 14th of July.
- Non-significant differences in the number of incoming foragers (bees/5 minute) at all the distances in each respective months were recorded. It increased from 14 days after placement (103 bees/5 minute) to 56 days after placement and decreased during July (109 bees/5 minute).
- Number of outgoing foragers (bees/5 minute) increased significantly from 1st of May and 14th of June at all the distances. The activity of outgoing bees was not affected by the cell phone tower at Wadura as non-significant variation in the bee number was noticed among all the distances.

As per the present investigation, all the colonies receiving mobile tower waves performed well in terms of bee strength, sealed and unsealed brood, sealed

and unsealed honey, pollen, initiation and cessation of foraging, number of incoming and outgoing foragers at all distances ranging from 0-800 m and none of the colonies perished during this period. Under Kashmir conditions, there is no effect of present level of electromagnetic waves on colony development, when only one mobile phone tower is present in a locality within 800m distance range, therefore, there is no threat of any negative impact on the Apiaries which are under/close to the mobile phone tower. Thus present investigation showed no effect of the radiations emitted from cell phone tower and on studied developmental and behavioural characteristics of *Apis mellifera* colonies. However, the variation recorded in the characteristics sat fortnight intervals from 1st of May to 14th of July 2016 was as per the availability of nectar and pollen sources.

LITERATURE CITED

Aday, W. R. 1975. Introduction: Effects of electromagnetic radiation on the Nervous system. *Annals of the New York Academy of Sciences* **247**: 15-20

Aikin, R. C. 1897. Bees evaporated: a new malady. *Glngs Bee Culture.* **25**: 479-480.

Aldrich, T. E. and Easterly, C. E. 1987. Electromagnetic fields and public health. *Environmental Health Perspectives* **75**: 159-171.

Anonymous, 1999. Agriculture status of J&K state. Directorate of Agriculture department, Government of Jammu and Kashmir.

Anonymous, 2007. Colony collapse disorder action plan. **In**: *Service* (Ed. U. S. D. A. A. R.) Washington DC pp. 1-27. http://www.ars.usda.gov/is/br/ccd/ ccd actionplan.pdf.

Anonymous, 2010. Expert group to study the possible impacts of communication towers on wildlife including birds and bees. Government of India.

Apeda, 2013. Agricultural and Processed Food Products Export Development Authority, Ministry of Commerce and Industry, Government of India. www.apeda.gov.in.

Balmori, A. 2005. Possible effects of electromagnetic fields from phone masts on a population of White Stork (*Ciconia ciconia*). *Electromagnetic Biology and Medicine* **24**: 109-119.

Balmori, A. 2006. The incidence of electromagnetic pollution on the amphibian decline: Is this an important piece of the puzzle? *Toxicological and Environmental Chemistry* **88**(2): 287-299.

Balmori, A. 2009. Electromagnetic pollution from phone masts. Effects on wildlife. *Pathophysiology* **16**: 191-199.

Balmori, A. 2010. Mobile Phone mast effects on common frog (*Rana temporaria*) tadpoles: the city turned into a laboratory. *Electromagnetic Biology and Medicine* **29**: 31-35.

Belyavskaya, N. A. 2001. Ultrastructure and calcium balance in meristem cells of pea roots exposed to extremely low magnetic fields. *Advances in Space Research* **28**(4): 645-450.

Beuhne, R. 1910. Bee mortality. *Journal of the Department of Agriculture Victoria* **8**: 149-151.

Bindokas, V. P., Gauger, J. R. and Greenberg B. 1989. Laboratory investigations of the electrical characteristics of honey bees and their exposure to intense electric fields. *Bioelectromagnetics* **10**: 1-12

Bindokas, V. P., Gauger, J. R. and Greenberg, B. 1988a. Exposure scheme separates effects of electric shock and electric field for honey bees, *Apis mellifera* L. *Bioelectromagnetics* **9:** 275-284.

Bindokas, V. P., Gauger, J. R. and Greenberg B. 1988b. Mechanism of biological effects observed in honey bees (*Apis mellifera*, L.) hived under extra-high voltage transmission lines: implications derived from bee exposure to simulated intense electric fields and shocks. *Bioelectromagnetics* **9**: 285-301.

Blacquiere, T. and Hoofwijk, H. 2010. Sham or reasons for concern? The influences of electromagnetic fields on honey bees. Science shop Wageningen UR, Nov-Dec.

Blacquiere, T., Van, D. S. J. J. M. and Cornelissen, A. C. M. 2009. Visie bijenhouderij eninsectbestuiving: analyse van bedreigingen en knelpunten, Report 227, *Plant Research International* pp. 64.

