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FULL PAPER

Honeybees, *Apis cerana* colony performance in the non-protected and protected beehive methods in relation to climatic factors

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Abstract

Honeybees, *Apis cerana* is one of the local bee species in Malaysia. *Apis cerana* plays important role in beekeeping activities, especially in producing honey known as a superfood and helping in pollination activities. However, a low survival rate of *Apis cerana* in the beehive box was observed because *Apis cerana* had a high tendency to migrate from the beehive box due to some reasons particularly natural enemies attack and climatic factors. Therefore this study was carried out to determine the effect of protected and non-protected beehive methods on the colony of *Apis cerana* under different method practices and fluctuated climatic factors. Ten standard beehives boxes with their colonies altogether were divided into two groups, five colonies of bees in the non-protected beehive boxes method while the remaining five protected beehives boxes method. Protected beehive is equipped with several protection techniques to avoid predator and queen of bees running away from the beehives. The *Apis cerana* colonies were examined, observed, collected and recorded regularly four times per month for one year interval of the sampling period. Data was also collected through the Snow Ball Sampling technique by ground trotting for verification such as pictures of every single comb of the beehives, and the numbers of an individual's bees calculated using an empirical measuring technique. As a result, there was a significant difference ($P<0.05$) in the population abundance of bees colony in the protected beehive box as compared to the population abundance of bees colony in non-protected beehive box. Additionally, there was no significant relationship ($P>0.05$) between the population of *Apis cerana* with temperature for both methods protected and non-protected beehive boxes except for rainfall in the protected beehives. Beekeepers who face similar problems, particularly in mass rearing of *Apis cerana* for commercial could use protected beehive boxes since the population abundance of bees and its colonies was successfully developed in the protected beehive practices as climatic factors was also considered. Hopefully, the findings of this study could contribute to a significant increase in income for farmers and subsequently encouraged the apiculture industry in future.

1. Introduction

Asian honey bee is scientifically known as *Apis cerana. Apis cerana* was an indigenous bee species found in nature and the third smallest of nine species of honey bees in the world (Koeniger, 2010; Carr, 2011). Bees have many types of sizes ranging from the smallest (2.1 mm) and the biggest (39 mm). Some bees were introverted, but most of them live in a large family group and work as a team. When some of their members are attacked or threatened, the whole colony will react. As for the colony, if it was being damaged or had been infected by diseases, the colony has the capability to heal itself by dividing or separating its colonies. Based on the statement of Katie *et al.* (2007), bee colonies were divided into three castes, the queen colony, the worker colony, and the drone colony. Currently, honeybees have captured the attention of scientists and researchers around the world. The uniqueness of the bees' behaviour and characteristics has attracted their interest to study more about them.

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Nowadays, *Apis cerana* plays important role in beekeeping activities, especially in producing honey known as a superfood, potential in diversification, pollination agent, bee-fencing in mitigating wild elephant and beekeeping activities could also increase the income and lifestyle of local farmers. However, low survival rate and performance of *Apis cerana* in the beehive box because they highly tend to migrate or run away from the beehive box due to some reasons particularly natural enemies and climatic factors. Firstly, in terms of predation against bee colonies especially high mortality was observed and adult individual bees tend to depart from the beehive, they are attacked by predators particularly occurring at the exit point of unprotected beehive's box such as lizards and wasps. In this study, the protected mesh wire designed and attached to the beehive box was recorded to able to reduce the mortality of bee colonies and subsequently reduce the tendency for bee colonies leaving their nest. Additionally, several techniques could be done to reduce predators attacked by using mesh wire to cover up the beehives boxes for mass rearing *Apis cerana* and encouraging higher population abundance with a slight modification of protected beehive box with considerations of the ecology and abiotic factors in a particular study area. This technique probably could increase the survival rate of bee colonies when it is applied in the field as a protected beehive box as predation avoidance which minimizes the predation rate against a colony. This research study contributed to fundamental knowledge about the local wild bees, *Apis cerana* performance, and the protected beehive box could also increase income for a smallholder. Another advantage of beekeeping is that smallholders could produce honey, have the potential for diversification, and increase the income and lifestyle of local farmers (King, 2009). In addition, according to Klatt *et al.* (2014), the pollination done by the bees could also help to increase the success rate of flowering and fruiting and upgrade the quality of the crops planted surrounding beekeeping activities.

Climate could have a direct impact on bee life because the honey bee is cold-blooded which has a strong dependence on environmental conditions (Moradi, 2013). Climatic is very important to be studied by identifying and determining the climatic effect in the area, it could also possibly influence the biological characteristics of plant and animal species according to the time and place (Salehizadeh *et al.*, 2020). Salehizadeh *et al.* (2020) also reported that every region had their own climatic conditions that affected the activities of honey bees because they were very active during flower production and there was a direct relationship between climatic parameters and the production of honey bee colonies.

