SEASONAL VARIATION OF ECTOPARASITE MITE *Varroa destructor* ANDERSON AND TRUEMAN, 2000 ON *Apis cerana* FABRICIUS, 1793 IN MADANPOKHARA, PALPA, NEPAL

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in Zoology with special paper Entomology

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Central Department of Zoology
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Nepal

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DECLARATION

I hereby declare that the work presented in this thesis has been done by myself and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

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RECOMMENDATION

This is to recommend that the thesis entitled **"SEASONAL VARIATION OF ECTOPARASITE MITE *Varroa Destructor* ANDERSON AND TRUEMAN, 2000 ON *Apis cerana* FABRICIUS, 1793 IN MADANPOKHARA, PALPA, NEPAL"** has been carried out by Nripesh Shrestha for the partial fulfilment of Master's Degree of Science in Zoology with special paper Entomology. This is his original work and has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted for any other degree in any institution.

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LETTER OF APPROVAL

On the Recommendation of supervisor "Dr. Ishan Gautam" this thesis submitted by Nripesh Shrestha entitled **"SEASONAL VARIATION OF ECTOPARASITE MITE *Varroa Destructor* ANDERSON AND TRUEMAN, 2000 ON *Apis cerana* FABRICIUS, 1793 IN MADANPOKHARA, PALPA, NEPAL"** is approved for the examination and submitted to the Tribhuvan University in partial fulfilment of the requirements for Master's Degree of Science in Zoology with special paper Entomology.

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This thesis work submitted by Nripesh Shrestha entitled **"SEASONAL VARIATION OF ECTOPARASITE MITE *Varroa Destructor* ANDERSON AND TRUEMAN, 2000 ON *Apis cerana* FABRICIUS, 1793 IN MADANPOKHARA, PALPA, NEPAL"** has been accepted as a partial fulfilment for the requirements of Master's Degree of Science in Zoology with special paper Entomology.

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ABSTRACT

The ectoparasitic mite, *Varroa destructor* is the largest threat to apiculture and honey bee health world-wide.

A. cerana Fabricius is endemic to most of Asia where it has been used for honey production and pollination services for thousands of years. *Varroa destructor* is most important enemy and ectoparasitic mite that feeds on the hemolymph of adult and immature honey bees that has been recorded to have causal devastation to honeybee population. The results of this present study highlighted the seasonal variation of *Varroa destructor* in *A. cerana* colony in Madanpokhara Palpa, Nepal. The study was carried out at two sites as new hive and old, new mixed types of hives in Madanpokhara, Palpa. A total of 498 Varroa mites were counted at site 1 (279) and site 2 (219). The highest number of Varroa mite were observed in March and the lowest in September at the both sites. The population was gradually decreased in April, May and increased in June and July. The population again decreased in September and October at both sites. Population of Varroa was significantly different at both sites with p-value 0.002756 (df 2,24) and 0.002581 (df 2,24) respectively. The population was observed higher in brood cell and lower in adult bees. Relationship between the population of mite with inner hive temperature and outer temperature showed significant different with p-value of 0.64 and 0.17 respectively. Population of mite with inner hive humidity and outer humidity showed significant with p-value of 0.022 and 0.051 respectively at site 1. Relationship between population of mite with inner hive temperature and outer temperature showed significant difference of p-value of 0.83 and 0.47 respectively. The population of mite with inner hive humidity and outer humidity showed p-value of 0.15 and 0.39 respectively at site 2 respectively. Possible solutions to the threat of *Varroa* are discussed, which may offer a sustainable long-term solution, and the need for better general beekeeping techniques that reduce the use of chemical treatments and inhibit the spread of disease.

1. INTRODUCTION

1.1 Background of the study

1.1.1 Honey Bee

Honey bees are the most familiar insects of the order Hymenoptera grouped in the sub family Apinae of the family Apidae all within the genus *Apis* (Hopla *et al*., 1994). Nepal 's diverse climatic condition and wide range of flora makes it a host of five out of seven bee species found in the world. The four-native species of genus *Apis* found in Nepal are *Apis cerana, Apis dorsata, Apis florae* and *Apis laboriosa.* Out of them only two are domestic and the rest are wild species. Of the total pollination activities, over 80% is performed by insects and bees contribute nearly 80% of the total insect pollination, and therefore, they are considered the best pollinators (Thapa, 2006).

Asian bee *A. cerana* is an indigenous and domestic species. It is friendly and suitable for hilly region and can be reared up to an altitude of 3400 meters. *A. dorsata* is a wild and furious species. It is common in the areas below 1000-meter altitude. Bees from this species are called Giant bee. *A. florea,* a small bee, is found at an altitude ranging from 300 meters to 500 meters. The bees from this species are of smaller size. It is a wild species, generally build their hives on the branch of trees. The rockbee *A. laboriosa* is a high-altitude species, which is found at an altitude ranging from 1200 meter to 3500 meters. This species is wild and furious found in limited number only. The honey from this species is harvested once a year known as rock honey. As the honey from this species has unique taste and quality, it fetches higher value than the honey from other species. Similarly, it is popular and more in demand, particularly due to its wider medical values, than other species. The European bee *A. mellifera* is domestic but imported from Europe. These honey bees are friendly and due to higher yield of honey and wax it is more in demand and popular among the beekeepers than other species commercially. It can be reared at an altitude below 1500 m.

The *A. cerana* found in a very wide area comprising mainly southern and eastern Asia. In the west it extends from Afghanistan up to the Philippines in the east and in the north from Ussuria to Java in the south (Ruttner, 1985, 1986, 1987). Thus, this species is found not only in the tropical and sub-tropical regions of Asia, but also cooler climate such as Siberia, norther China and higher altitudes of the Asian mountains at altitude of up to 3,600 m (Koeniger, 1976; Partap, 1997). Including Nepal Ruttner (1986, 1988) classified the different Asian hive bee populations into four groups: of *A. c. japonica, A. c. cerana, A. c. himalaya,* and *A. c. indica*. The former three races also occur in Nepal: *Apis cerana cerana* in the high hills, *Apis cerana himalaya in the* mid hills and *Apis cerana indica* in low lands (Verma, 1990).

A. cerana bees build parallel combs inside a cavity. Colonies are found in forests or agricultural areas in the plains, and even in urban areas with good vegetation. It is larger than the dwarf bee but is much smaller than the rock bee. Natural nests of this honeybees occur in tree trunks, rock crevices, ant hills, underground deserted nests of white ants, or any dark enclosure, sometimes even in the open, but quite dark spaces in forests or unused rooms in buildings. This honeybee's species is domestic and managed for honey production and crop pollination. It is highly social and cosmopolitan in behaviour and distribution emcompassing economic value that provide hive products like honey, beewax, royal jelly, bee venom and ecosystem services by cross pollination of several cultivated and wild plant species that result in increased productivity. But the services are at risk due to declining bee pollination resulting from exposure of bees to parasites, pathogens and environmental chemicals such as pesticide and other anthropogenic substances (Van Engelsdrop *et al*., 2009).

1.1.2 *Apis cerana* and Beekeeping

As mentioned above, *A. cerana* Fabricius is endemic to most of Asia where it has been used for honey production and pollination services for thousands of years. The first references of *A. cerana* in relation to beekeeping appear from the 300s BC in northern India and from 200s BC in China and Vietnam (Crane, 2004). In tropical south-east Asia bee-hunting seemed to be more common than beekeeping due to the larger number of open-hive bee species living in the favorable ad warm environment. Box-hives were also introduced around this time probably by Chinese traders and frame hives appeared from 1900 introduced by European and American missionaries (Crane, 1999). *A. cerana* are kept traditionally as well as in modern top-bar removable frame hives in Nepal.
Beekeeping practice with this species is common across Asia (Ahmad *et al.*,2007; Bradbear, 2009; Crane, 1999; Oldroyd and Wongsiri, 2006; Partap and Verma, 2000; Verma and Attri, 2008). Although *A. cerana* has declined dramatically in some areas since the introduction of the non-native *A. mellifera* (Oldroyd and Nanork, 2009; Partap and Verma, 1998; Verma, 1990) in many areas of Nepal in 1993. It is important to state, *A. cerana* beekeeping is an integral part of social and cultural heritage (Verma, 1990) and a valuable part of rural livelihood (Bradbear, 2009; Koetz, 2013) for bee products and services include honey and brood for consumption, beeswax and pollination services (Oldroyd and Wongsiri, 2006; Partap, 2011; Koetz, 2013).

A. cerana beekeeping varies greatly and ranges from finding and harvesting natural nests in forests to keeping simple hives made of grass or bamboo in walls of houses, logs, pots or boxes, cavities gauged out of trees and closed with a wooden board to modern beekeeping techniques including movable frame or comb (top-bar) hives (Bradbear, 2009; Crane, 1999; Ruttner *et al*., 1972; Verma and Attri, 2008; Crompton, 1987). This species is prone to abscond due to various reasons. Asian beekeepers have developed methods to deal with this problem. Methods of reducing absconding and managing swarming include caging the queen of a new colony until some comb is built clipping the queen’s wings after her mating flight removing new queen cells and managing the amount of brood comb and available space within the hive by splitting colonies (Crane, 1999; Anne and Michael 2005).

Beekeeping is one of the major income sources mainly for those beekeepers who have limited options for cash income. Therefore, provides not only cash income but other benefits like food, nutrition and medicine as well (Howe *et al.,* 1980). Further, it is equally important to maintain biodiversity at society, national, regional and global levels and performs several ecological functions without competing for scare land resources, provides benefits for better farm yield through pollination service (Gurung *et al.,* 2002). So, Beekeeping with *A. cerana* does not require a lot of management practice. It is easy for an isolated farming community to practice beekeeping with this bee species on the basis of their indigenous knowledge also (Gurung *et al.,*2002).

1.1.3 In Context of Nepal

Apiculture is rich tradition of beekeeping in remote villages of Nepal which is associated with genetic diversity of *A. cerana*, availability of bee forage plants and a wealth of indigenous knowledge in sustainable management of beekeeping in traditional log hives. *A. cerana* beekeepers possess high degree of social capital and are strongly integrated within the society as compared to other commercial beekeepers. Selling bee products contribute cash income to the livelihood of remote and isolated communities in Nepal (Gurung *et al.,* 2002). Therefore, it has huge potential in Nepal's rural sustainable development as it increases the productivity of agricultural crops and provides various products like honey, royal jelly, pollen, wax etc. Still commercial apiculture with *A. cerana* is not very common in Nepal because of different factors. On the other hand, there is high preference of apicultural practice with *A. mellifera* in different regions of the country. After the introducing *A. mellifera* there was also availability of same species of mites in their colony and transferred one place to another in the same place.

1.1.4 Bee Pest

Different pests and predators attack all lifecycle stages of many species of honey bees, because of their togetherness in a tightly knit social group. Among pest's honey bee colonies are infested by wide diversity of mites largely because of diverse food and micro habitat it offers (Woo *et al.,* 1993, 1997). In Nepal, importation of queen bees from infested areas and movement of infested bee colonies for pollination have allowed rapid spread of mites so that apiculture industry is being severely affected. Remaining unchecked, the infestation by mites are leading to colony collapse. Despite the number of honey bee colonies have grown across the country, poor bee health has reached alarming levels in some regions of Nepal because of the mites, one of the main honey bee’s worst enemies (Abrol, 1997). Those mites can be broadly classified in to three groups: parasitic, predatory and phoretic. Most important mites are endoparasite *Acarapis woodi* Rennie, *A. externus* Morgenthaler and ectoparasite *Varroa jacobsoni* Oudemans, *V. destructor* Anderson and Trueman and *Tropilaelaps clareae* Delfinando and Baker. Both endoparasite and ectoparasite mites attack different species of honey bees throughout the world (Grobov, 1975; Burgett *et al.,* 1983) including Nepal. The primary problem causing ectoparasite mites are *Tropilaelaps* and *Varroa*. Mites in the genus *Tropilaelaps* are brood parasites of honey bee (*Apis* spp.). The *T. clareae* was first discovered and originally described by Delfindo and Baker in 1961 from a collection of dead *A. mellifera* and from field rat nesting near a bee hive in the Philippines (Delfinado and Baker, 1961). The *T. clareae* is a light brown in colour and feeds on both brood and adult bees. Whereas, *V. jacobsoni* is large, dorsoventrally flattened mite of reddish brown colour visible to nacked eye. It feeds on hemolymph of brood cell as well as adults (Mattu, 1992).

1.1.5 *Varroa destructor*

The *Varroa destructor* is one of the destructive species of Varroa, is most important enemy and ectoparasitic mite that feeds on the hemolymph of adult and immature honey bees (Poonia *et al.,* 2013). It is highly adapted to its natural and adopted honey bee hosts. Adult female mite perforates the integument of bee pupae in such a way that they and their progeny can feed on the hemolymph from the adult bees and developing brood (Kanbar and Engels, 2005; Aydin *et al.,* 2007; De Jong *et al.,* 1979). This species, like *V. jacobsoni,* is wide spread and found in most part of the world causing almost 100 percent mortality in western part of the world (De Jong *et al.,* 1982).

The genus *Varroa* includes in excess of 18 genetically different strains of mites (Cobey, 2001; Akratanakul *et al.,* 1975) and the two species *Varroa destructor* and *Varroa jacobsoni* are thought to be closely related (Zhang, 2000; Delaplane, 2001), both parasitizing the Asian honey bee, *Apis cerana*. However, *V. jacobsoni,* originally described by Oudemans in 1904, is not the same species as that which also attacks *A. mellifera* and Anderson and Trueman (2000) corrected previous confusion and mislabeling in the literature prior to 2000, recognizing *V. destructor* as a separate species.

Adult female mites of *Varroa destructor* are reddish-brown to dark-brown in colour (Sanford *et al.*, 2007), 1.00-1.77 mm long and 1.50-1.99 wide (Denmark *et al*., 2000) bodies curved, fitting into abdominal folds of adult bees, held in place by the ventral setae of the host so protected from the bee's cleaning habits. Adult male mites are yellowish in colour with slightly tanned legs, 0.75-0.91 mm long and 0.71-0.88 mm wide, with a spherical body. The male chelicerae are modified for the transfer of sperm, only occurring in sealed broods. The protonymph and deutonymph stages described by Delfinado-Baker in 1984.

The *V. destructor* primarily parasitizes primarily the Asian honey bee *Apis cerana,* which also infect *A. mellifera* (Sanford *et al.,* 2007). The introduction of the western honey bee, *A. mellifera,* by *Varroa destructor* is attributed to two mitochondrial haplotypes (K and J) that shifted last century from their primary host *A. cerana* in north-east Asia (Navajas *et al.,* 2010) and is now a cosmopolitan species and causing serious threat to beekeeping industry of Nepal.

Morphological differences have been recorded in mites parasitizing honey bees in hive-logs as well. The winter generation had bigger dorsal and ventral shields, smaller gnathosoma, and increasing transversal body size, greater ventral shield size and smaller legs compared to the winter generation from hives (Akimov and Benedyk, 2004), and a lower morphological variability compared to summer generations (Akimov *et al.,* 2004). *V. destructor* can be present in any habitat where its hosts are found; these include *A. mellifera* and *A. cerana*, native to Asia east of Afghanistan, and *A. koschevnikovi* native to Borneo (Denmark *et al*., 2000) including Nepal.

The fitness and virulence of the mite depends not only upon the ability of mites to reproduce and spread within the colony but also on the ability to spread between colonies (Webster, *et al.,* 2000). Since *A. cerana* occupies a large range of climatic conditions from cool regions in higher latitudes and altitudes to dry, semi-desert environments as well as tropical climates, it rarely causes serious damage to its native hosts the eastern honey bees *A. cerana* (Wu *et al.,* 2017) caused by *V. destructor.* Nevertheless, effects in *A. cerana* colonies have been observed in Nepal.

1.1.6 Management Practice of Varroa mite

Different traditional and chemical are being used for treatment of bee pests and diseases. Varroa management practices are used differently by different beekeepers. In Nepal, it is destructive to colony loss situation *A. mellifera* whereas, in *A. cerana* it is threat leading to colony damage. The good colony management are being practiced by beekeeper's. Removing of brood cells having mites, application of fume of certain plant parts such as Surti, Titepati, Neem. Some of the *A. cerana* beekeepers do nothing for its management because of its assumed destructive nature.

1.2 Objectives of the study

1.2.1 General Objective

The primary purpose was to study the seasonal variation of ectoparasite mite *Varroa destructor* found on *A. cerana* colony in Madanpokhara, Palpa, Nepal.

1.2.2 Specific Objectives

- To observe the seasonal occurrence of *Varroa destructor* in *Apis cerana* colonies.
- To study the seasonal variation in population dynamics of the *Varroa destructor*.
- To study the seasonal variation of the *Varroa destructor* in relation to temperature and humidity.