Bliss, T. V. P. and Collingridge, G. L. 1993. A synaptic model of memory: long-term potentiation in the hippocampus. *Nature* **361**: 31-39.

Brandes, C. and Frish, B. 1986. Production of mutant drones by treatment of honeybees with X-rays. *Apidologie* **17**(4): 356-358.

Brent, R. L. 1999. Reproductive and teratologic effects of low-frequency electromagnetic fields: A review of in vivo and in vitro studies using animal models. *Teratology* **59**: 261-286.

Cammaerts, C. M. 2017. IS electromagnetism one of the causes of CCD? A work plan for testing this hypothesis. *Journal of Behavior* **2**(1): 1-6.

Cane, J. H. and Tepedino, V. J. 2001. Causes and extent of declines among native North American invertebrate pollinators: detection, evidence and consequences. *Conservation Ecology* **5**(1): 1.

Castro, D. 2001. Propolis: biological and pharmacological activities. Therapeutic uses of this bee-product. *Annual Review Biomedical Science* **3**: 49-83.

Chhuneja, P. K. Singh, J., Kaur, Choudhary and Amit. 2013. Effect of electromagnetic waves of mobile phone tower on colony development and performance. Biennial Report-All India Coordinated Research Project on honey bees and pollinators pp. 8-15.

Cleveland, R. F., Fields, R. E. and Ulcek, J. L. 1999. Questions and answers about biological effects and potential hazards of radiofrequency electromagnetic fields, 4th ed. Washington: *Oet Bulletin* pp. 56.

Dalio, S. J. 2015. Effect of electromagnetic (cell phone) radiations on *Apis mellifera. Journal of Research in Agriculture and Animal Science* **2**(12): 06-10.

Daniells, C., Duce, I., Thomas, D., Sewell, P., Tattersall, J. and Pomerai, D. 1998. Transgenic nematodes as biomonitors of microwave-induced stress. *Mutation Research* **399**(1): 55-64.

Darney, K. Giraudin, A. Joseph, R. Abadie, P. Aupinel, P. Decourtye, A. Bourg, L. E. and Gauthier, M. 2015. Effect of high-frequency radiations on

survival of the honeybee (*Apis mellifera* L.). *Apidologie* DOI: 10. 1007/s13592-015-0421-7

Eichenbaum, H. 2004. Hippocampus: cognitive processes and neural representation that underlie declarative memory. *Neuron* **44**: 109-120.

Everaert, J. and Bauwens, D. 2007. A possible effect of electromagnetic radiation from mobile phone base stations on the number of breeding house sparrows (*Passer domesticus*). *Electromagnetic Biology and Medicine* **26**: 63-72.

Favre, D. 2010. Mobile phone-induced honeybee worker piping. *Apidologie* **42**: 270-279

Fernie, K. J. and Bird, D. M. 2001. Evidence of oxidative stress in American kestrels exposed to electromagnetic fields. *Environmental Research* **86**: 198-207.

Free, J. B. 1993. Insect pollination of crop, 2nd ed. London: Academic Press.

Gallai, N. Salles, J. M., Settele, J. and Vaissiere, B. E. 2009. Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. *Ecolgical Economics Elsevier* **68**: 810-821.

Gandhi, A. G. and Singh, P. 2005. Cytogenetic damage in mobile phone users: preliminary data. *International Journal of Human Genetics* **5**: 259-265.

Ghamdi, M. S. A. 2012. The effect of static electric fields on *Drosophila* behaviour. Master of Philosophy Thesis University of Southampton.

Girish, K. 2010 Report on cell tower radiation. Electrical Engineering Department IIT Bombay, Powai, Mumbi. pp. 25-26.

Giurfa, M. 2003. The amazing mini-brain: lesions from a honey bee. *Bee World* **84**: 5-18.

Gould, J. L., Kirschvink, J. L. and Deffeyes, K. S. 1978. Bees have magnetic remanence. *Science* **201**: 1026-1028.

Greenberg, B., Bindokas, V. P. and Gauger, J. R. 1981. Biological effects of a 765 kV transmission line: exposure and thresholds in honeybee colony. *Bioelectromagnetics* 2(4): 315-328.

Grigoriev, I. G. 2003. Influence of the electromagnetic field of the mobile phones on chickens embryo, to the evaluation of the dangerousness after the criterion of this mortality. *Journal of Radiation Biology* **5**: 541-544.