While foraging, *Apis cerana* species were exposed to a broad range of abiotic factors or ambient weather parameters such as temperature, rainfall, wind speed, relative humidity and others that may have a positive or negative effect on the developmental parameters of honeybees (Kovac and Stabentheiner, 2011). Honey bee foraging activity results from each related weather parameter. Manoj *et al.* (2017) reported that brood rearing activity was measured in terms of area under egg, grub, and pupa as well as honey and pollen collection must take into consideration as an important developmental parameter. The mean of the maximum day temperature for ideal weather to the best brood rearing activity was 34.40°C in plain type bees with long daily hours of sunshine and completely calm weather (Subbiah, 1956). According to Reddy (1979), a study shows a positive relationship between the relative humidity and rainfall with the pollen gathering activity of the bees.

From this study, the best practice should be determined for a successful mass rearing of *Apis cerana* and later on aid in sustaining the population of *Apis cerana* in beehives box in order to encourage a strong colony population for success in mass rearing or beekeeping activities. Besides, to combat the elephant in the field. This study also identified and measured the relationship between the population of *Apis cerana* in different method practices toward abiotic factors to avoid the bee from running away from beehives and increasing their population. The main purpose of this study is to determine the effect of protection methods and non-protection of beehive boxes box and the abiotic factors on the performance of *Apis cerana* colony.

2. Materials and methods

2.1 Location and duration of the study

This study was carried out in a smallholder oil palm plantation at Kampung Gol, Mukim Tembeling Tengah, 27000, Jerantut, Pahang (3.9468°N, 102.3799°E) and conducted for 12 months starting from April 2018 until March 2019.

2.2 Preparation non-protected and protected beehive box preparation

A basic beehive consists of the following parts of boxes, frame and cover. The beehives boxes were made from wood. The size of the beehives box was 9 5/8 inches deep, 11 1/4 inches wide and 16 7/8 inches long. The box had 3 controlled doors the upper had one circle hole with one controlled door and the bottom beehives had two rectangle holes with two controlled doors. The upper door is opened only during transfers of the wild bees into the beehive box and closed during mass rearing but another two doors at the bottom beehives were opened in 3 mm during mass rearing or culture of wild bees. This process of work is crucial to control the queen bee from absconding and avoiding predator attacks.

The frame is functional to attach the comb of *Apis cerana* and the size of the frame is about 8 inches in height, 5/8 inches wide and 16 inches in length of up-frame and 15 ½ inches length low-frame. The cover of the beehive box is 1 inch in depth, 13 inches in width and 17 inches in length. The beehive boxes were built consisting of 6 frames. Frames need to be in the centre of the hive box, equally spaced with not more than 30 mm between their pulled wax foundations. Broad frames must have small communication holes at the bottom to allow bee movement. The beehives had protection used such as a zinc roof to avoid direct sunlight and rainfall, lathing mesh and water barrier to avoid predators and a bee excluder to prevent the queen from running away from the beehives.

2.3 Method in culture wild bees

Identified species of bees, *Apis cerana*' colony was collected and brought back to the laboratory. The colony's comb of bees was cut into several pieces and subsequently attached to the nesting frame of the beehive's box by a rubber band. Then, the colonies of bees were transferred into the beehives box for both non-protected and protected beehive box methods respectively. Finally, all protected and non-protected beehive boxes were transferred into a smallholder oil palm' area at night to prevent the bees from leaving the beehive box.

2.4 Experimental design

Ten beehives with their colonies altogether were chosen in this study which was classified into two groups of treatments where the first group consisted of five colonies of bees placed under the non-protected beehive (Figure 1-B) method while the remaining five beehives as the second group placed under protected beehive (Figure 1-A) method. A total of ten (10) beehive samples were taken and considered as replication. The *Apis cerana* colonies were examined, observed, collected and recorded regularly times per month every weekend for one year interval of the sampling period and observation of colony growth parameters including population abundance *of Apis cerana* was recorded utilizing a standard technique. Observation of the population of *Apis cerana* in the non-protected beehive method and protected beehive method were correlated with weather parameters including mean temperature, relative humidity, and rainfall in the field area. The data on the various weather parameters were taken from the Malaysian Meteorological Department.

Figure 1. Non-protected (A) and protected beehive boxes (B) and colony of bees (C) under rain shelter structure

2.5 Colony breeding and stabilizing preparation

All equipment and materials were needed and prepared for this study including bee handling suit, beehive boxes, and materials for the preparation of the bee colonies breeding and stabilizing beehives in the studied field. The beehives boxes were prepared and made from wood. *Apis cerana* nests were originally purchased from the bees' farmers and the colony of bees generally found in tree hollows or rock crevices (Ruttner, 1972; Koetz, 2013), was found in the ground (Karlsson, 1990), but also in human and natural structures (Hyatt, 2012; Koetz, 2013). *Apis cerana* colonies were collected from various places of states such as from Pahang, Melaka, Selangor, Kuala Lumpur, Putrajaya, Negeri Sembilan and Johor. During the on-site collection process, the bee colonies were transferred from the nesting area to the beehive boxes.

2.6 Field experimental layout

The colonies of wild bees were transferred into every beehive box which was placed randomly at the smallholder's oil palm for mass rearing. Then, all protected and non-protected beehive boxes that contained colonies were inspected daily to ensure all the colonies in each beehive box adapted to their colonies. After a month, data were collected weekly to record the population abundance of *Apis cerana*. The bee population had been measured and collected through every single comb or brood of the beehive was captured, marked by grid area (cm^2) and individual bees were calculated by using empirical measuring techniques.