1.3 Justification of the study

The Varroa mite, *V. destructor* is currently the greatest threat to apiculture that has been recorded to have causal devastation to honeybee population. Insect pollinated crops are estimated to provide approximately one third of human food, and about 80% of this pollination is provided by the European honeybee, *Apis mellifera*. Thus, a loss in numbers of *A. mellifera* due to infestation by *V. destructor* could lead to substantial negative but indirect impacts from lower crop yields due a lack of adequate pollinators. The most significant potential trace impacts of mites include *V. destructor* economic, social and environmental concerns.
As well as their direct effects on the honeybees, *Varroa* mites also have an impact by spreading various bee diseases. Viruses causing mortality of bees infested with *Varroa* mite include Kashmir bee virus, showing virus transmission from mite to bee pupae and a virus transfer rate of over 50% from mite to mite (Chen *et. al*., 2004; Todd *et. al*., 2004). Other viruses thought to be transmitted by *V. destructor* are Deformed wing virus, Sac brood virus, Acute bee paralysis virus (Tentcheva *et. al.,* 2004; Chen *et. al.,* 2005) and Slow paralysis virus. European foulbrood caused by the coccoid bacteria *Melissococcus pluton* (Kanbar *et al.,* 2004), and *Paenibacillus,* which causes American foulbrood, may also be transmitted by *V. destructor* (Rycke *et. al.,* 2002). Benoit *et al*. (2004) reported on the potential of *V. destructor* to disperse spores of *Aspergillus, Penicillium, Fusarium, Trichoderma, Alternaria, Rhizopus* and *Mucor* throughout bee colonies. The fungi have only been recorded on the surface of mites and not internally, indicating that the mite is not a fungivore. The mould fungus, *Aspergillus flavus* is the agent of stonebrood disease in honey bees and *V. destructor* is implicated as a vector (Benoit *et al*., 2004). So, apiculture is severely affected by the activities of *V. destructor*, either by direct parasitism or indirectly by facilitating the spread of bee viruses and diseases. If remained unchecked, mites can infest hives beyond an economic threshold and lead to colony collapse (Fera, 2010). Since *V. destructor* attack all life cycle stages of bees by sucking blood through punctures made in the host body wall, using its sharp mouthparts, weakening the insect and shortening lifespan, and as mentioned above also acting as a virus vector in colonies and aiding the harmful effects of other bee diseases such as acarapisosis caused by tracheal mites *Acarpis woodi* (Fera, 2010).

The work done by honey bees is of great importance to humans. It offers an immeasurable contribution to floral biodiversity and conservation by pollinating a wide number of crop plants making the important part of food production. Therefore, the horticulture and agriculture sectors rely on these pollinating insects. *V. destructor* is devastating to bee colonies and a reduction in pollinating bees could result in reduced pollination and ultimately decreased overall yields and crop quality. That is why protecting and improving the health of honeybees is so important. Impacts of *Varroa destructor* can cause a serious effect on apiculture and thus is of particular concern to those who rely on beekeeping for their livelihoods (Allsopp, 2004).

There were several research works carried out on the Varroa mite. As suggested by Denmark *et. al.,* 2000 the movement of infested colonies of bees has facilitated the rapid local spread of *V. destructor* and is the main means of spread over long distances (Fera, 2010). Thapa (2006) reported that the Asian mite *V. jacobsoni* is associated with *A. cerana* and *A. dorsata* bees but causes no serious problem to them but it is fatal to *A. mellifera* colonies. Around the decades ago, Thapa *et. al.* (2000) reported there were no serious pest, predators and diseases of honey bees in Nepal but introducing of *Apis mellifera* that has been spreading dramatically all over the country is becoming the major threat for beekeeping in Nepal. Whereas, according to Neupane (2009) *V. destructor* was threat to *A. cerana* bees in Nepalese context.

Varroa mites are mobile and can easily spread within a bee colony (Fera, 2010) though they are unable to travel outside of the hives without a vector. It can spread from colony to colony via drifting workers and drones within an apiary and when bees rob smaller colonies (Bessin, 2001). In addition to being carried on honey bees, this mite has been recorded on flower-feeding insects such as bumblebees *Bombus pennsylvanicus* (Hymenoptera: Apidae), flower flies *Palpada vinetorum* (Diptera: Syrphidae) and rainbow scarab beetles *Phanaeus vindex* (Coleoptera: Scarabaeidae). These insects will aid in short distance dispersal, but *V. destructor* can only reproduce on honey bees (Kevan *et.al.*, 1990; Denmark *et. al.*, 2000). Therefore, an ability of the *Varroa* mite to kill eventually honey bee colonies of *A. mellifera* can be a serious threat to *A. cerana* as well in spite of its hygienic behavior against varroa mites.

As mentioned above, *Varroa destructor* is the mite responsible of Varroatosis (or Varroosis), an external parasitic disease that attacks honeybee colonies (adult bees and especially the brood). This parasitic disease is transmitted very easily by direct contact from infested to healthy bees (e.g. during the visit of a flower, by drones who can freely enter different hives, during robbing of infested hives, as effect of drifting of infested worker bees among adjacent hives, etc.). The weakened bees are more susceptible to other diseases. The first to suffer are the stronger colonies with more brood because of the higher possibility of the mite to replicate at the brood level. Therefore, the occurrence to this mite cause the major economic losses to the beekeeping sector and because it is wide spread, it has a strong adaptability to the treatments as well.

Keeping these factors in mind, *A. cerana* honey bees and its beekeeping techniques and management practices are also important for availability of the Varroa mites. The transmission and diseases may also occur by the direct action of the beekeeper for example by transferring parasitized brood combs from one colony to another or by the migratory beekeeping practice. Moreover, another factor of varroa transmission is linked to migratory beekeeping due to the transfer of heavily infested colonies or due to the delayed application of treatments. In fact, this practice increases exponentially the physical contact between healthy and infested colonies.

A long reproductive season causes increase in the strong varroa population which often results in colony losses. Some factors other than reproduction may contribute to the growth of the mite population. An artificial interruption of the seasonal brood cycle can be a useful option to reduce the Varroa infestation levels in the hive. During brood less, periods all mites can be forced in a phoretic stage and can easily be trapped with open brood combs or killed by Varroacides. Therefore, it is especially important to get to know the enemy better through intensive evaluation of the Varroa mite population. It can be gained significant facts and figures about the seasonal mite's population and the efficacy of counter measures. The results help to optimize and complement Varroa treatments in the future keeping in view the serious threat of Varroa mite in the *A. cerana* beekeeping and effective management potion for the mite population control.

Today apiculture is a threatened industry largely due to the spread of honeybee diseases. The beekeeping practices actually encourage the spread of disease and increase pathogen virulence by facilitating pathogen transmission routes. The Varroa mite population determines its severity in honeybee colonies along with important facts and figures regarding the seasonal occurrence and the possibilities of counter control measures. In addition, the findings can help to optimize and compliment the Varroa treatment in future. So, there is an urgent need for a sustainable solution in the threat of Varroa mites for the economic viability of apiculture and agriculture as well as honeybee health, conservation and for ecosystem services. Understanding the seasonal population of the Varroa mites is an essential first step towards achieving goals of control operations. Therefore, this study will provide insight and give optimistic viewpoint for a potentially sustainable solution through treatment and control. In addition, the study on population of the Varroa mites emphasize the influence that apiculture has on the development of infection in *A. cerana* honey bees colonies and consequently by example would suggest that the most effective solution for sustainably improving honeybee health acquired from better management practices.

1.4 Limitation of the study

A one-year detail study was not possible to carry out due to the limited budget and time frame. Collection of Varroa mites through suger shake method on adult bees as described by Dietemann *et al.,* (2013) was not applicable due to informed consent.

2. LITERATURE REVIEW

The longest Varroa association of honeybees and the Varroa mites its devastation to honey bee's populations have been reported almost throughout the world. Varroa mites were first discovered more than 100 years ago on the Asian honey bee (*Apis cerana*) in Java, Indonesia and named *Varroa jacobsoni* (Oudemans, 1904). They were assigned to a new genus, Varroa and eventually to a new family Varroidae (Delfinado-Baker and Baker, 1974). Varroa mites are native brood parasites of a group of cavities nesting Asian honey bees that are closely related to *A. cerana* (Dietemann, *et al*. 2013). V. destructor is one of the most recently described species of the genus and are native to *A. cerana* in northeast Asia (Anderson and Trueman, 2000). Adult female *Varroa* can be found either on adult or immature honey bees. It reproduces on honey bee brood (developing larvae or pupae). Immature *Varroa* can be found only on capped brood. Adult females undergo two phases in their life cycle, the phoretic and reproductive phases. During the phoretic phase female *Varroa* feed on adult bees and are passed from bee to bee as bees walk past one another in the colony. During phoresy, the female *Varroa* live on adult bees and usually can be found between the abdominal segments of the bees (Ellis, 2010). *Varroa* puncture the soft tissue between the segments and feed on bee hemolymph through the punctures.

Their flattened shape allows them to fit between the abdominal segments. They have claws that allow them to grasp the bee and ventral setae that allow them to remain attached to the bee. The mite's cuticle has a chemical pattern similar to that of the bee's possibly allowing it to escape notice while on the bee. The phoretic period of the mite appears to contribute to the mite's reproductive ability. Although mites artificially transferred to brood cells immediately after they mature are able to reproduce. Their reproductive rate is lower than that of mites undergoing a phoretic period. The entire life-cycle of *V. destructor* occurs within the hive. A female mite lays eggs in bee brood cells and developing mites feed on developing bee larvae (Denmark *et al.*, 2000) preferring drone brood (Bessin, 2001). Males and females copulate inside the cell and the male dies, leaving the pregnant females to emerge from the cell with the bee host. Another cell is located to repeat the cycle and the mite population increase may be significantly greater if the post capping time is longer. The phoretic period may last 4.5 to 11 days when brood is present in the hive or as long as five to six months during the winter when no brood is present in the hive. Female mites living when brood is present in the colony have an average life expectancy of 27 days (Ellis, 2010).

The general morphology and chaetotaxy of *V. jacobsoni and V. destructor* are very much similar to each other but their size varies. *V. jacobsoni V. rindereri* and *V. underwoodi* are also similar however *V. jacobsoni* and *V. rindereri* are transversely oval as opposed to the ellipsoidal shape of *V. underwoodi*. *V. jacobsoni* can be distinguished from *V. rindereri* by several characters including small size, short and sharp-looped periderm, fewer endopodal setae and presence of a seta on the palpal trochanter (Guzman and Rinderer, 1999). Delfinado-Baker and Houck (1989) found some morphological differences between populations of *V. jacobsoni*, especially regarding body size. In general, *V. jacobsoni* that infests *A. cerana* is smaller than those infesting *A. mellifera*. These differences may be due to the existence of at least three genotypes of *V. jacobsoni* are very similar. *V. underwoodi* can easily be distinguished from *V. jacobsoni* and *V. rindereri* by its small size, ellipsoidal shape and long lateral marginal setae radiating outward. Among populations of *V. underwoodi*, size variation (Delfinado-Baker and Aggarwal, 1987). *V. rindereri* is a parasite of *A. koschevnikovi*, another cavity nesting honey bee commonly known as the red bee, which is sympatric with *A. cerana* in Borneo, Malaysia (de Guzman *et al.*, 1996). Adult females of *V. rindereri* are similar to *V. jacobsoni* females but *V. rindereri* is larger than *V. jacobsoni* (Guzman and Rinderer, 1999).

Brettell *et al.*, (2017) showed *Varroa destructor* transformed the previously inconsequential Deformed Wing Virus (DWV) into the most important honey bee viral pathogen responsible for the death of millions of colonies worldwide and unique association between mite and bee persists due to the evolution of low *Varroa* reproduction rates. Ryabov (2017) studied *Varroa destructor* virus-1 (VDV1), the most widespread honey bee viruses and identified VDV1 in honey bee pupae in the US. It had been tested 603 apiaries the US in 2016 and found that VDV1 was present in 66.0% of them, making it the second most prevalent virus after Deformed wing virus, which was present in 89.4% of the colonies but VDV1 was present in only 2 colonies (2.7%) of 75 colonies in 2010. Study detected newly emerged recombinants between the US strains of VDV1 and Deformed wing virus. A nationwide survey on the occurrence and prevalence of pathogens and parasites in Asian honeybees, *A. cerana*, in China demonstrated that infections of *A. cerana* by pathogenic Deformed Wing Virus (DWV), Black Queen Cell Virus (BQCV), *Nosema ceranae*, and *Crithidia bombi* have been linked to population declines of European honeybees *A. mellifera* and bumble bees by Li *et al.* (2012).

Begna (2014) performed diagnostic survey in 10 districts of Tigray region of Ethiopia in October and November 2010. A total of 200 honeybee colonies were randomly sampled and inspected internally and externally for adult bee brood diseases and pests. All the surveyed areas tested positive to the Varroa mite with infection levels ranging from 37.5% to 100%. Chaudhary (2013) recorded 139 honey bee pests of 3 families, 2 orders and 3 species. The study found two species of mites *T. clareae* and *V. jacobsoni* that caused damage in beekeeping industry at different VDC's of Chitwan and Makawanpur district in Nepal. According to Baker (2010) *Varroa destructor* is worldwide and the most familiar and destructive of the bee mites, causing death and damage to large numbers of honeybees in Asia, and are a potential threat to bee keepers in many parts of the world. The *V. destructor* mite transmission as well as the host transfer from the *A. cerana* to *A. mellifera* bee was studied. Study found on the genetic diversity of mites based on the variation of the cytochrome oxidase I (CO I) gene was also investigated by Borsuk *et al*. (2012).

Garg and Kashyap (1997-98) and Woyke (1985) identified *T. clareae* as a measure pest of *A. mellifera* as well as of *A. dorsata* and *Varroa* of *A. cerana* bees in Nepal. Shrestha

(Pradhan) (1996) recorded four types of major honey bee diseases Thai sac brood, European foulbrood, Nosema and mites (*Varroa* and *Tropilaelaps*) at five different experimental sites in Kathmandu valley, Nepal. Koeniger (1990) reported that the closely related *Apis* spp. may host the same mite species and also closely related mite species can parasite the same *Apis* species. They may occur even in the same colony. It concluded that natural distribution of the mites corresponds well to the systematic position of host and parasites. The ectoparasitic mite *Varroa destructor* switched hosts from the Eastern honey bee *A. cerana* to the western honey bee *A. mellifera* which was a key factor driving the losses and infestation levels were significantly found to be lower in surviving colonies and mite reproductive success was reduced by 30% when compared to the controls. The study found no significant differences between surviving and control colonies for either grooming (Oddie, 2017).

Koumad (2015) studied varroa population increased in spring and declined in June. Population approximately followed the development of its host. The average population 4417 was recorded during Spring (March to May). The level of infestation of mite in colonies varied depending on the weather (season) and internal conditions of each colony. Pinto *et al.* (2015) studied the infestation rate of the mite *V. destructor* in commercial apiaries of the Vale do Paraíba and Serra da Mantiqueira southeastern Brazil. The infestation rates were measured 3.0%, varying from 0.0 to 5.5% (municipalities of Paraibuna and Lorena, respectively). Lorena was the municipality with the highest IR, followed by Tremembé (4.6%), Bananal (4.5%), São José dos Campos (4.5%) and Pindamonhangaba (4.4%). Relationship between infestation rate of the mite in adult bees and environmental temperature was found to be positively correlated (R = 0.676, $P<0.05$). Asha *et al.* (2013) recorded maximum incidence of Varrosis on adults of *A. mellifera* L. The study recorded 8% in second fortnight of May 2008 corresponding to the peak in *V. destructor* population. Percent deformity was calculated by observing 100 adult bees.

The infestation level of mites was higher in *A. mellifera* than the *A. cerana* and *A. dorsata*. Honeybee mites *T. clareae* was identified as major threat to *A. mellifera* and *A. dorsata* whereas *V. destructor* was threat to *A. cerana* bees in Nepalese context. Results showed the high infestation was in *A. mellifera* (78%) than in *A. cerana* (70%) and *A. dorsata* (50%) bees. The occurrence of *V. destructor* was found to be lowest in rainy (4 per sample) and highest in spring (27.7 per sample) season in *A. cerana* colonies Neupane (2009). Guzman *et al.*, (2007) studied the growth rate (r) of *Varroa destructor* Anderson and Trueman (Acari: Varroidae) populations in *Apis mellifera* colonies from 2001 to 2003 in Baton Rouge, Louisiana of United States. Over this period consistently showed lower mite growth in the Russian than in the Italian colonies was observed. In 2001, instantaneous growth rates per week (r_7) were r_7=0.191±0.011 for mites in Italian colonies and r_7 = 0.137±0.012 in Russian honey bees for 24.3 wk were recorded. These growth rates were equivalent to 159.1- and 61.6-fold increase respectively. Alattal *et al.*, (2006) recorded the Varroa mite infestation levels in Jordan covering 180 colonies of *A. mellifera. syriaca* and *A. mellifera. syriaca* hybrids from six locations of 4 climatic zones. The study found average adult bee infestation of 10.9 % and 13.1 % on hybrid and local bee types.