Haggerty, K. 2010. Adverse Influence of radio frequency background on trembling aspen seedlings: Preliminary observations. *International Journal of Forestry Research* pp. 7.

Halabi, L. N., Achkar, R. and Haidar, A. G. 2013. The Effect of Cell Phone Radiations on the Life Cycle of Honeybees. IEEE Eurocon 2013 Conference Zagreb, Croatia pp. 529-536

Halabi, L. N., Achkar, R. and Haidar, A. G. 2014. The Effect of Cell Phone Antennas on the Life Cycle of Honeybees *17th IEEE Mediterranean Electrotechnical Conference Information and Communication System.*

Hanowski, J. A. M., Niemi, G. G. and Blake J G. 1996. Response of breeding and migrating birds to extremely low frequency electromagnetic fields. *Ecological Applications* **6**: 910-919.

Hardell, L. and Sage, C. 2008. Biological effects from electromagnetic field exposure and public exposure standards. *Biomedicine and Pharmacotherapy* **62**: 1-6.

Hardell, L., Carlberg, M., Soderqvist, F. and, Mild, K. H. 2008. Meta-analysisof long-term mobile phone use and the association with brain tumours. *International Journal of Oncology* **32**: 1097-1104.

Hardell, L., Carlberg, M., Söderqvist, F., Mild, K. H. and Morgan, L. L. 2007. Long-term use of cellular phones and brain tumours: increased risk associated with use for? 10 years. *Occupational and Environmental Medicine* **64**: 626

Harst, W., Kuhn, J. and Stever, H. 2006. Can electromagnetic exposure cause a change in behaviour? Studying possible non-thermal influences on honeybees. An approach within the framework of educational informatics. *Acta Systematica International Journal* **6**(1): 1-6.

Hart, F. M. 1893. The nameless bee disease California. *American Bee Journal* **31**: 468.

Ho, M. W. 2007. Mobile phones and vanishing bees. *Science in Society* pp. 34.

Hoskote, S. S., Kapdi, M. and Joshi, S. R. 2008. An epidemiological review of mobile telephones and Cancer. *Journal of the Association of Physicians of India (Japi).* **56**: 980-984.

Hsu, C. Y. and Li, C. W. 1994. Magnetoreception in honeybees. *Science* **265**: 95-97.

Hsu, C. Y., Ko, F. Y., Li, C. W., Fann, K. and Lue, J. T. 2007. Magneto reception system in honeybees (*Apis mellifera*). *Plos one* **2**: 395.

I. C. N. I. R. P. 1998. Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz), international commission on non-ionizing radiation protection. *Health Physics* **74**: 494-522.

Keim, C. N., Cruz, L. C., Carneiro, F. G. and Farina, M. 2002. Ferretin in iron containing granules from the fat body of the honeybees *Apis mellifera* and *Scaptotrigona postica. Micron* **33**: 53-59.

Kejriwal, P. 2012. An Overlook on the Indian Honey Industry. www.cseindia. org/user.files/food safety

Kimmel, S., Kuhn, J., Harst, W. and Stever, H. 2007. Effects of electromagnetic exposition on the behavior of the honeybee (*Apis mellifera*). *Environmental Systems Research* **8**: 1-8.

Klein, A. M., Vaissiere, B. E., Cane, J. H., Steffan, D. I., Cunningham, S. A., Kremens, C. and Tscharntke, T. 2007. Importance of crop pollinators in changing landscapes for world crops. *Proceedings of the Royal Society* **274**: 303-313.

Korall, H. and Martin, H. 1988. Bursts of magnetic fields induce jumps of misdirection in bees by a mechanism of magnetic resonance. *Journal of Comparative Physiology* **162**: 279-284.

Kumar, N. R., Sangwan, S. and Badotra, P. 2011. Exposure to cell phone radiations produces biochemical changes in worker honey bees. *Toxicology International* **18**(1): 70-72.

Kumar, N. R., Verma, T. and Anudeep. 2012. Influence of cell phone radiations on *Apis mellifera* semen. *Journal of Global Biosciences* **1**: 17-19.

Kumar, R. N., Rana, N. and Kalia, P. 2013. Biochemical changes in haemolymph of *Apis mellifera* L. drone under the influence of cell phone radiations. *Journal of Applied and Natural Science* **5**(1): 139-141.

Kwak, M. M., Velterop, O. and van, A. B. J. 1998. Pollen and gene flow in fragmented habitats. *Applied Vegetation Science* **1**: 37-54.