Harris *et al.,* (2003) measured the significant variation in the instantaneous growth rates for varroa mites *Varroa destructor* from 1993 to 2002 in Baton Rouge, Louisiana United States. The mite population growth was monitored in colonies of *A. mellifera* in the beginning and in the end of short field tests that started in the late spring of each year. Study demonstrated that the lowest growth rates occurred in three consecutive years of drought in Louisiana United States. Temperature and relative humidity found to be correlated to growth of mite populations among different years. Study also concluded that reduced growth rates were probably the result of diminished reproductive rates by varroa mites during periods of hot and dry weather. Rath (1999) described that *A. cerana* acquired a high degree of hygienic efficiency with a differentiated set of behavioral traits. Approximately 20 % of the reproducing mite population can be eliminated by entombing of lethally parasitized drone pupae.

Tewarson *et al.* (1992) studied natural reproduction of mite in *A. cerana* to drone brood in spring (January-April) in Allahabad. Reproduction in worker brood was investigated by artificially induced infection. Since the bees recognized and eliminated any mites originating from other hives the grafting was performed within the same colony. The study showed 75% of the mites were removed by the bees. Of the remaining varroa females about 90% were found to be infertile.

Read *et al.* (2012) studied the chelifers as controlling agent of *Varroa* and found helpful in the control of *Varroa* mite. They found two native species, *Nesochernes gracilis* and *Heterochernes novaezealandiae* (previously named *Maorichernes vigil*) of chelifers in Newzeland. Hou *et al.,* (2016) showed that initial temperatures of the colonies with high and low mite infestation were 34.69° and 33.05°C and the final temperatures were 34.73° and 32.99°C respectively. Humidity with relation to high and low infestation groups were 73.87% and 77.73% respectively. Mite infection in honeybee colonies was positively correlated with temperature but negatively correlated with humidity. It also concluded that infestation in highly infested broods was higher than that in broods with low infestation. Results showed that the expression levels of these genes in colonies with high mite infestation were closely associated with changes in hive temperature and humidity.

Maggi *et al.* (2015) studied Varroa control under spring and summer climatic conditions in Argentina. The formulation consisted of four strips made of cellulose impregnated with a solution based on oxalic acid. Average efficacy of the organic product was found 93.1 % with low variability. Study mentioned that organic treatment designed for the Varroa control during brood presence can be a good alternative to the synthetic treatments. Adjlane *et al.* (2016) evaluated the effectiveness of Varroa treatment using organic acid (oxalic acid) in Algeria identifying its side effects on bee colonies. The percentage of average efficiency obtained for the 100g of oxalic acid in 1 liter of syrup was 81% and 72.19% for the second dose 70g of oxalic acid in 1 liter of syrup and 65% 50g of oxalic acid in 1 liter of syrup while the dose of 100 g oxalic acid causes a weakening of honey bee colonies.

3. MATERIALS AND METHODS

3.1 Study area

The study was conducted in Palpa district located in Lumbini zone in the western part of Nepal lies between 27˚34'-27˚57' N and 83˚15'-83˚22' E. Palpa is a hilly district bounded by Nawalparasi and Tanahun district towards east, Arghakhachi and Gulmi district towards west, Syangja and Tanahun district towards north and Nawalparasi and Rupandehi district towards south. The total land area of this district is about 1,373 sq. km. with approximate length of 70 km and breadth of 20 km. The forest area is about 711 sq. km., which constitute 52.11% of the total land area. The altitude varies from tropical (about 213m) to upper subtropical region (1,900m). The headquarter of Palpa district is Tansen at an altitude of 1350m. The study was conducted at Madanpokhara, 15 km far from Tansen Municipality which lies between 27˚34'-27˚57' N and 83˚15'-83˚22' E.

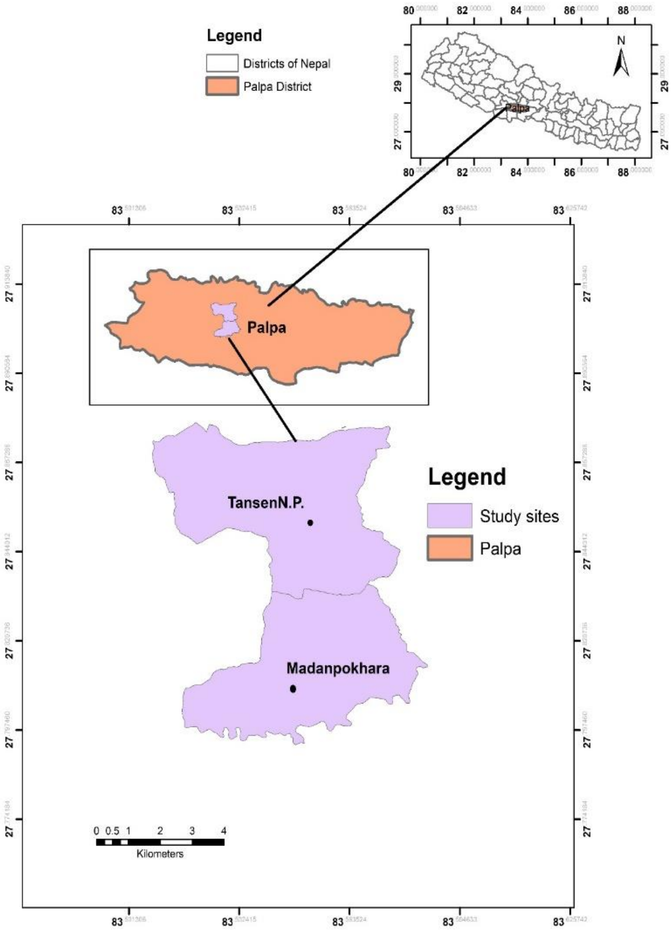


Fig. 1. Palpa district and sampling sites

3.2 Climate

Palpa district is a hilly district of central Nepal ranges from Churia hill to high Mahabharat range. The climate varies from tropical to subtropical type due to variation in altitude and topography. It possesses monsoon type of climate with wet summer and dry winter. The average maximum and minimum temperature recorded in the local meteorological station (Tansen station, altitude 1067 m., $27^0$52' latitude and $83^0$32' longitude) during the last 5 years (2010-2014) was 31.02^0C in June and 6.56^0C in January. The district receives average annual rainfall of 0 mm. to 388.72 mm.

3.3 Vegetation

About 71,170 hectre area (51.8%) of Palpa district is covered by forests. Among total forest cover, 18% lies in Churiya range and 82% lies in Mahabharat range. The Palpa district comprises 634 community forest covering an area of 321 sq. km (DFO, 2015). The dominant vegetation is Sal-forest, *Shorea robusta-Terminalia alata* forest, Riverine forest, *Dalbergia sissoo-Acacia catechu* forest, *Terminalia alata - Schima wallichii* forest in Tropical zone (300-1000m) and *Schima wallichii* forest, *Alnus nepalensis* forest, *Castanopsis forest*, *Pine* forest, *Rhododendron* forest and *Schima -Castanopsis - Quercus* forest in Subtropical zone (1000-1900m).

3.4 Materials

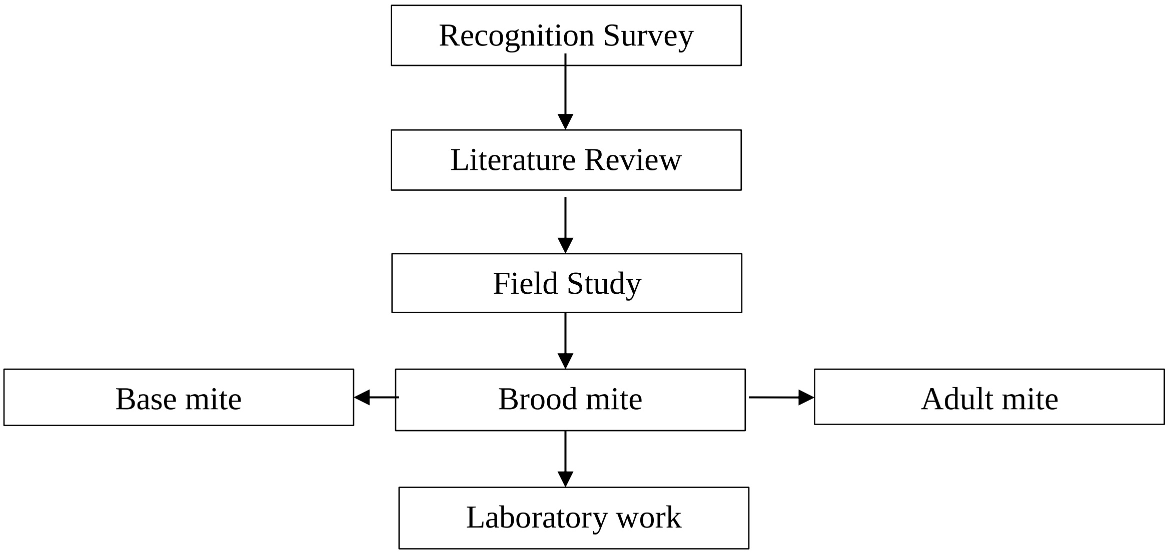
Different tools such as veil, hive tool, forceps (pointed and blunt), camel hair brush, viles, smoker were used and chemicals like ethyl alcohol was used during this study.

3.5 Methods

3.5.1. Sampling Design

Two different established and managed apiaries were selected at Madanpokhara. Twenty colonies of *A. cerana* were selected at each site (site 1 and site 2). Both sites were 2 km. apart. One apiary at site 1 possessed all two years old bee hives and another site 2 had two years old and new bee hives. Study was carried out twice of week during nine months (February to October, 2017). The outside and inside temperature and relative humidity of each hives were recorded during the field visit using thermohygrometer HTC-01.

Flow Chart



3.5.2. Bee hive mite's observation

The debris presented on the bottom board of bee hive was collected regularly and was floated in 70 percent alcohol. The mites and pieces of chitin floated while wax and other heavy materials were drained off in separate petri dishes and the mite species were picked up with the help of a fine camel hair brush (Ritter and Ruttner, 1980).

3.5.3. Brood mite's observation

Analysis of brood mites was done by examining 50-100 capped brood cells in each colony of *A. cerana*. Only brood cells with perforations caps or sucken caps were selected and sampled (Aggarwal, 1988; Wongsiri *et al*., 1989).

3.5.4. Adult bee mite observation

Adult honey bee mites were examined by direct visual observation methods in every frame of the bee hive. The thorax and leg region were carefully watched and collection of mites were collected using brush and forceps.

3.7 Mite identification

The mites were collected and slides were prepared (dehydration alcohol series) and identified using Standard methods for Varroa research Dietemann *et al*. (2013) and Shaara and Tabikha (2016).

3.8 Species deposition

Collected samples were preserved in 70% alcohol and further permanently mounted slides were deposited at the Central Department of Zoology Kirtipur, Kathmandu, Nepal.

3.9 Data analysis

The data was analyzed through ANOVA of two different sites of population of Varroa mites in nine-month periods with MS-Excel 2016. The relation between mite's population with temperature and humidity were analyzed by correlation.

3. RESULTS

The study was carried out during February to October 2017 to determine the seasonal variation of the varroa mites found in *A. cerana* colony. Two sites were selected in Madanpokhara Palpa, Nepal representing the concerned honeybee keeping practice commercially. The selected sites with a number of bee hives coupled with seasonally populated Varroa mite are tabulated in table 1 and 2 and shown in figure 2 along with its relationship with temperature and humidity in figure 3 and 4.

Table 1. Varroa mite's population on base, brood cell and adult at site 1.

Month	Base	Brood	Adult	Total
February	21	31	10	62
March	22	32	9	63
April	4	9	0	13
May	11	17	4	32
June	6	24	1	31
July	16	14	2	32
August	4	11	0	15
September	8	2	0	10
October	5	13	3	21
Total	97	157	29	279

Table 2. Varroa mite's population on base, brood cell and adult at site 2.

Month	Base	Brood	Adult	Total
February	7	16	3	26
March	14	28	4	46
April	3	7	0	10
May	19	9	0	28
June	18	13	2	33
July	10	14	6	30
August	2	16	0	18
September	3	4	0	7
October	7	8	6	21
Total	83	115	21	219

4.1 Population of Varroa mite

A total of 498 Varroa mites were counted in both of sites (279 at site 1 and 219 at site 2). The highest number of Varroa mites were observed in March and the lowest in September 2017 in both sites (table 1 and 2). The mite population was found higher in two years old bee hive (site 1) compared to mixed types of bee hives at site 2. The population was found higher in month of February and March (spring season) and lower in August and September (rainy season). The population was gradually declined in April and May and clearly increased at June and July. The infestation was found to be declined in September and

October in both sites (table 1 and 2). The monthly population of Varroa was found statistically significant difference at site 1 (df 2, 24, P= 0.002756) and site 2 (df 2, 24, P= 0.002581). The higher population was observed in brood cell and lower on adult bees.

As shown in figure 2 the mite count was found higher in Spring season, February and March (62 and 63) and lower in rainy season, August and September (15 and 10). The higher mite counts were observed in brood cells and lower in adult bees from February to October at site 1. Similarly, the higher mite counts were observed in Spring season, February and March (26 and 46) and lower in rainy season, August and September (18 and 7) at site 2. The mite population was observed higher in brood cell and lower in adult bees from February to October at site 2.

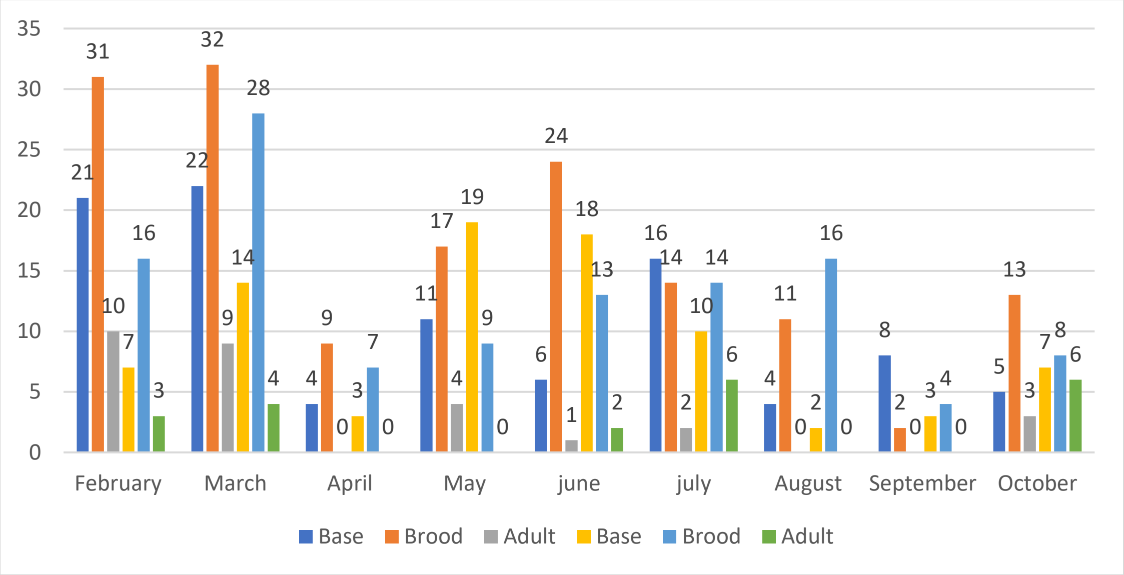


Fig. 2. The numbers of *V. destructor* collected from bottom broad, brood and adult through study period at two sites.

4.2 Relation with temperature and humidity

Relationship between population of Varroa mite with inner hive temperature and outer temperature showed significant different with p-value of 0.64 and 0.17 respectively. Inner hive temperature and outer temperature negatively correlated and positively correlated with mite population as 0.18 and -0.5 respectively at site 1. The relationship between population of mite with inner hive temperature and outer showed significant difference (p-value of 0.83 and 0.47 respectively). Inner hive temperature and outer temperature negatively correlate with mite as -0.08 and -0.27 respectively at site 2.

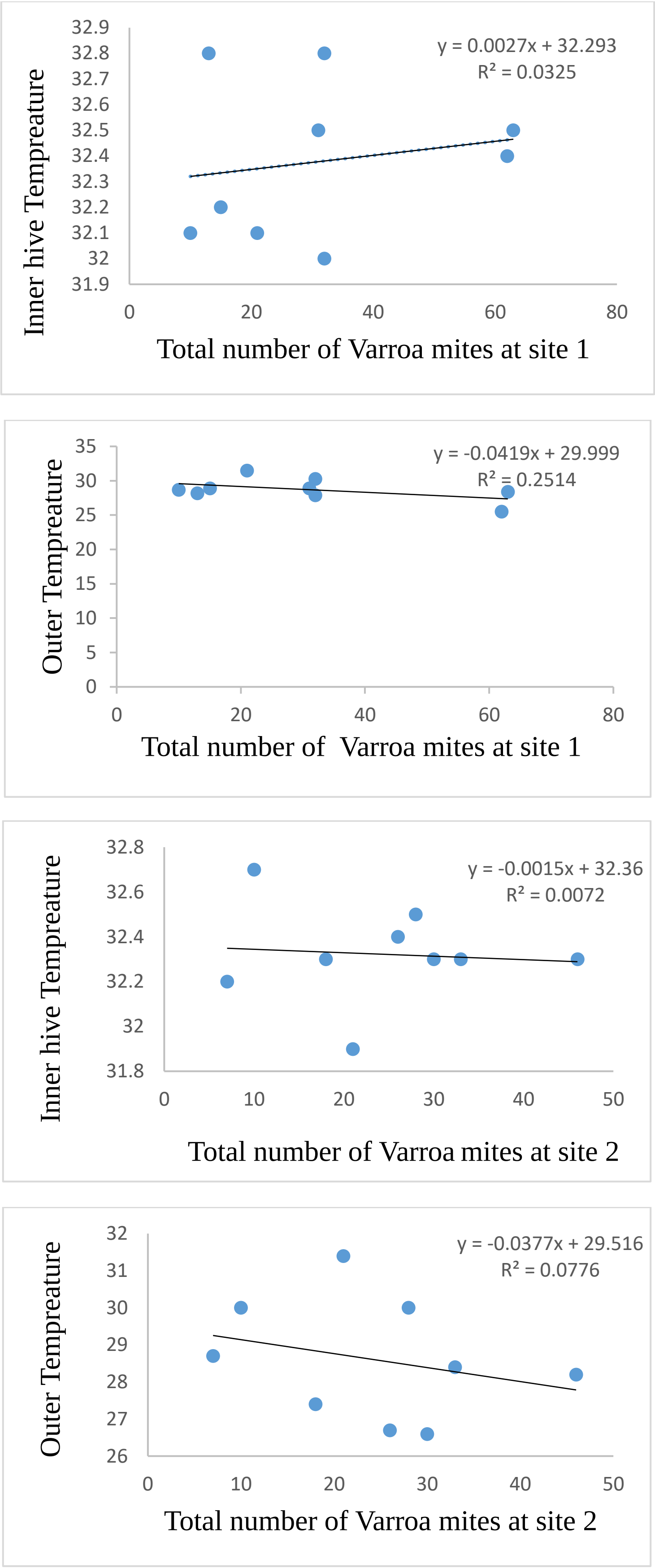
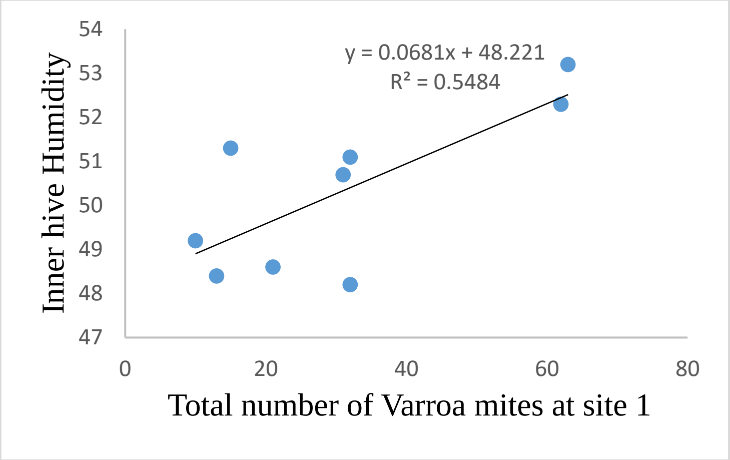
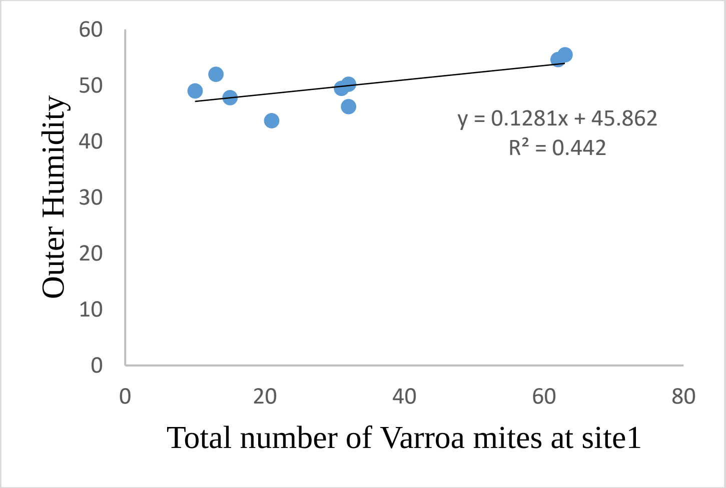
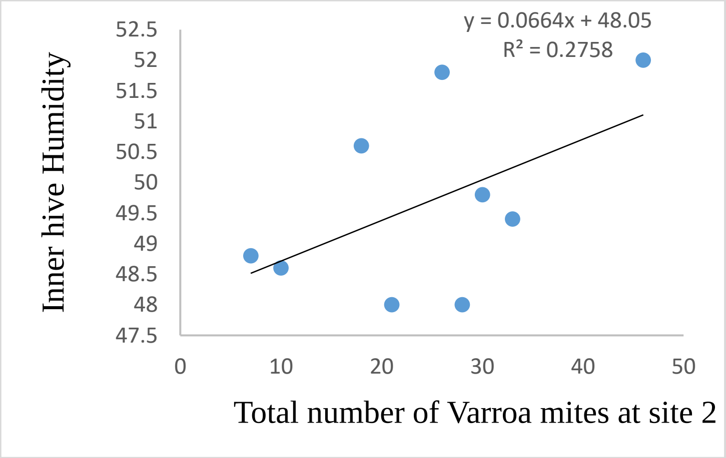


Fig. 3. Relationship between inner hive temperature and outer temperature with total population of Varroa mites at site 1 and site 2.

Population of Varroa mite with inner hive humidity and outer humidity were significantly different with p-value of 0.022 and 0.051 respectively. Inner hive humidity and outer humidity positively correlated with mite population as 0.74 and 0.66 respectively at site 1. Similarly, the mite population with inner hive humidity and outer humidity showed p-value 0.15 and 0.39 respectively. Inner hive humidity and outer humidity positively correlated with mite population as 0.53 and 0.33 respectively at site 2.







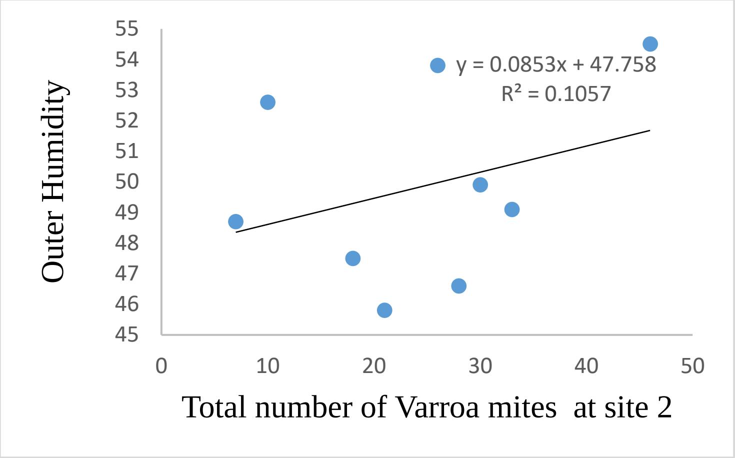


Fig. 4. Relationship between inner hive humidity and outer humidity with total population of Varroa mites at site 1 and site 2.

5. DISCUSSION

Understanding the interaction between honeybees and Varroa mites is an essential first step towards achieving a long term sustainable solution. This study presents an aspect covering the occurrence of Varroa mites by investigating the population. Population of Varroa mites were higher in month of Spring season (February and March) and lower in rainy season (August and September) a significant different in both the sites with p-value 0.002756 (df 2,24) and 0.002581 (df 2,24) respectively. The number of Varroa mite reproductive cycle in brood and its reproductive ability were related to the mite population growth at site 1 and 2 in Madanpokhara when brood rearing peaked in spring season the number of mites found on the bottom board and adult bees were low. Finding of this study identified *V. destructor* in *A. cerana* bees as the threat of honey bees in Nepal which is supported by Garg and Kashyap, 1997-1998 and Woyke, 1985. It has been observed that the Varroa mite could not damage high rate in *A. cerana* but it is a natural host of Varroa so it has been threating to *Apis* spp. Neupane (2009) reported availability of *A. cerana* which is a natural host for *V. destructor* at the same ecological niches and region might attract *V. destructor* to brood in large number in *A. cerana* colonies rather than in *A. mellifera. T. clareae* and *V. destructor* was regular in colonies of honey bees throughout the year with significant population fluctuation during different seasons.

The findings were similar to Koumad (2015) study of Varroa population increased in spring and declined in June. Population approximately followed the development of its host. Neupane (2009) concluded similar result of the occurrence of *V. destructor* lowest in rainy and highest in spring season in *A. cerana* colonies and differ from Fries *et al*. (1994) and Tibor and Szabo (2003) who observed peak period of infestation by *Varroa* spp. between September to December in different parts of the World. The study revels with Mattu and Sharma (2016) conclude peak period in April. Deosi and Chhuneja (2012) also reported a maximum number of *Varroa* spp. in adult bees in the second week of May and the minimum in the end of October. The results contradict with Sharma *et al.* (2011) said that seasonal variations of *Varroa* species in *A. mellifera* colonies with the maximum infestation during the month of April in 2008-09. Although the peak period of *Varroa* species infestation was noticed in October, November and December in 2009-2010 but no infestation found in *A. cerana*. The incidence found (8%) in second fortnight of May corresponding to the peak in *V. destructor* population in hive debris which differs to the results of Asha *et al.* (2013). The findings contrary to Salima (2015) who reported the mite's population of varroa in brood with the greater rate of infestation in March pass high in early May. The population was high in the brood cell than adult and bottom base in different month also opposite to Woyke (1987) who reported that *V. jacobsoni* infested a higher percentage of adult workers than *T. clareae.* On the other hand, the findings were similar to Alattal *et al.* (2006) who reported brood sealed cells had 4 times more *Varroa* than on adult bees which showed mites were high in brood cells than adult and Hou *et al.* (2016) conclusion that infestation in highly infested broods was higher than that in broods with low infestation.

When the mite population initializes its effect on honeybees, the colony ultimately affected leading to low brood production. Finally, the adult bees decreased in numbers with restlessness. Therefore, once the varroa mite established at the study area, beekeeping is only possible with the chemical treatment of colonies and the chemicals create higher risk to bees and pollination as well. A usual scheduled Varroa control practice (chemical treatment) in autumn would be insufficient botanical insecticides can be the environmental friendly measures for Varroa control. When integrated with chemical treatment additional damages or even colony loses determination of infestation rate, studies on the population of the varroa mites are required to better understand the bee's survival with varroa to know whether it is a result of bee population, mite virulence or combination of all aspects.

The findings showed humidity is correlated with mite's population where temperature was negatively correlated with mite's populations which was indirectly supports by Bonoan *et al.* (2014) observation as there is a significant correlation between the densities of mite infection and environmental factors (temperature and humidity) which were induced to fluctuate because of accelerated honeybee behavior. According to Koumad (2015) level of infestation of mite in colonies varied depending on the weather (season) and internal conditions of each colony. Rosenkranz *et al*., (2010) also reported environmental factors have an influence on IR of the mite in colonies. Variables such as temperature, humidity, nectar flow and pollen availability may indirectly influence the proportion of viable offspring of Varroa which were supports. It was contradicted to Pinto *et al.*, (2015) who found the relationship between infestation rate of the mite in adult bees and environmental temperature was positively correlated. Findings were opposite to Hou *et al.* (2016) mite infection in honeybee colonies was positively correlated with temperature but negatively correlated with humidity.

Chemicals were not found to control Varroa mites in bee hives of *A. cerana.* Although The study confined different traditional method as Surti (*Nicotiana tabacum)* (Shrestha, 1998), Neem (*Azadirachta indica*) and Titepati (*Artimisia indica*) (Shrestha, 1998) using practices in honey bee colonies. They were applied in the form of fumigation as well as liquidation. Tulsi (*Ocimumspp*), Timur (*Zanthoxylum armatum*), Sughandhawal (*Valeriana jatamansii*) and Chutro (*Berberis aristate*) also used against the honey bee diseases but not in practice properly. Sancho Viks was used by beekeepers for controlling Varroa mites and different diseases as well (Personal Observation). Study revels to Adjlane *et al.* (2016) and Maggi *et al.* (2015) of chemical treatments. Chelifers have played important role in Varroa management in study area unknowingly which also one of the controlling factor of Varroa mites as said by Fagan *et al.* (2011). Chelifers (pseudoscorpions) have shown potential as a biological control alternative for Varroa management and revels to Maggi *et al.* (2015) report a new formulation based on oxalic acid with high acaricide activity against *V. destructor*.

Altogether 50 beekeepers were interviewed using questionnaire encompassing beekeeping, their knowledge regarding Varroa mites, its management practice and different socio-economic prospective. Mainly beekeepers were found inspired through self, locally and government. Most beekeepers were involved for commercial purpose and as hobby. All interviewed people know the significance and importance of honey bees and used protective measures against the predators, parasites and diseases. Some of the beekeepers were well known about varroa mite whereas, some had no idea about varroa which shows there is little bit knowledge about varroa. Similarly, people were found practicing traditional control methods against the honeybee diseases and pests. Beekeepers were not found practicing the chemical control measures. Chemical control was found to be used low amount. The infestation of the diseases in bee-hive were also lower. Some of beekeeper's hives were remained free from the diseases (Personal Observation).

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6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The ectoparasitic mite, *Varroa destructor*, has become the largest threat to apiculture and honey bee health world-wide. This study was carried out at two sites as new hive and old, new mixed types of hives in Madanpokhara, Palpa. The results of study highlight the seasonal variation of the Varroa mites. A total of 498 Varroa mites were counted at site 1 (279) and site 2 (219). The highest number of Varroa mite were observed in March and the lowest in September at the both sites. The number of mites were found lower number at site 2 compared to site 1. The population was gradually decreased in April, May and increased in June and July. The population again decreased in September and October at both sites. Population of Varroa mite was significantly differed at both sites with p-value 0.002756 (df 2,24) and 0.002581 (df 2,24) respectively. The population was observed higher in brood cell and lower in adult bees. Relationship between the population of mite with inner hive temperature and outer temperature showed significant different with p-value of 0.64 and 0.17 respectively. Population of mite with inner hive humidity and outer humidity showed significant with p-value of 0.022 and 0.051 respectively at site 1. Relationship between population of mite with inner hive temperature and outer temperature showed significant difference of p-value of 0.83 and 0.47 respectively. The population of mite with inner hive humidity and outer humidity showed p-value of 0.15 and 0.39 respectively at site 2.

There is an urgent need for a sustainable solution to the possible threat of Varroa mites for the economic sustainability of beekeeping industry, as well as for honeybee health and conservation. Understanding the seasonal population of Varroa mites is an essential step towards this end. The mite populations may provide an insight and give an optimistic viewpoint for a potentially long-term solution for its control. Furthermore, these populations also way forward of the possibility of the effect of infections in honeybee colonies suggesting the viable solution for improving colony health would come from adopting better management practices. This will not only improve honeybee health but also ensure the quality and safety of honey and other honey bee products by reducing the need for chemicals or antibiotics as disease control treatments.

6.2 Recommendations

Based on the present study the following recommendations have been made as,

Further study on hygienic behavior of *Apis cerana* to be carried out. A deeper understanding of how honey bee colonies naturally coevolve with parasites and understanding the mechanisms behind such coevolution, is necessary for establishing long-term sustainable honey bee health management strategies in apiculture.

Further work is required on the virus-vector epidemiology and interactions will be important in order to implement effective techniques for managing different virus infections.

A detail season-wise study on Varroa mites could be done.

Further experiment based on treated and untreated bee hives should be done.

Awareness programmes and training should be given to beekeepers about Varroa mites.

Action should be taken to make sure that pesticides are not inappropriately used, and beekeepers are trained so that they may ride-out the permanent colony losses.

Further advancement and experiment should be applied in effectiveness of traditional control methods.

Further study of Varroa mites on adult by sugar method should be carried out.

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Appendix 1. Use of different Plant species for Varroa Control at Site 1 and Site 2.

S.N.	Plant	Part Used	Mode of Uses
1.	Surti (*Nicotiana tabacum)*	Leaf	Fume from leaves by buried and spraying in hive.
2.	Neem (*Azadirachtaindica)*	Leaf, stem and root	As a oil by grinding leaves and stem applied to brood cell in small amount. Fresh leaf kept in hive for several hours. Root grinding as paste and applied in small amount.
3.	Titepati (*Artimisiaindica*)	Leaf	Obtain drop from leaves by grinding. Fume of dry leaves by buried. Fresh leaf dipped in water and applied to hive.

Appendix 2. Varroa mites on Bottom Base at site 1.

Date	Hive number and number of Varroa mites																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2/15/2017	2	2	1	0	0	0	0	0	6	0	0	0	0	0	0	0	4	0	1	0
2/21/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
2/27/2017	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0
3/5/2017	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3/11/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3/19/2017	4	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
3/25/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0
3/29/2017	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4/7/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
4/25/2017	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
4/28/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/2/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/8/2017	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/11/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/13/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/15/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/18/2017	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
5/22/2017	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/27/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/1/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/7/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/12/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/16/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/20/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/24/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/27/2017	4	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
7/1/2017	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
7/8/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/11/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/20/2017	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
7/24/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/28/2017	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
8/4/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/8/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
8/13/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/17/2017	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/22/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/26/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/31/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/7/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
9/10/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/16/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/22/2017	0	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
10/2/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10/10/2017	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10/16/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10/27/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
10/31/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 3. Varroa mites on Brood at site 1.