Lai, H. and Singh, N. P. 1996. DNA single and double-strand DNA breaks in rat brain cells after acute exposure to low-level radiofrequency electromagnetic radiation. *International Journal of Radiations Biology* **69**: 513-521.

Leszczynski, D., Joenvaara, S., Reivinen, J. and Kuokka, R. 2002. Non-thermal activation of the hsp27/p38MAPK stress pathway by mobile phone

radiation in human endothelial cells: Molecular mechanism for cancer and blood-brain barrier-related effects. *Differentiation* **70**: 120-129.

Levitt, B. B. and Lai, H. 2010. Biological effects from exposure to electromagnetic radiation emitted by cell tower base stations and other antenna arrays. *Environmental Reviews* **18**: 369-395.

Lonn, S., Ahlbom, A., Hall, P and Feychting, M. 2005. Long-term mobile phone use and brain tumor risk. *American Journal of Epidemiology* **161**: 526.

Mall, P. and Kumar, Y. 2014 Effect of electromagnetic cell radiations on Brooding, honey production and foraging behaviour of European honeybees (*Apis mellifera L.*) *African Journal of Agriculture Research* **9**(13): 1078-1085.

Manzel, R. and Muller, U. 1996. Learning and memory in honeybees: from behavior to neural substrates. *Annual Review of Neuroscience* **19**: 379-404.

Martin, H., Korall, H. and Förster, B. 1988. Magnetic field effects on activity and ageing in honeybees. *Journal of Comparative Physiology A* **164**(4): 423-431.

Mixson, A. T., Abramson, C. I., Nolf, S. L., Johnson, G. A., Serrano, E. and Harrington, W. 2009. Effect of GSM cellular phone radiation on the behavior of honeybees (*Apis mellifera*). *Science of Bee Culture* **1**(2): 22-27.

Moorhouse, T. P. and Macdonald, D. W. 2005. Indirect negative impacts of radiocollaring: sex ratio variation in water voles. *Journal of Applied Ecology* **42**: 91.

Nicholis, B. and Paul, A. R. 2007. Bats avoid radar installations: Could electromagnetic fields deter bats from colliding with wind turbines? *Plos One* **2**(3): 297.

Panagopoulos, D. J., Karabarbounis, A. and Margaritis, L. H. 2004. Effect of GSM 900 MHz mobile phone radiation on the reproductive capacity of *Drosophila melanogaster*. *Electromagnetic Biology and Medicine* **23**: 29-43.

Parmanik, C. R. and Parmanik, A. 2016. Cellular effects of mobile radiations on honey bees. *International Journal of Informative and Futuristic Research (IJIFR)* **3***:* 4508-4515.

Partap, U., Partap, T., Sharma, H. K., Phartiyal, P. and Munawar, S. M. 2012. The economic valve of insect pollination. **In**: *Value of insect pollinators.* International Centre of Integrated Mountain Development Kathmandu pp. 17-22.

Patel, S., Kumar. S., Yadav and Mall. P. 2016. Influence of electromagnetic radiations on *Apis mellifera* L. colonies. *Agriculture Research Journal* **53**(3): 442-443.

Pattazhy, S. 2011. Electromagnetic radiations (EMR) clashes with honeybees. *Journal of Entomology and Nematology* **4**: 1-3.

Preece, A. W. Georgiou, A. G. Dunn, E. J. and Farrow, S. C. 2007. Health response of two communities to military antennae in Cyprus. *Occupational and Environmental Medicine* **64**: 402.

Rana, B. S. and Goyal, N. P. 1994. Comparative brood rearing activity of *Apis mellifera* and *Apis cerana indica* at Nauni (Solan), Mid Hills of Himachal Pardesh. *Indian Bee Journal* **56**: 24-33.

Rubin, E. B., Shemesh, Y., Cohen, M., Elgavish, S., Robertson, H. M. and Bloch, G. 2006. Molecular and phylogenetic analyses reveal mammalian-like clockwork in the honey bee (*Apis mellifera*) and shed new light on the molecular evolution of the circadian clock. *Genome Research* **16**: 1352-1365.

Sahib, S. 2011. Impact of mobile phone on density of honey bees. *International Journal of Environmental Sciences* **1**: 396-399.

Sangwan, S. 2009. Biochemical changes in *Apis mellifera* worker induced by cell phone radiations. M. Sc. Dissertation, Department of Zoology, Punjab University, Chandigarh (Punjab).

Sarswat, B. L. 2012. Beekeeping scenario in India and role of National Bee Board for overall development of scientific and robust beekeeping industry. National Bee Board, Deptt. of Agriculture and Cooperation, Ministry of Agriculture, Govt. of India, Janpath Bhawan, New Dehli.