Date	Hive number and number of Varroa mites																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2/15/2017	0	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0
2/21/2017	2	0	0	0	0	0	0	0	6	0	0	0	0	0	4	0	0	0	2	0
2/27/2017	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2
3/5/2017	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
3/11/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3/19/2017	2	4	2	0	0	0	0	0	7	0	0	0	0	0	0	2	6	0	0	0
3/25/2017	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3/29/2017	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
4/7/2017	0	2	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
4/25/2017	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
4/28/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/2/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/8/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/11/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/13/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/15/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/18/2017	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0
5/22/2017	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
5/27/2017	0	0	4	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
6/1/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
6/7/2017	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/12/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/16/2017	2	0	4	0	0	0	0	0	0	0	0	0	0	0	4	0	4	0	0	0
6/20/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/24/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/27/2017	0	3	0	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0
7/1/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/8/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/11/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/20/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
7/24/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/28/2017	4	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	4	0	0	0
8/4/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/8/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/13/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/17/2017	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/22/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
8/26/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/31/2017	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/7/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/10/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/16/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/22/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
10/2/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
10/10/2017	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
10/16/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10/27/2017	2	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10/31/2017	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 4. Varroa mites on Adult at site 1.

Date	Hive number and number of Varroa mites																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2/15/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
2/21/2017	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
2/27/2017	3	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
3/5/2017	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
3/11/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3/19/2017	1	0	2	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
3/25/2017	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3/29/2017	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
4/7/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4/25/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4/28/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/2/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/8/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/11/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/13/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/15/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/18/2017	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
5/22/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/27/2017	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/1/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/7/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/12/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/16/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/20/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/24/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/27/2017	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/1/2017	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/8/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/11/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/20/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/24/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/28/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/4/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/8/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/13/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/17/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/22/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/26/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/31/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/7/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/10/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/16/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/22/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10/2/2017	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10/10/2017	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10/16/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10/27/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10/31/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 5. Varroa mites on Bottom Base at site 2.

Date	Hive number and number of Varroa mites																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2/15/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2/21/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2/27/2017	0	0	0	0	0	5	0	0	0	0	0	0	2	0	0	0	0	0	0	0
3/5/2017	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	3	0
3/11/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3/19/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
3/25/2017	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
3/29/2017	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
4/7/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4/25/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
4/28/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/2/2017	0	0	0	0	0	3	0	0	0	0	0	0	2	0	0	0	0	0	0	0
5/8/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/11/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/13/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/15/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/18/2017	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	2	0
5/22/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/27/2017	0	0	0	0	0	4	2	0	0	0	0	0	2	0	0	0	0	0	0	0
6/1/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/7/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/12/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/16/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
6/20/2017	0	0	0	0	0	5	0	0	0	0	0	2	0	0	0	0	0	0	4	0
6/24/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/27/2017	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
7/1/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/8/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/11/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/20/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/24/2017	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	3	0
7/28/2017	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
8/4/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/8/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/13/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/17/2017	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/22/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/26/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/31/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/7/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/10/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/16/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/22/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
10/2/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10/10/2017	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0
10/16/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10/27/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10/31/2017	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0

Appendix 6. Varroa mites on Brood at site 2.

Date	Hive number and number of Varroa mites																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2/15/2017	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	5	0
2/21/2017	0	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0
2/27/2017	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3/5/2017	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	6	0
3/11/2017	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0
3/19/2017	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	5	0
3/25/2017	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
3/29/2017	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4/7/2017	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	4	0
4/25/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4/28/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/2/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/8/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/11/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/13/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/15/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/18/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
5/22/2017	0	0	0	0	0	0	0	0	0	0	3	0	2	0	0	0	0	0	0	0
5/27/2017	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/1/2017	0	0	0	0	0	0	3	0	0	0	0	2	0	0	0	0	0	0	0	0
6/7/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/12/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
6/16/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/20/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/24/2017	0	0	0	0	0	4	0	0	0	0	0	0	2	0	0	0	0	0	0	0
6/27/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/1/2017	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	2	0
7/8/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/11/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/20/2017	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	3	0
7/24/2017	0	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0
7/28/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/4/2017	0	0	0	0	0	4	0	0	0	0	0	2	0	0	0	0	0	0	0	0
8/8/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/13/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/17/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
8/22/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/26/2017	0	0	0	0	0	3	0	0	0	0	0	0	2	0	0	0	0	0	0	0
8/31/2017	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
9/7/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/10/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/16/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/22/2017	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	1	0
10/2/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10/10/2017	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0
10/16/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10/27/2017	0	0	0	0	0	2	0	0	0	0	0	0	2	0	0	0	0	0	1	0
10/31/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 7. Varroa mites on Adult at site 2.

Date	Hive number and number of Varroa mites																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2/15/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2/21/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
2/27/2017	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3/5/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3/11/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3/19/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3/25/2017	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3/29/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
4/7/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4/25/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4/28/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/2/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/8/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/11/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/13/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/15/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/18/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/22/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/27/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/1/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/7/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/12/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/16/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/20/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/24/2017	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
6/27/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/1/2017	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/8/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/11/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/20/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/24/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
7/28/2017	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
8/4/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/8/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/13/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/17/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/22/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/26/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/31/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/7/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/10/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/16/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/22/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10/2/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10/10/2017	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0
10/16/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10/27/2017	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
10/31/2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 8. Inner Hive Humidity of site 1.

Date	Inner Hive Humidity																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2/15/2017	51	51	50	52	51	51	50	52	52	51	50	49	49	51	52	50	51	52	50	50
2/21/2017	59	56	56	56	54	55	51	50	50	51	51	50	49	51	53	52	53	52	50	51
2/27/2017	59	59	55	57	56	61	60	53	52	54	52	52	50	49	51	51	50	49	49	51
3/5/2017	49	51	52	54	55	53	52	51	52	51	51	53	53	53	51	52	52	53	53	52
3/11/2017	51	49	49	49	50	51	51	52	52	53	54	50	50	51	51	52	52	53	52	52
3/19/2017	51	50	52	52	52	50	52	46	45	52	46	51	52	48	48	46	46	48	48	52
3/25/2017	54	54	56	56	58	58	58	59	58	58	58	56	57	58	58	59	59	58	58	58
3/29/2017	54	52	51	57	57	57	54	54	56	59	58	58	57	55	57	56	56	58	58	57
4/7/2017	59	58	59	58	60	58	57	57	57	54	53	53	55	54	54	55	53	54	54	54
4/25/2017	50	49	49	47	48	46	46	47	47	47	46	45	44	44	45	43	43	44	45	45
4/28/2017	44	45	44	45	44	44	44	43	45	45	43	42	42	43	42	44	43	43	43	42
5/2/2017	45	48	48	48	47	48	46	46	46	46	45	47	45	45	45	44	45	44	43	45
5/8/2017	49	46	48	46	45	45	45	45	46	47	44	45	45	45	46	46	44	45	43	44
5/11/2017	46	52	50	49	49	49	49	48	47	48	48	45	44	44	44	45	45	46	44	44
5/13/2017	44	45	45	45	45	43	42	42	45	42	44	45	46	45	45	43	43	44	43	45
5/15/2017	52	53	52	52	56	55	51	53	52	52	53	51	53	53	56	55	54	53	52	52
5/18/2017	50	49	49	52	52	52	51	50	51	52	50	54	55	54	55	56	53	54	55	56
5/22/2017	51	50	50	52	53	53	53	55	54	54	54	54	53	53	53	52	51	50	52	52
5/27/2017	52	49	51	50	51	52	53	53	53	50	50	51	52	53	53	52	52	49	49	50
6/1/2017	50	49	49	52	53	53	52	53	53	53	55	52	52	52	52	51	54	56	53	53
6/7/2017	48	49	47	46	45	43	41	42	43	44	45	43	42	46	49	48	48	50	51	50
6/12/2017	50	49	48	48	50	52	51	52	51	51	52	52	53	51	52	54	53	53	50	51
6/16/2017	56	52	53	51	51	51	50	52	50	51	54	49	50	51	50	50	50	52	51	52
6/20/2017	51	50	51	52	52	52	54	53	52	52	49	49	50	48	50	46	50	50	50	51
6/24/2017	51	54	53	52	57	56	56	53	49	50	51	50	50	51	52	53	52	52	52	52
6/27/2017	50	52	52	50	50	50	49	51	52	53	51	50	50	50	51	49	50	51	49	50
7/1/2017	53	53	55	54	51	52	52	52	51	51	51	52	49	50	51	52	52	52	51	51
7/8/2017	49	50	50	50	48	48	45	45	47	46	45	45	48	49	46	48	44	48	49	49
7/11/2017	49	51	50	50	51	50	50	51	49	50	50	52	51	52	53	54	49	50	50	50
7/20/2017	54	56	57	57	59	58	58	58	58	59	59	59	58	55	55	54	55	56	56	55
7/24/2017	55	51	50	49	51	50	50	48	50	45	44	47	46	48	50	52	53	52	51	52
7/28/2017	52	51	50	49	50	51	51	51	50	49	49	50	50	50	50	53	51	51	52	52
8/4/2017	52	50	51	51	52	55	57	52	52	54	54	53	53	52	50	51	52	52	52	50
8/8/2017	53	50	48	49	50	51	60	54	57	57	57	54	55	53	52	52	51	53	53	55
8/13/2017	53	51	54	53	51	50	49	49	52	52	51	49	49	52	52	51	53	53	53	52
8/17/2017	52	52	52	50	50	50	47	49	49	49	50	52	52	53	53	55	57	56	56	56
8/22/2017	50	49	50	52	53	53	52	52	53	49	50	50	51	48	49	50	51	48	46	48
8/26/2017	50	50	50	50	52	51	50	55	53	53	54	55	49	49	49	50	50	49	51	52
8/31/2017	51	53	53	52	46	48	49	50	51	45	48	50	52	44	44	48	49	48	49	50
9/7/2017	52	50	50	51	51	50	50	51	53	50	51	52	52	47	46	49	50	48	49	50
9/10/2017	52	51	51	50	50	53	52	50	50	48	47	47	48	48	50	49	49	48	49	45
9/16/2017	48	46	47	48	47	47	47	48	48	49	49	50	51	51	50	50	52	51	51	50
9/22/2017	53	52	50	49	48	50	50	50	50	48	47	49	48	48	48	46	45	46	45	45
10/2/2017	50	49	52	51	53	52	48	48	48	48	50	52	45	46	45	45	45	46	46	46
10/10/2017	48	50	50	50	48	48	48	49	49	51	51	52	48	48	48	47	47	49	49	49
10/16/2017	49	46	46	48	48	48	48	50	49	52	51	50	52	50	50	50	49	49	49	50
10/27/2017	45	48	46	48	48	48	45	46	46	45	45	46	45	45	47	47	47	45	45	45
10/31/2017	48	50	51	52	53	50	50	52	53	50	50	51	52	52	50	50	49	49	49	50

Appendix 9. Outer Humidity of site 1.

Date	Outer Humidity																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2/15/2017	51	51	50	52	51	51	50	52	52	51	50	49	49	51	52	50	51	52	50	50
2/21/2017	59	56	56	56	54	55	51	50	50	51	51	50	49	51	53	52	53	52	50	51
2/27/2017	59	59	55	57	56	61	60	53	52	54	52	52	50	49	51	51	50	49	49	51
3/5/2017	49	51	52	54	55	53	52	51	52	51	51	53	53	53	51	52	52	53	53	52
3/11/2017	51	49	49	49	50	51	51	52	52	53	54	50	50	51	51	52	52	53	52	52
3/19/2017	51	50	52	52	52	50	52	46	45	52	46	51	52	48	48	46	46	48	48	52
3/25/2017	54	54	56	56	58	58	58	59	58	58	58	56	57	58	58	59	59	58	58	58
3/29/2017	54	52	51	57	57	57	54	54	56	59	58	58	57	55	57	56	56	58	58	57
4/7/2017	59	58	59	58	60	58	57	57	57	54	53	53	55	54	54	55	53	54	54	54
4/25/2017	50	49	49	47	48	46	46	47	47	47	46	45	44	44	45	43	43	44	45	45
4/28/2017	44	45	44	45	44	44	44	43	45	45	43	42	42	43	42	44	43	43	43	42
5/2/2017	45	48	48	48	47	48	46	46	46	46	45	47	45	45	45	44	45	44	43	45
5/8/2017	49	46	48	46	45	45	45	45	46	47	44	45	45	45	46	46	44	45	43	44
5/11/2017	46	52	50	49	49	49	49	48	47	48	48	45	44	44	44	45	45	46	44	44
5/13/2017	44	45	45	45	45	43	42	42	45	42	44	45	46	45	45	43	43	44	43	45
5/15/2017	52	53	52	52	56	55	51	53	52	52	53	51	53	53	56	55	54	53	52	52
5/18/2017	50	49	49	52	52	52	51	50	51	52	50	54	55	54	55	56	53	54	55	56
5/22/2017	51	50	50	52	53	53	53	55	54	54	54	54	53	53	53	52	51	50	52	52
5/27/2017	52	49	51	50	51	52	53	53	53	50	50	51	52	53	53	52	52	49	49	50
6/1/2017	50	49	49	52	53	53	52	53	53	53	55	52	52	52	52	51	54	56	53	53
6/7/2017	48	49	47	46	45	43	41	42	43	44	45	43	42	46	49	48	48	50	51	50
6/12/2017	50	49	48	48	50	52	51	52	51	51	52	52	53	51	52	54	53	53	50	51
6/16/2017	56	52	53	51	51	51	50	52	50	51	54	49	50	51	50	50	50	52	51	52
6/20/2017	51	50	51	52	52	52	54	53	52	52	49	49	50	48	50	46	50	50	50	51
6/24/2017	51	54	53	52	57	56	56	53	49	50	51	50	50	51	52	53	52	52	52	52
6/27/2017	50	52	52	50	50	50	49	51	52	53	51	50	50	50	51	49	50	51	49	50
7/1/2017	53	53	55	54	51	52	52	52	51	51	51	52	49	50	51	52	52	52	51	51
7/8/2017	49	50	50	50	48	48	45	45	47	46	45	45	48	49	46	48	44	48	49	49
7/11/2017	49	51	50	50	51	50	50	51	49	50	50	52	51	52	53	54	49	50	50	50
7/20/2017	54	56	57	57	59	58	58	58	58	59	59	59	58	55	55	54	55	56	56	55
7/24/2017	55	51	50	49	51	50	50	48	50	45	44	47	46	48	50	52	53	52	51	52
7/28/2017	52	51	50	49	50	51	51	51	50	49	49	50	50	50	50	53	51	51	52	52
8/4/2017	52	50	51	51	52	55	57	52	52	54	54	53	53	52	50	51	52	52	52	50
8/8/2017	53	50	48	49	50	51	60	54	57	57	57	54	55	53	52	52	51	53	53	55
8/13/2017	53	51	54	53	51	50	49	49	52	52	51	49	49	52	52	51	53	53	53	52
8/17/2017	52	52	52	50	50	50	47	49	49	49	50	52	52	53	53	55	57	56	56	56
8/22/2017	50	49	50	52	53	53	52	52	53	49	50	50	51	48	49	50	51	48	46	48
8/26/2017	50	50	50	50	52	51	50	55	53	53	54	55	49	49	49	50	50	49	51	52
8/31/2017	51	53	53	52	46	48	49	50	51	45	48	50	52	44	44	48	49	48	49	50
9/7/2017	52	50	50	51	51	50	50	51	53	50	51	52	52	47	46	49	50	48	49	50
9/10/2017	52	51	51	50	50	53	52	50	50	48	47	47	48	48	50	49	49	48	49	45
9/16/2017	48	46	47	48	47	47	47	48	48	49	49	50	51	51	50	50	52	51	51	50
9/22/2017	53	52	50	49	48	50	50	50	50	48	47	49	48	48	48	46	45	46	45	45
10/2/2017	50	49	52	51	53	52	48	48	48	48	50	52	45	46	45	45	45	46	46	46
10/10/2017	48	50	50	50	48	48	48	49	49	51	51	52	48	48	48	47	47	49	49	49
10/16/2017	49	46	46	48	48	48	48	50	49	52	51	50	52	50	50	50	49	49	49	50
10/27/2017	45	48	46	48	48	48	45	46	46	45	45	46	45	45	47	47	47	45	45	45
10/31/2017	48	50	51	52	53	50	50	52	53	50	50	51	52	52	50	50	49	49	49	50

Appendix 10. Inner Hive Humidity of site 2.

Date	Inner Hive Humidity																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2/15/2017	50	51	50	51	50	50	52	50	50	50	49	50	52	48	50	48	50	50	48	49
2/21/2017	58	54	56	55	55	56	52	50	52	50	50	52	50	50	51	50	50	51	51	50
2/27/2017	57	57	58	58	58	59	60	59	59	59	50	50	48	47	48	49	49	47	48	49
3/5/2017	47	50	50	49	50	50	50	52	50	49	48	51	52	50	52	53	53	50	52	51
3/11/2017	50	48	48	50	51	50	52	51	50	50	49	52	51	50	50	52	50	49	50	53
3/19/2017	50	48	51	50	50	49	48	48	49	49	48	50	49	50	49	49	47	47	46	50
3/25/2017	53	52	54	55	57	58	58	56	57	56	58	54	59	55	54	60	59	57	59	58
3/29/2017	51	50	53	53	52	52	52	55	57	54	54	52	54	54	56	54	58	54	55	55
4/7/2017	58	56	56	54	58	56	57	56	55	55	51	50	52	52	53	50	54	55	53	52
4/25/2017	49	48	50	48	49	50	51	52	49	50	47	48	48	46	45	45	46	42	47	43
4/28/2017	48	47	45	44	42	45	43	43	44	44	44	43	43	45	43	44	45	42	43	42
5/2/2017	46	44	45	45	48	49	45	44	49	45	47	48	48	46	44	47	47	45	44	48
5/8/2017	50	44	47	45	45	44	44	46	47	46	45	48	47	47	45	45	49	44	45	46
5/11/2017	47	49	50	49	48	48	49	47	49	45	44	48	45	43	43	42	43	45	44	43
5/13/2017	45	43	42	45	46	44	45	46	43	45	45	46	47	44	45	44	42	43	42	44
5/15/2017	50	51	50	49	54	53	50	50	51	50	52	50	54	51	52	52	52	54	53	54
5/18/2017	49	50	52	53	50	51	51	50	52	53	50	53	54	52	53	52	53	55	53	56
5/22/2017	52	49	49	51	54	52	52	53	55	56	53	56	57	57	54	55	55	52	51	48
5/27/2017	50	47	49	48	47	50	51	50	51	49	49	50	51	52	50	50	50	47	49	48
6/1/2017	52	48	50	51	49	54	50	49	48	48	51	53	54	53	53	53	52	53	52	54
6/7/2017	49	48	48	47	48	44	46	43	44	45	47	43	44	42	44	42	44	47	45	47
6/12/2017	51	48	47	48	48	48	47	50	48	49	50	50	51	50	49	49	50	51	51	50
6/16/2017	53	50	52	52	52	53	49	50	49	49	51	48	49	50	49	49	49	50	50	51
6/20/2017	50	52	51	50	51	52	52	48	48	49	47	48	48	49	49	47	48	48	49	50
6/24/2017	51	50	52	52	55	54	56	57	50	49	50	48	48	49	50	49	50	49	48	49
6/27/2017	52	50	49	48	48	50	49	40	51	54	49	48	48	52	50	47	46	48	52	48
7/1/2017	50	53	52	53	52	50	52	53	52	52	53	54	48	48	49	50	51	49	50	49
7/8/2017	53	49	48	48	47	48	44	48	45	47	44	44	46	47	47	49	42	43	44	45
7/11/2017	48	50	48	48	48	47	52	50	50	49	49	51	50	50	50	52	48	52	49	49
7/20/2017	55	52	56	56	56	54	57	56	56	56	57	54	54	52	52	54	51	52	52	51
7/24/2017	52	51	50	48	48	48	51	49	51	44	47	48	47	47	49	48	51	50	50	51
7/28/2017	50	50	51	51	48	48	49	49	49	51	50	51	51	52	48	48	47	50	49	49
8/4/2017	49	49	50	52	50	51	54	53	54	53	56	54	52	53	51	49	50	50	51	49
8/8/2017	52	49	48	48	49	49	57	52	58	56	56	55	53	54	57	53	52	50	49	50
8/13/2017	52	50	49	51	50	49	48	50	51	50	52	48	47	51	50	49	51	50	54	51
8/17/2017	53	50	51	49	48	48	49	50	48	50	49	49	50	51	50	51	52	52	53	55
8/22/2017	51	51	51	50	50	50	49	51	54	51	52	49	48	49	50	52	52	49	50	49
8/26/2017	49	51	52	49	51	50	49	51	54	52	51	54	50	50	48	48	52	51	52	53
8/31/2017	52	50	49	51	47	49	49	51	48	44	49	51	53	48	42	44	45	47	48	51
9/7/2017	50	50	49	48	52	49	51	51	54	49	50	51	48	49	47	48	46	50	50	49
9/10/2017	53	50	52	48	48	48	51	49	49	47	46	46	49	48	49	50	49	46	48	49
9/16/2017	50	47	45	45	46	47	48	45	47	50	48	49	49	48	49	48	48	49	50	49
9/22/2017	53	50	49	49	47	49	49	51	50	49	48	50	51	49	47	48	49	49	43	47
10/2/2017	51	49	51	51	52	50	49	48	47	47	49	51	46	47	48	42	43	44	44	43
10/10/2017	49	50	51	49	47	46	48	48	48	48	50	48	47	46	48	47	49	46	47	48
10/16/2017	50	49	44	46	45	48	47	51	48	49	51	49	49	51	49	49	48	51	50	49
10/27/2017	54	49	47	47	48	50	44	42	43	44	44	47	44	47	44	43	44	43	42	48
10/31/2017	51	49	48	51	52	50	49	49	51	53	53	48	49	49	51	52	54	47	50	48

Appendix 11. Outer Humidity of site 2.

Date	Outer Humidity																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2/15/2017	54	53	48	51	53	52	50	65	60	51	54	53	55	54	53	52	53	51	50	50
2/21/2017	59	58	54	59	55	56	50	50	50	48	49	50	50	53	54	54	54	54	53	53
2/27/2017	60	60	60	56	56	60	62	53	52	53	55	57	51	50	53	55	56	50	50	52
3/5/2017	50	52	53	55	56	56	56	50	52	53	52	52	55	56	54	54	57	50	51	52
3/11/2017	52	50	51	53	52	53	50	52	51	53	53	50	54	54	53	50	54	55	50	52
3/19/2017	52	52	52	56	53	52	52	46	45	47	46	50	48	48	49	49	50	49	49	48
3/25/2017	57	59	59	59	60	60	62	58	58	58	59	59	56	56	58	59	60	60	59	60
3/29/2017	60	55	57	56	56	59	58	60	60	58	58	60	59	60	59	59	59	55	63	57
4/7/2017	59	60	57	59	56	59	61	58	58	58	55	59	60	57	57	59	59	58	57	58
4/25/2017	51	59	52	50	50	51	50	59	50	53	52	53	50	48	48	48	49	49	50	50
4/28/2017	47	48	50	48	48	49	49	47	47	49	49	49	50	48	50	50	47	47	50	50
5/2/2017	49	49	49	49	47	44	45	47	48	47	47	48	49	48	48	45	45	46	44	47
5/8/2017	50	50	48	49	50	50	52	52	53	55	49	48	46	48	47	49	50	51	52	50
5/11/2017	48	50	50	51	51	51	50	50	52	46	48	46	45	45	48	48	49	48	45	45
5/13/2017	49	46	45	45	50	46	47	48	49	46	45	48	49	45	47	48	44	45	45	46
5/15/2017	45	48	46	43	44	43	43	47	46	45	44	43	42	47	44	45	44	42	45	42
5/18/2017	48	44	46	46	46	48	45	45	46	42	42	44	43	43	44	45	44	42	43	44
5/22/2017	46	45	45	45	45	47	42	45	43	44	42	45	43	44	44	45	47	47	45	45
5/27/2017	46	46	46	43	45	45	44	42	43	45	46	47	47	45	43	46	45	46	45	45
6/1/2017	48	49	46	45	44	44	42	45	45	43	45	46	47	47	43	44	44	45	45	44
6/7/2017	49	50	50	50	45	46	45	42	43	43	46	45	45	43	43	46	46	45	45	44
6/12/2017	55	52	54	55	55	54	53	52	53	54	56	54	53	54	52	53	53	52	55	54
6/16/2017	58	55	57	52	52	52	50	50	51	50	52	52	50	50	50	52	52	51	52	52
6/20/2017	50	51	50	53	53	52	50	50	50	48	49	48	47	48	45	46	46	46	47	48
6/24/2017	53	55	56	53	54	56	58	51	52	53	56	57	52	50	51	50	52	51	52	53
6/27/2017	50	53	52	50	50	50	49	52	52	53	50	50	51	49	49	49	47	48	48	48
7/1/2017	54	50	51	50	49	48	50	52	50	50	50	51	53	54	52	52	52	50	50	51
7/8/2017	50	48	48	50	49	49	46	46	45	47	48	48	46	46	46	45	48	48	49	49
7/11/2017	50	51	50	50	49	50	48	48	49	50	52	51	53	48	47	47	47	45	46	46
7/20/2017	53	57	57	58	58	55	56	56	50	55	51	53	55	55	52	52	54	50	52	54
7/24/2017	53	53	50	50	53	49	49	50	50	49	49	49	45	46	46	47	49	51	50	50
7/28/2017	47	50	49	50	50	50	50	48	46	47	48	48	46	46	48	50	47	49	49	50
8/4/2017	51	51	50	50	50	51	51	50	51	51	52	50	50	51	52	53	53	50	50	49
8/8/2017	52	54	50	50	50	47	48	48	48	45	43	46	46	48	46	46	47	43	42	41
8/13/2017	52	57	54	53	50	49	50	50	49	48	48	49	49	49	48	48	42	45	45	46
8/17/2017	48	45	49	50	45	45	44	42	48	46	47	47	42	48	43	41	42	45	47	45
8/22/2017	49	50	49	49	50	49	49	51	51	53	44	46	47	47	44	43	43	46	47	46
8/26/2017	47	47	45	46	48	48	48	43	44	46	44	43	44	46	47	48	45	45	47	43
8/31/2017	50	49	49	49	45	46	49	46	50	49	49	47	46	45	47	47	42	43	43	47
9/7/2017	55	57	57	54	53	50	50	50	52	45	48	47	47	47	46	45	49	49	50	49
9/10/2017	50	49	49	50	50	49	49	49	50	50	49	47	48	48	46	47	47	46	48	46
9/16/2017	52	46	49	49	46	46	50	46	47	50	52	44	45	46	42	43	42	43	43	47
9/22/2017	57	54	53	53	53	50	50	50	50	49	49	50	48	48	47	49	49	48	49	45
10/2/2017	52	49	49	48	48	48	49	47	47	48	42	44	45	45	43	43	43	42	42	46
10/10/2017	50	50	50	47	48	48	47	48	48	48	48	46	45	45	46	46	45	46	45	46
10/16/2017	49	48	48	48	45	42	43	43	42	42	44	45	46	42	42	43	45	44	45	47
10/27/2017	49	49	47	47	46	46	46	47	46	46	46	47	44	45	46	46	45	45	45	45
10/31/2017	47	50	49	49	48	49	48	43	44	42	44	43	43	42	44	44	42	42	45	43

Appendix 12. Inner Hive Temperature of site 1.

Date	Inner Hive Temperature																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2/15/2017	32.3	32	32	32.2	32.3	33	33	33.2	33.2	33.1	33.1	33.1	33.2	33.2	33.1	33.4	33.2	33.5	33.1	33.1
2/21/2017	32.2	32.4	32.4	32.3	32.2	32.4	32.4	32.4	32.4	32.5	32.5	32.5	32.6	32.6	32.7	32.4	32.5	32.5	32.5	32.5
2/27/2017	31.8	31.7	31.8	31.7	31.8	31.7	31.6	31.7	31.8	31.8	31.8	32	32	32	32	32	31.9	31.9	31.8	31.8
3/5/2017	32	32	32.1	32.1	32.1	32.3	32.2	32.2	32.2	32.2	32	32.3	32.4	32.2	32.1	32.1	32.3	32.1	32.3	32.4
3/11/2017	31.2	31.8	31.9	31.5	31.8	31.7	31.9	31.9	31.9	31.9	31.8	31.8	31.8	31.8	31.9	31.9	31.9	31.8	31.8	32
3/19/2017	32.1	32.2	32.4	32.4	32.2	32.2	32.5	32.6	32.5	32.6	32.6	32.6	32.6	32.7	32.8	32.7	32.9	32.8	32.7	32.8
3/25/2017	33	33.2	33.5	33.4	33.2	33	32	32	32.4	32.4	32.3	32.2	32.2	33.2	33.4	33.4	32.9	32.1	32.4	32.4
3/29/2017	32.4	32.3	32.2	32.1	33	33	33	33.2	33.2	33.4	33.4	33.2	33.3	33.4	33.5	33.4	33.5	33.7	33	33.2
4/7/2017	32.8	32.7	32.7	32.6	32.6	32.6	33	32.9	32.9	32.8	32.8	32.8	32.9	32.9	33	33	33	33	32.9	32.8
4/25/2017	33.1	33	33.2	33.1	32.9	32.8	32.9	32.8	32.8	32.8	32.8	32.9	32.9	32.8	32.8	32.8	32.9	32.9	32.9	32.9
4/28/2017	34	32.4	32.7	32.6	32.6	32.6	32.6	32.6	32.7	32.8	32.8	32.7	32.7	32.7	32.8	32.8	32.9	32.9	33	33
5/2/2017	32.9	32.9	32.8	32.8	32.8	32.8	33	33	33	31.1	31.1	31.1	32	32	32	32.8	32.8	32.9	32.9	32.9
5/8/2017	33	32.9	32.9	32.9	32.9	33	33	32.9	32.9	32.9	33	33.1	33.2	33.4	33.2	33.2	33.4	33.7	33.8	33.9
5/11/2017	32.1	32.4	32.5	32.5	32.5	32.5	32.6	32.6	32.5	32.5	32.6	32.7	32.7	33	32.9	32.8	32.9	32.9	32.9	33
5/13/2017	32.8	32.8	32.8	33.6	33	32.8	32.4	32.8	32.7	32.6	32.7	32.8	32.9	32.7	32.8	32.9	32.9	32.9	32.9	32.8
5/15/2017	32.8	32.8	33.2	33	32	34	33.9	33.8	33.6	33.6	33.9	33.1	32.9	32.4	32.8	32.7	32.9	32.8	32.9	32.9
5/18/2017	31.9	31.9	32	32	32	32	33	33.2	33.8	32.1	32.6	32.4	32.7	32.8	32.7	32.6	32.9	32.4	32.6	32.5
5/22/2017	31.9	32.4	32.4	32.9	32.5	32.2	32.3	33	32.9	32.8	32.4	32.7	32.5	32.6	32.9	33	33.4	33.3	33.2	33.5
5/27/2017	32.1	32.1	33	32.2	33.4	32.9	33.2	33.8	32.1	32.3	32.1	32.1	32.2	33.2	33.4	33	32.8	32.9	32.8	32.1
6/1/2017	33.4	32.8	33.9	32.4	33	32.1	32.4	31.2	31	31	31	32.2	32	32	30.9	31	32.8	32.9	32.9	33
6/7/2017	32.6	32.3	33	33	32	32	32.8	32.5	32.5	32.6	33	32.6	33	32.9	32.1	32	31	31.9	31.9	32.7
6/12/2017	32	32	31	32.4	32.5	32.7	32.8	33	33.9	33.2	33.2	33.5	33.1	32.2	31.8	31.6	32.2	32.7	32.6	33
6/16/2017	31.9	32	32.4	32.8	32.9	32.7	32.9	32.4	32.7	32.9	33	33.1	31.8	32.3	32.8	33	32.8	32.1	32.2	32
6/20/2017	32	32.1	32.4	33	32.8	32.8	33	33	33.1	33.2	33.2	33.4	31.1	31.2	30.9	31.2	32.8	32.8	32.8	33