Schneider, S. S. and Lewis, L. A. 2004. The vibration signal, modulatory communication and the organization of labor in honey bees, *Apis mellifera*. *Apidologie* **35:** 117-131.

Schwarzel, M. and Muller, U. 2006. Dynamic memory networks: dissecting molecular mechanisms underlying associative memory in the temporal domain. *Cellular and Molecular Life Science* **63**: 989-998.

Sharma, V. P. and Kumar, N. R. 2010. Changes in honeybee behaviour and biology under the influence of cell phone radiations. *Current Science* **9810**: 1376-1378.

Sivani, S. and Sudarsanam, D. 2012. Impacts of radio-frequency electromagnetic field (RF-EMF) from cell phone towers and wireless devices on biosystem and ecosystem. *Biology and Medicine* **4**: 202-216.

Soares, A. E. E. 1981. First eye mutation induced by gamma radiation in honey bees. *Journal of Apiculture Research* **20**(3): 1378-139.

Stefan, M. K., Matthias, S., Wilhelm, K. and Andrea, M. 2013. Radiation hydrodynamics integrated in the code Pluto. Institute for Astronomy and Astrophysics, Section Computational Physics. Eberhard Karls University, Tubingen **10**: D-7207.

Stever, H., Harst, W., Kimmel, S., Kuhn, J., Otten, C. and Wunder, B. 2007. Change in behaviour of the honeybee *Apis mellifera* during electromagnetic exposure-follow up study 2006. http://agbi.uni-landau.de/ materialdownload/elmagexpbienen06.pdf.

Vacchia, P., Matthes, R., Ziegelberger, G., Lin, J., Saunders, R. and Swerdlow, A. 2009. Exposure to high frequency electromagnetic fields, biological effects and health consequences (100 kHz-300 GHz). *ICNIRP* 16p. *Ecology* **65**: 1641-1647.

Valberg, P. A. 2010. Summary of potential effects of 345-kv power-line electric and magnetic fields (EMFs) on honeybee hives and honeybee behavior. Prepared for: CapX2020. 20 University Road Cambridge, MA pp. 1-8.

VanEngelsdorp, D. 2009. A survey of honey bee colony losses in the United States, fall 2008 to spring 2009. *Journal of Apiculture Research* **49**: 7-14.

VanEngelsdrop, Evans, J. D., Saegerman, C., Mullin, C., Haubruge, E., Nguyen, B. K., Frazier, M., Frazier, J., Cox, Foster, D., Chen, Y., Underwood, R., Tarpy, D. R. and Pettis, J. S. 2009. Colony collapse disorder: a descriptive study. *Plos One* **48**(648): 1-17.

Warnke, U. 1976. Effect of electrical charges on honey bees. *Bee World* **57**(2): 50-56.

Warnke, U. 2007. Bees, birds and mankind: destroying nature by "Electrosmog". Effects of mobile radio and wireless communication. A series of papers by the competence initiative for the protection of mankind, environment and democracy Kempten. http://www.hese-project.org/heseuk/en/papers/ war nkebbm.pdf.

Wilson, W. T. and Menapace, D. M. 1979. Disappearing disease of honey bees survey of the United States. *American Bee Journal* **119**: 184-186.

Wiltschko, W. and Wiltschko, R. 2005. Magnetic orientation and magnetoreception in birds and other animals. *Journal of Comparative Physiology A* **191**: 675-693.

Zach, R. and Mayoh, K. R. 1984. Gamma radiation effects on nestling tree swallows. *Ecology* **65**: 1641-1647.

Zach, R. and Mayoh, K. R. 1986. Gamma-radiation effects on nestling House Wrens: a field study. *Radiation Research* **105**: 49-57.

Zhang, S. W., Lehrer, M. and Srinivasan, M. V. 1999. Honeybee memory: Navigation by associative grouping and recall of visual stimuli. *Neurobiology of Learning and Memory* **72**: 180-200.

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CERTIFICATE

Certified that all the corrections/amendments as suggested by External Examiner Prof. Zahoor Ahmad Baba, Ex-Professor-cum-Dean, Faculty of Agriculture, SKUAST-Kashmir during Viva-Voce examination held on 20th of November, 2017 have been incorporated in the manuscript entitled **"Effect of Electromagnetic Waves of Mobile Phone Tower on Colony Development and Performance of *Apis mellifera*"** submitted by **Ms. Syed Tazkiya Manzoor (Regd. No. 2015-A-1062-M)**.

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