Cont……

Date	Inner Hive Temperature																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6/24/2017	32.9	32	31.9	32	32.8	32.7	33.1	31.7	31.9	31.8	31.8	31.9	32	32.1	32	32	33	32.1	33	32.8
6/27/2017	31	31	32	32.1	32.2	32.3	32.3	32	32	33	33	33	33	32.8	32.7	32.7	32.9	32.8	32.8	33
7/1/2017	33	32.8	32.9	32.6	32.9	32.6	32	32.1	32.4	32.8	32.8	32.9	32.8	32.7	32.9	32.8	32.2	32.2	32.7	32
7/8/2017	31.6	31.2	32	32	31.8	31.7	31.2	31.7	32	32.1	32	32.1	32	32	33.1	33.8	32.5	32.7	31.4	30
7/11/2017	30	31.7	31.6	31.6	31.8	31.8	31.6	31.5	31.7	31.5	31.6	32	31.9	32.1	32	31.5	31.3	32	31.6	31.1
7/20/2017	30.8	31	30.9	30.6	30.8	31.4	31.2	31.9	31.7	32	31.1	31.5	30.1	31	32	32.8	32	32.2	31.9	32
7/24/2017	32	31.9	32	31	31.9	31.2	31.1	32.6	32.1	32	32	31.9	31.8	31.6	32	31.9	31.9	32.2	32	31.9
7/28/2017	31.8	32.2	33	32.8	32.4	32.8	33.1	32.1	32.8	32.5	32	32.2	32.2	33	32.7	32.6	32.6	31	31.2	32
8/4/2017	32.6	32	31	31	31.9	31.8	31.8	32.2	32.3	32.9	32	32.8	32.8	32.4	32.8	32.9	32.8	32	33	32.8
8/8/2017	31.7	32.1	32.6	32.8	32.6	32.7	33	32.4	32.1	32.7	32.8	32.4	31	32	32.4	32	32	33	32.8	32
8/13/2017	32.2	32.5	33	32.5	31	31.8	31.7	31.9	31.9	31.7	31.8	32	32.1	32.1	32.7	32	32.1	32.2	32.4	32
8/17/2017	31	30.9	31	31.1	31	31	32.8	32.4	32.5	32.9	32.8	32.7	32.9	32	31.9	32	32	33.2	33	31.9
8/22/2017	32	32.2	32.8	32.8	33	33.1	33.2	33.8	32.8	32.9	33	31.9	32.2	31.4	32	32.4	32.5	32.2	32	32.8
8/26/2017	31.8	32	32.5	32.3	32.2	32.6	32.1	32.4	32.1	32.1	32.5	32.4	32.4	31	32.1	32.8	32.9	32.8	32.4	32
8/31/2017	32	30.9	31	32	32.9	31.9	32.8	32.8	32	32	31.9	31.6	31.3	31.9	31.9	32	32	32.4	32.5	33
9/7/2017	31.2	30	30.5	30.8	32.1	32.8	32.1	32.6	32.4	33	32.1	32	33	32.8	32.7	32.4	32.6	32.7	32.8	31.8
9/10/2017	32	31.8	31.9	32	32.1	32.9	33	32.4	32.4	32.1	32.7	32.3	32.4	32.7	32.9	31.9	32	31.9	32.8	33
9/16/2017	31.8	32.1	30.8	31.8	32.2	32	32.5	32.5	32.1	32.8	31.9	32.4	33.9	31.8	30.9	31	31.7	32	32.8	32.9
9/22/2017	32	31.6	31.6	31	31	32	31.2	31.4	31.2	32	33	32.5	32.4	32.9	32.9	32.9	32.7	31.9	31.2	30.9
10/2/2017	31.7	30	32	32.4	32.8	32.9	32.1	33.2	33.1	32.8	31.9	31.8	31.5	31.7	31.8	32	32.1	32.8	32.9	32.8
10/10/2017	32	32.2	32.1	31.9	31.8	31.9	32.1	32.8	32.3	31.9	31.6	31.7	31.8	30.8	30.9	31.1	31.9	31.8	32	31
10/16/2017	30.1	32	32.8	32.1	32.6	32.2	32.9	32.4	32.1	32.1	32.9	32.7	32.8	32.7	32.8	31.1	31.9	30.9	32	32.8
10/27/2017	32.8	31.1	32	33	32.8	32.1	32.2	32.9	32.8	32.8	32.8	31.6	31.5	32	32.4	32	32.4	32	33	33.1
10/31/2017	33	32.1	32.7	32.4	32.8	32.9	32.9	31.9	31.8	31	31.2	31.7	32	31.2	31.4	31.2	31.8	31.7	32	31.9

Appendix 13. Outer Temperature of site 1.

Date	Outer Temperature																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2/15/2017	24.8	24.9	24.2	24	24.2	25.2	25.4	25.4	25.4	25.5	25.4	25.4	25.3	24.8	24.6	24.8	24.8	24.7	25	25.2
2/21/2017	26.1	26	26.2	26.3	25.9	25.8	25.8	25.8	25.9	26	26.2	26.2	26.3	26.3	25.9	25.8	25.7	25.7	25.4	25.2
2/27/2017	25.3	25.2	25.2	25	25.5	25.2	25.6	25.5	25.7	25.5	25.6	25.4	25.3	26	26.2	25.9	25.8	25.4	25.9	25.5
3/5/2017	25.5	26.9	27.1	27.2	27.2	27	27.1	28	28.2	28.1	28.9	28.4	28.2	28.1	28.4	28.3	28.4	28.2	28.3	28
3/11/2017	27.9	27.1	27.4	27.3	27.6	27.9	28	27.9	27.4	27.2	28.1	28.2	28.4	28	28.2	28.1	28.4	28.1	28	27.9
3/19/2017	29.2	28.9	29.1	29	29.4	29.2	29.1	29.2	29.1	29	29.5	29.1	29.4	29.8	29.1	29.2	29	29.1	29.5	29.9
3/25/2017	28.4	28.2	28.6	28.4	28.1	28.1	28.4	28.9	28.5	28.6	29	29	28.8	28.7	27.9	28.1	28.1	28	28.6	28.4
3/29/2017	28.9	28.1	28.1	28.5	28.2	28.3	28.2	28.1	28.1	28.5	28.8	28.8	28.7	28.9	28.7	28.9	28.1	28.6	28.9	29
4/7/2017	24.1	25.2	25	24.9	24.4	24.9	24.7	24.8	24.8	24.9	24.8	24.8	24.8	24.8	24.1	24.5	24.6	24.5	24.6	24.9
4/25/2017	30	30.2	30.2	30.3	30.1	30.2	30.2	30.2	30.4	30.3	30.3	30.5	30.1	30.2	30.2	30.1	30.1	30.3	30.4	30.2
4/28/2017	29.9	29.8	29.8	29.9	29.9	29.8	29.9	29.7	29.7	29.8	29.8	29.9	29.9	29.8	30	30	29.6	29.2	29.2	29.5
5/2/2017	30	30.6	30.7	30.5	30.5	30.1	30.2	30.2	30.1	30.2	30.5	30.4	30.2	30.1	30.2	30.3	30	30.5	30.3	30.3
5/8/2017	29.9	29.9	29.7	29.9	30	30.1	30.2	30.2	30.1	30.4	30.2	30.3	30.4	30.1	30	30.2	30.4	30.5	30.6	30.1
5/11/2017	29.9	30	29.8	29.9	29.7	29.8	29.9	29.8	29.9	29.9	30	30.2	30.3	30.4	30.2	30.1	30.2	30.2	30.2	30
5/13/2017	29.1	29.7	29.7	29.9	29.9	30	30.1	30.7	30.7	30.9	30.8	30.4	30.5	30.6	30.7	30.8	30.7	30.9	30.4	30.1
5/15/2017	28.3	28.6	28.6	28.7	28.6	28.7	28.7	28.7	28.8	28.7	28.7	28.9	28.9	28.9	28.6	28.6	28.7	28.7	28.5	28.6
5/18/2017	31.5	31.7	31.9	32	31.9	31.8	31.8	31.9	31.9	31.8	31.8	31.8	31.9	32	32	31.9	31.9	31.9	31.8	31.8
5/22/2017	32	31.9	31.9	32	32	32	32.1	32.1	32	31.9	31.9	31.9	31.9	31.9	32	32.1	31.8	31.9	31.9	31.9
5/27/2017	31.8	31.7	31.9	31.8	31.8	31.8	31.9	31.9	31.9	31.9	31.8	31.8	32	32.1	32.1	31.8	31.8	31.2	31.2	31.6
6/1/2017	30.1	30.4	30.5	30.5	30.6	30.8	30.8	30.8	30.8	30.8	31	30.9	30.9	30.9	31	31	31	31	31.1	31.1
6/7/2017	31.2	31.7	31.8	31.9	31.7	31.7	31.8	31.9	31.8	31.8	31.8	31.9	31.9	32	32	31.8	31.8	31.8	31.8	31.8
6/12/2017	26.1	26.7	26.6	26.7	26.8	26.7	26.8	26.8	27	27.1	27.1	27.1	27.4	27.1	27.1	27.2	27.2	27.4	27.5	27.6
6/16/2017	26.9	26.9	26.8	26.8	26.8	26.8	26.9	26.7	26.7	26.7	26.8	26.8	26.9	26.9	26.9	26.8	26.8	26.8	26.9	26.8
6/20/2017	27	27	27.1	27.2	27.3	27.4	27.3	27.3	27.2	27.2	27.2	27.3	27.5	27.5	27.5	27.6	27.6	27.6	27.8	27.8

Cont…….

Date	Outer Temperature																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6/24/2017	26.9	26.8	26.8	26.8	27	26.9	26.9	26.9	27	27	26.9	26.9	26.9	26.8	26.6	26.9	26.9	26.8	26.7	26.8
6/27/2017	25.9	25.9	25.7	26	26.5	26.8	26.8	26.7	26.7	26.9	26.8	26.8	26.9	26.9	26.9	26.8	26.8	26.8	26.7	26.9
7/1/2017	26.1	26.3	26.3	26.3	26.3	26.4	26.4	26.4	26.4	26.5	26.5	26.5	26.8	26.9	26.8	26.8	26.8	26.9	26.9	26.8
7/8/2017	27.1	27.1	27.2	27.2	27.2	27.2	27.2	27.3	27.3	27.5	27.4	27.5	27.5	27.4	27.5	27.7	27.7	27.8	27.8	27.8
7/11/2017	27.6	27.6	27.9	27.9	27.8	27.9	27.9	27.8	27.9	28	28	27.8	27.6	27.6	27.8	27.8	28	28	28.2	27.4
7/20/2017	28.2	28.1	28.1	28.1	28.1	28.5	28.5	28.5	28.5	28.4	28.8	28.7	28.7	28.7	28.8	28.7	28.9	28.8	28.8	28.8
7/24/2017	27.9	27.8	27.8	27.8	27.9	27.9	27.9	28	27.9	27.9	28	28	28	28	28	27.9	27.8	27.8	27.8	27.9
7/28/2017	28.8	28.5	28.5	28.6	28.7	28.8	28.8	28.9	28.9	28.9	28.8	28.9	28.9	28.7	28.8	28.8	28.9	28.9	28.9	28.9
8/4/2017	29	28.9	29.3	29.4	29.4	29.4	29.4	29.4	29.4	29.4	29.5	29.6	29.6	29.6	29.8	29.8	29.7	29.6	29.8	29.9
8/8/2017	28.9	28.9	29.2	29.4	29.3	29.3	29.3	29.3	29.3	29.5	29.5	29.7	29.6	29.6	29.8	29.8	29.8	29.9	29.6	29.8
8/13/2017	28.8	28.8	28.7	28.8	28.8	28.8	28.9	28.9	28.9	28.9	28.9	29	29	29	29	29	28.9	28.9	28.8	29
8/17/2017	29.6	29.5	29.7	29.8	29.8	29.8	29.7	29.7	29.7	28.9	28.8	28.7	28.8	28.8	28.8	28.8	28.9	28.9	28.9	28.9
8/22/2017	28.5	28.3	28.6	28.4	28.6	28.6	28.7	28.7	28.7	28.7	28.9	28.7	28.7	28.7	28.2	28.6	28.7	28.7	28.8	28.6
8/26/2017	27.9	27.9	27.9	28.4	28.4	28.4	28.4	28.4	28.4	28.5	28.6	28.9	28.5	28.7	28.7	28.7	28.6	28.4	28.5	28.5
8/31/2017	28.6	28.6	28.5	28.5	28.5	28.6	28.6	28.6	28.7	28.8	28.8	28.9	28.9	28.9	28.8	28.9	28.8	29	28.9	28.9
9/7/2017	28.7	28.6	28.6	28.6	28.8	28.7	28.9	28.9	28.9	28.7	28.9	28.7	28.5	28.5	28.6	28.6	28.6	28.9	28.9	28.9
9/10/2017	27.6	27.4	27.4	27.3	27.6	27.8	27.8	27.4	27.9	27.8	27.8	27.8	28	28	28	27.9	27.9	27.9	27.9	28
9/16/2017	28.2	28	28.1	28.1	28.1	28.1	28.2	28.4	28.4	28.3	28.3	28.4	28.3	28.5	28.5	28.5	28.6	28.4	28.6	28.6
9/22/2017	29.9	29.9	30	30	30	30	30	30	30.3	30.2	30.3	30.3	30.3	30.3	30.2	30.1	30.1	30.2	30.2	30.1
10/2/2017	30.1	30.4	30.7	30.6	30.6	30.7	30.6	30.6	30.6	30.6	30.7	30.7	30.7	30.4	30.6	30.7	30.7	30.7	30.8	30.8
10/10/2017	31	31.4	31.3	31.2	31.3	31.3	31.3	31.3	31.6	31.4	31.3	31.3	31.3	31.3	31.3	31.5	31.5	31.5	31.5	31.5
10/16/2017	31.4	31.2	31.5	31.5	31.2	31.3	31.5	31.5	31.5	31.5	31.6	31.6	31.6	31.8	31.8	31.7	31.7	31.7	31.7	31.8
10/27/2017	31.9	32	32	32	32.1	32.1	32.1	32.1	32.1	32	32.2	32.2	32.2	31.9	31.9	31.9	32.4	32.4	32.4	32.2
10/31/2017	31.9	31.9	31.9	31.8	31.6	31.8	31.8	31.9	31.7	31.7	31.8	31.9	32	32	32	31.9	31.9	31.8	31.9	31.9

Appendix 14. Inner Hive Temperature of site 2.

Date	Inner Hive Temperature																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2/15/2017	32.2	32	32.1	32.4	32.5	32.6	32.8	33	33.1	32.9	33	33.2	33.2	32.8	32.8	32.1	33	33.4	33.2	33.1
2/21/2017	32.3	32.8	32.3	32.8	32.6	32.8	32.9	32.7	32.6	32.7	32.6	32.6	32.5	32.5	32.8	32.6	32.9	32.7	32.9	32.8
2/27/2017	31.4	32	32.1	31.9	31.5	31.8	32	32.1	32.1	32	31.9	31.6	32.1	32.2	32.2	32.2	31.8	31.2	31.9	31.7
3/5/2017	31.2	31.9	32.2	32.4	32.1	32.7	32.8	32.9	32.9	32.4	32.4	32.4	32.8	32.3	32.8	32.5	32.9	32.4	32.1	32.5
3/11/2017	31.4	31.9	32	32	32	31.7	32	32.1	32	32	32.4	32.1	31.2	32.4	32.4	32.1	31.9	31.9	31.2	31
3/19/2017	32.4	32.3	32.2	32.6	32.1	32.2	32.6	32.4	32.4	32.1	32.4	32.1	32.1	32.4	32.1	32.5	32.2	32.4	32	32.1
3/25/2017	32.8	32.9	32.1	32.2	32.4	32.9	32.2	32.4	32.1	32.5	32.6	32.4	32.5	32.9	33	32.8	32.6	32.4	32.4	32.5
3/29/2017	32.2	32.1	31.2	32.5	32.5	32.8	32.9	32	32.8	32.8	32.9	33	33.1	32.8	32.1	32.3	32.7	32.7	32.8	32.9
4/7/2017	32.9	32.7	32.8	32.8	32.6	32.7	32.8	32.6	32.6	32.4	32.5	32.7	32.9	32.6	32.5	32.6	32	32.9	32.7	32.7
4/25/2017	32.8	32.9	32.9	32.7	32.4	32.9	32.8	32.6	32.8	32.7	32.9	32.7	32.6	32.7	32.6	32.9	32.7	32.7	32.9	32.9
4/28/2017	33.1	33.5	32.6	32.9	32.4	32.4	32.7	32.6	32.5	32.6	32.6	32.7	32.8	32.8	32.7	32.7	32.7	32.6	32.9	32.9
5/2/2017	32.4	32.7	32.6	32.3	32.7	32..9	32.8	32.7	32.7	32	32	32.1	32.7	32.7	32.1	32.5	32.6	32.9	32.7	32.7
5/8/2017	32.8	32.1	32.4	32.7	32.8	32.8	32.7	32.6	32.7	32.9	32.8	33	32.8	32.7	32.6	32.7	32.9	32.8	32.9	32.4
5/11/2017	32.4	32.2	32.7	32.8	32.6	32.6	32.4	31.9	32.1	32.7	32.2	32.1	32.2	32.3	32.1	32.3	32.2	32.2	32.5	32
5/13/2017	32.8	32.7	32.2	32.9	32.8	32.6	32.8	32.6	32.7	32.9	32.7	32.5	32.8	32.6	32.6	32.5	32.6	32.9	32.1	32.7
5/15/2017	32.6	32.7	32.9	32	32.8	33	32	32.1	32.6	32.5	32.9	32.4	32.8	32.5	32.7	32.3	32.2	32.5	32.6	32.5
5/18/2017	32.2	31.7	32.2	32.1	31.2	32	32.7	32.9	32.6	32.2	32.9	32.6	32.8	32.5	32.8	32.8	32.8	32.9	32.1	32.4
5/22/2017	32	31.8	32.1	31.1	32	31.9	32.1	32	32.2	32.1	32.8	32.4	32.8	32	32.1	32.2	33	32.8	32.9	32.8
5/27/2017	32.2	32.5	32.9	32.4	32.6	32.1	32.2	32.9	32.6	32.5	32.4	32.5	33	32.6	32.6	32.6	32.8	32	32.2	32.4
6/1/2017	32.8	32.7	32.4	32.1	32.4	32.7	32.9	32.4	32.1	32.4	32.4	32.1	31.9	31.8	31.7	30.8	32	32.1	32.5	32.6
6/7/2017	32	32.1	32.3	32	32.7	32.8	32.6	32.4	32.5	32.9	32.6	32.4	32.9	32.7	32.6	32.2	33	32.8	32.7	32.7
6/12/2017	31.9	31.8	31.8	32	32.2	32.1	32.5	32.8	32.8	32.4	32.1	32	32.2	32.4	32.1	32.4	32.7	32.1	32	31
6/16/2017	32	31.9	31.2	31.6	31.9	32	32.2	32.8	32.6	32.9	32.9	31	31.9	32	32.1	32.1	32.8	32.4	32.8	32
6/20/2017	31.9	32	32.2	32.8	32.9	32.9	32	32.4	32.1	32.4	32.7	32.6	32.7	31.9	32	31.6	31.9	31.9	32	32.1

Cont…….

Date	Inner Hive Temperature																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6/24/2017	32.1	31.9	31.8	33	32	32.8	33.3	32.1	32.4	31.7	31.8	31.6	31.9	32	32.2	32.4	32.1	32.4	32	32.9
6/27/2017	32	31.9	32.1	32.4	32.1	32.5	32.9	32.8	32.7	32.6	32.9	32.4	32	32.9	31.9	31.9	32	32	32.5	32.8
7/1/2017	32.9	31.4	32	32.1	32.5	32.1	32	32.4	32.6	32.9	32.4	32.7	32.6	32.7	32.4	32.7	32.9	32.4	32.1	32.2
7/8/2017	32.4	32	32.4	32.9	32	32.4	31.9	32	32.2	32.7	32.8	32.6	32.7	32.4	32.8	32.9	32.9	33	31.8	31.9
7/11/2017	32	32.2	32.4	32	31.8	31.9	32.1	32	32	32	32.4	32.5	32.4	32.4	32.1	32.1	31.9	31.7	32	31.9
7/20/2017	31.8	32	32.6	32	31.9	32	32.4	32.1	32	32.1	31.4	31.9	32.8	32.4	32.7	32.8	32.9	32.9	32	32.2
7/24/2017	32.1	31.9	31.2	32.2	32.7	32.1	32.4	32.6	32.8	32.4	32.8	32	31.9	32	31.7	31.9	32	32	32.5	32.4
7/28/2017	32	32.1	31.9	31.7	31.9	31.7	32	32.1	32.8	32.5	32	32.2	32.2	33	32.7	32.6	32.6	31	31.2	32
8/4/2017	32.6	32	31	31	31.9	31.8	32.4	31.7	31.6	31.9	31.8	32	32.8	32.4	31.9	32.1	32.4	32.8	32.9	32.5
8/8/2017	32	31.9	32.4	31.9	31.4	31.8	32	32.8	33	32.8	32.6	32.8	32	31.9	31.7	31.8	32.1	32.7	32	32.2
8/13/2017	32	31.8	32.6	32	32	32.8	32.1	32.3	32.4	32	32	32.7	32.7	32.9	32.7	32.4	32.7	32.2	32.3	33
8/17/2017	32	31.9	32	32.1	32	32	32.1	32.2	32.1	32.3	32.1	32.1	32.2	33	32.8	32.9	32.8	32.8	32.4	32.8
8/22/2017	32.7	32.4	32	32	32.8	32.9	33	32.2	32.6	32.8	32.2	32.7	32.5	32.4	32.4	32.6	32.9	32.4	32.4	32.9
8/26/2017	32	31.9	31.9	32	31	32	32	32.7	32.7	32.9	32.8	32.9	32	32.5	32.4	32.8	32.9	32.4	32.5	32.1
8/31/2017	31.9	31.2	32	32.4	32.7	32	32.4	32.1	32.3	32.4	31.8	32	32	32.4	32.4	32.2	32.4	32.1	32.4	32.4
9/7/2017	32	31.9	32	31.9	32	32.4	32.1	32.1	32.7	32.4	32.9	32.4	32.5	32.4	32.8	32.1	32.4	32.8	33	32
9/10/2017	31.9	32	32	33	32.4	32.8	32.9	32.1	32.2	32.3	32.4	32.5	32.4	32.8	32.7	32.1	32.7	32.4	32.6	32
9/16/2017	32	32.4	31.4	32.7	32	31.9	31.2	31.8	31.2	32	31.8	31.5	31.2	31.8	31.7	32	32.1	32.2	32.4	32.6
9/22/2017	31.9	32	32	32.4	32.4	32.2	32.2	32.1	32	32.1	32.4	32.5	32.1	32.8	32.7	32.8	32.7	32	32.1	31.9
10/2/2017	32	32.4	32.6	32	32	31.9	30	30.8	30.8	31.7	31.9	31.6	31.5	32	32.4	32.1	32.4	32.4	33	30
10/10/2017	31	31.9	32	32	32	32.4	32	32.7	32.7	32.4	32.5	32	32	32.4	32.5	32.4	32.6	32.4	32.1	32
10/16/2017	30	30.1	30.2	30.2	30.3	30.7	30.8	30.5	30.1	30.2	32.4	32.1	32.4	32.1	32.4	32	32.2	31.9	32.1	32.2
10/27/2017	32	32	32.1	32.1	32.6	32.4	32	32.9	32	32.1	32	32	32	32.1	31.9	32.4	32.1	32.1	32.4	32
10/31/2017	32.1	32.4	32	32	32.4	32.5	32.4	32.4	32.9	32	32	32.3	32.6	32.6	32	32.1	32.4	32	32.4	32.2

Appendix 15. Outer Temperature of site 2.

Date	Outer Temperature																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2/15/2017	26.1	26.1	26.2	27	26.9	26.8	27	27	27	27.1	27.1	26.9	26.9	26.8	26.9	26.9	26.9	27	27.1	26.8
2/21/2017	25.9	25.9	25.8	26	26	26.1	26.3	26.4	26.6	26.9	26.7	26.8	26.9	26.9	26.9	26.9	26.9	27	26.8	26.9
2/27/2017	26.6	26.8	26.8	26.7	26.6	26.6	26.6	26.9	26.9	26.9	26.9	26.8	26.8	26.8	26.9	26.9	26.8	26.8	26.8	26.8
3/5/2017	27.1	27.1	27.1	27	27	27.2	27.2	27.2	27.1	27	27	27.1	27.2	27.3	27.3	27.3	27.2	27.2	27.1	27.1
3/11/2017	26.9	26.8	26.8	27.8	27.9	28.1	28	28	28.2	28.1	28.1	28	28	28.3	28.3	28.3	28.2	28.1	27.9	27.9
3/19/2017	28.2	28.2	28.2	28.5	28.6	28.6	28.6	28.6	28.6	28.5	28.5	28.5	28.5	28.6	28.6	28.7	28.7	28.7	28.7	28.6
3/25/2017	28.5	28.7	28.6	28.4	28.9	28.9	28.8	28.8	28.8	28.9	28.8	28.8	28.9	28.8	28.8	28.7	28.9	28.9	28.9	28.7
3/29/2017	28.9	28.7	28.9	29	29	29	29.1	29.1	28.9	28.9	28.9	28.1	28.9	28.9	28.9	28.9	29	29	29	28.9
4/7/2017	28.8	28.8	28.8	28.9	28.8	28.8	29	29	29	29	29	29	29.1	29	28.9	28.9	28.9	28.9	28.8	28.7
4/25/2017	29.1	29.6	29.9	30	30.4	30.4	30.3	30.4	30.4	30.6	30.7	30.7	30.7	30.7	30.6	30.8	30.8	30.7	30.7	30.8
4/28/2017	30.4	30.5	30.2	30.3	30.3	30.3	30.5	30.6	30.6	30.6	30.6	30.6	30.6	30.7	30.8	30.8	30.8	30.8	31	30.9
5/2/2017	29.9	29.9	29.9	30.1	30.1	30.1	30.1	30.2	30.2	30.2	30.2	30.2	30.3	30.1	30.4	30.4	30.4	30.4	30.4	30.4
5/8/2017	29.8	29.8	29.8	29.8	30	30.1	30.1	30.2	30.2	30.2	30.3	30.2	30.2	30.2	30.1	30.2	30.1	30.1	30.2	29.9
5/11/2017	29.9	29.9	29.9	30	30.1	30.1	29.9	29.8	29.2	29.7	29.9	29.9	29.9	29.9	29.9	29.9	30	29.9	29.9	29.9
5/13/2017	28.9	29	29	29.4	29.4	29.5	29.5	29.7	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.9	29.8	30	30	30
5/15/2017	28.9	28.9	28.8	28.8	28.8	28.8	28.9	28.9	29	29	29.1	29.1	29.1	28.9	28.9	28.9	28.8	28.8	28.8	28.9
5/18/2017	29.9	30.4	30.4	30.4	30.3	30.5	30.5	30.5	30.5	30.5	30.6	30.5	30.5	30.5	30.6	30.6	30.7	30.8	30.6	30.8
5/22/2017	30.1	30.2	30.2	30.2	30.4	30.2	30.3	30.4	30.4	30.4	30.4	30.4	30.3	30.4	30.4	30.4	30.4	30.3	30.4	30.4
5/27/2017	30.4	30.4	30.3	30.3	30.3	30.3	30	30.3	30.4	30.3	30.3	30.3	30.3	30.3	30.2	30.3	30.3	30.3	30.3	30.3
6/1/2017	29.9	29.9	29.9	29.9	30.1	30	30	30	30.2	30.2	30.2	30.2	30.2	30.2	30.3	30.3	30.1	30.2	30.1	30.2
6/7/2017	29.9	30	30	30	30.2	30	30	30	30.4	30.4	30.2	30.2	30.2	30.2	30.1	30.2	30.3	30.2	30.2	30.1
6/12/2017	28.8	28.8	28.9	28.5	28.3	28.2	28.3	28.3	28.2	28.3	28.9	28.9	28.9	28.9	28.7	28.8	28.8	28.8	28.8	28.8
6/16/2017	27.9	27.9	27.9	27.9	27.9	27.7	26.9	26.7	26.8	26.7	26.7	26.7	26.7	26.7	26.8	26.6	26.6	26.6	26.6	26.6
6/20/2017	25.9	25.9	25.9	25.9	25.9	25.9	25.8	25.9	25.9	25.4	25.7	25.7	25.7	25.5	25.7	25.7	25.9	25.9	25.6	25.5

Cont….

Date	Outer Temperature																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6/24/2017	26.4	26.5	26.4	26.7	26.7	26.7	26.7	26.7	26.7	26.8	26.7	26.7	26.7	26.7	26.7	26.7	26.8	26.8	26.8	26.7
6/27/2017	26.6	26.8	26.7	26.8	26.8	26.9	26.9	26.9	26.9	26.8	26.8	26.8	26.8	26.9	26.9	26.9	27	27	27	26.9
7/1/2017	27.2	27.2	27.1	27.1	27.1	27	27.2	27.2	27.1	27.1	27.1	27.1	27.2	27.2	27.2	27.2	27.1	27.1	27.2	27.2
7/8/2017	26.8	26.8	26.8	26.8	26.8	26.7	26.7	26.8	26.8	26.8	26.7	26.7	26.7	26.7	26.7	26.1	26	26.1	26	26
7/11/2017	25.8	26	26.3	26.3	26.3	26.3	26.2	26.7	26.8	26.7	26.7	26.7	26.7	26.7	26.6	26.6	26.6	26.6	26.6	27
7/20/2017	25.5	25.7	25.6	25.6	25.6	25.6	25.6	25.8	25.8	25.8	26	26	26	26	26.1	25.9	25.9	25.9	25.9	26
7/24/2017	26.2	26.2	26.2	26.7	26.7	26.7	26.7	26.8	26.7	26.7	26.9	26.8	26.8	26.8	26.8	26.8	26.9	26.9	26.9	26.9
7/28/2017	27	26.9	26.8	26.9	26.9	26.8	26.8	26.8	26.8	26.9	26.9	26.9	26.9	26.9	26.9	27	27.1	27.1	27.1	27.1
8/4/2017	25.9	25.6	25.4	25.7	25.7	25.7	25.6	25.8	25.7	25.9	25.9	25.9	25.9	26	26	26	26	26.3	26.3	25.9
8/8/2017	26.2	26.1	25.3	25.9	25.8	25.8	26	26.1	25.9	25.9	25.9	25.9	26.1	25.2	25.1	25.8	25.8	25.4	25.3	25.9
8/13/2017	25.6	25.7	25.7	25.7	25.7	25.7	25.7	25.7	25.7	25.7	26	26.3	26.1	26.1	26.1	26.1	26.1	26	26	25.9
8/17/2017	29.5	29.5	29.6	29.7	29.4	29.4	29.4	29.6	29.6	28.7	28.4	28.6	28.7	28.8	28.8	28.8	28.6	28.8	28.8	28.7
8/22/2017	28.6	28.3	28.4	28.5	28.5	28.5	28.6	28.5	28.5	28.5	28.6	28.5	28.6	28.7	28.4	28.6	28.6	28.7	28.7	28.8
8/26/2017	27.4	27.4	27.6	28.7	28.7	28.7	28.4	28.6	28.6	28.4	28.4	28.8	28.4	28.6	28.3	28.6	28.7	28.6	28.6	28.6
8/31/2017	28.7	28.7	28.6	28.5	28.6	28.6	28.6	28.6	28.7	28.4	28.4	28.3	28.6	28.5	28.7	28.8	28.7	28.6	28.6	28.6
9/7/2017	28.6	28.7	28.6	28.7	28.7	28.6	28.6	28.9	28.8	28.8	28.9	28.8	28.6	28.5	28.6	28.5	28.6	28.7	28.8	28.9
9/10/2017	27.8	27.6	27.7	27.6	27.6	27.5	27.9	27.6	27.4	27.6	27.5	27.8	27.9	27.9	28	27.8	27.8	27.8	27.9	27.9
9/16/2017	28.4	28.5	28.5	28.4	28.3	28.3	28.3	28.4	28.5	28.5	28.5	28.7	28.6	28.6	28.6	28.5	28.6	28.7	28.7	28.7
9/22/2017	29.7	29.8	29.8	29.9	30	30	29.9	29.8	30.1	30.2	30.2	30.2	30.1	30.2	30.2	30.2	30.1	30.3	30.2	30.2
10/2/2017	30	30.1	30.4	30.2	30.4	30.5	30.1	30.2	30.5	30.6	30.6	30.6	30.7	30.5	30.6	30.8	30.7	30.8	30.8	30.7
10/10/2017	31.1	31.2	31.2	31.2	31.4	31.3	31.3	31.4	31.6	31.4	31.2	31.2	31.2	31.4	31.5	31.5	31.2	31.3	31.2	31.7
10/16/2017	31.2	31.3	31.4	31.4	31.3	31.3	31.4	31.5	31.5	31.5	31.6	31.7	31.6	31.8	31.6	31.6	31.6	31.8	31.8	31.7
10/27/2017	31.4	31.7	31.7	31.9	32.1	32.1	32.1	32	32	32.2	32.1	32.3	32.2	31.8	31.7	31.8	31.9	31.7	31.8	31.9
10/31/2017	31.6	31.8	31.9	31.6	31.8	31.7	31.8	31.9	31.8	31.8	31.8	31.7	31.9	31.9	31.9	32	32	32	32.1	31.9

Photo 1. Experimental site 1

Photo 2. Experimental site 2

Photo 3. Observation of Brood

Photo 4. Observation of hive

Photo 5. Observation of brood

Photo 6. Interview with beekeeper

Photo 7. Damage brood caps

Photo 8. Varroa mites in brood cells

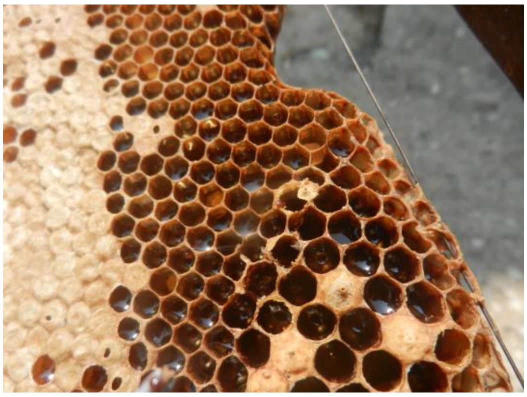

Photo 9. Varroa mite on Brood cells

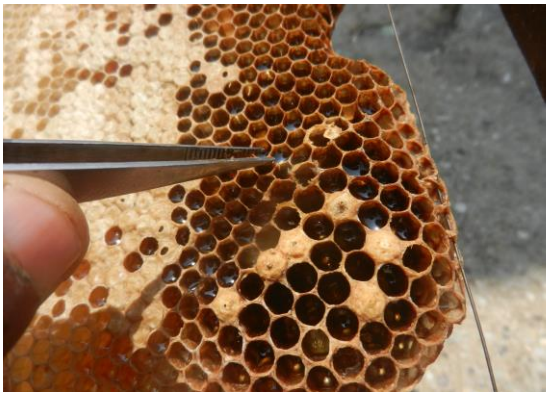

Photo 10. Varroa mite on Brood cells

Photo 11. Varroa mite on Adult

Photo 12. Varroa mite on bottom board

Photo 13. Infected brood frame

Photo 14. Counting of mites

Photo 15. Dorsal view of Varroa mite

Photo 16. Ventral view of Varroa mite

Photo 17. Ventral view of Varroa mite

Photo 18. Ventral view of Varroa mite