2.7 Treatment of non-protected and protected beehive methods against bees population abundance

The study site was prepared as shown in the layout plan (Figure 2), the site was cleared and the shelter was built for the beehive boxes. On-site beehive boxes were sheltered by zinc (2×2 ft) from rainfall and sunlight. The shelters were also designed to protect the beehive from hornets, ants, lizards, cockroaches and lesser wax moths. Outbreaks from hornets were found to be the main threat to the bee colonies. Flowering plants such as *Antigonon leptopus* (Bunga Air Mata Pengantin) were also planted around the stabilizing rearing site as food resources for *Apis cerana*.

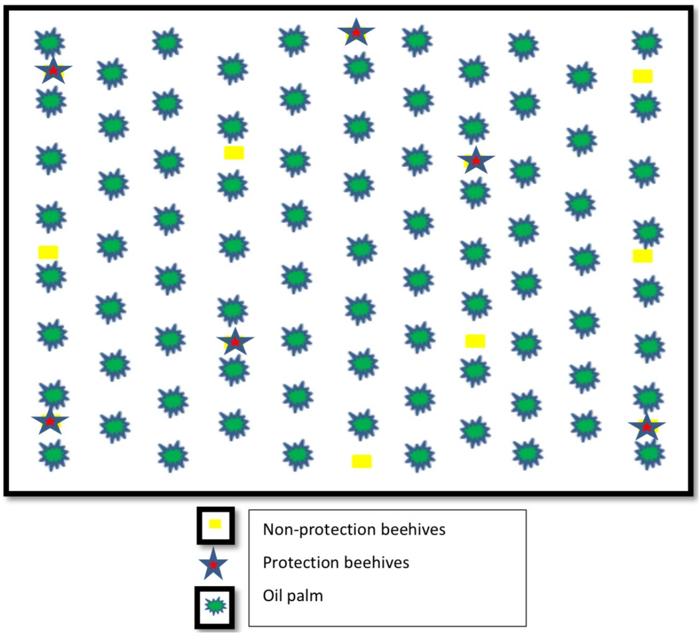

Figure 2. Experimental layout for protective and non protective beehives placed between oil palm crops in small holder plantation

2.8 Data collection

Data regarding the population dynamic of *Apis cerana* was related to the sampling time collected every weekend starting from April 2018 until March 2019. Data was also collected through the Snow Ball Sampling technique by ground trotting for verification. In this study, the sampling was conducted carefully and properly in order to differentiate the population number of *Apis cerana* between non-protected and protected beehive box practices for the whole sampling period. Subsequently, pictures of every single comb or brood of the beehives were captured for the sampling of the population of *Apis cerana* (Figure 1), inserted into the computer, marked by grid area (cm²), and numbers of individual bees were calculated by using an empirical measures technique. The scale was used to calculate the individual bees one by one and total unit area observations were taken and the calculation in numbers was analyzed in cm². Each observation of the comb was made. The bee population density per cm² was determined by counting the number of bees directly in squares equalling one cm². The data collection showed the number of *Apis cerana* bees in non-protection and protection beehives with 5 replicate, respectively. The data were recorded in excel software and analyzed in SPSS software. Secondly, data on abiotic factors were collected from the Malaysian Meteorological Department 2019 including rainfall, temperature, and relative humidity.

2.9 Data analysis

Data were subjected to an independent t-test (Statistical Package for Social Science (SPSS-Version 22) in order to differentiate the bee population abundance between the population of bees in the beehive's protection box and the beehive's non-protection box methods. Prior ANOVA and Normal Distribution (Kolmogorov Smirnov test) were carried out to verify the data are normal or abnormal to continue further analysis whether parametric or non-parametric tests. Karl Pearson's coefficient (Statistical Package for Social Science (SPSS statistics) version 22 was used to evaluate the relationship between *Apis cerana* population abundance and the climatic factors (temperature and rainfall).

3. Results

3.1 Comparison between population abundance of Apis cerana at non-protection method beehives and protection method beehives practices

In this study, the sampling of *Apis cerana* was conducted properly in order to differentiate the population number of *Apis cerana* for each method of protection practices between non-protection and protection practices for the whole sampling period (Figure 3). Statistically, the paired-sample T-test showed that there was a significant difference (T = -11.691; df-239; P<0.05) in a number of *Apis cerana* between the non-protection and protection beehives methods. This study revealed that a higher population of *Apis cerana* in the protected beehive method was recorded compared to the non-protected beehive method. Protected beehive box methods had the ability to encourage and increase the bee's population abundance. The comparisons between these two method practices revealed that protection methods in the mass rearing of *Apis cerana* do have the ability to help for increasing the bee population in the study area.

Figure 4 shows that the protection beehives method had a higher population abundance of bees when compared to the non-protection beehive method. The higher mean population of the bees was recorded by the protection method with 22443.8±353.84 compared to the

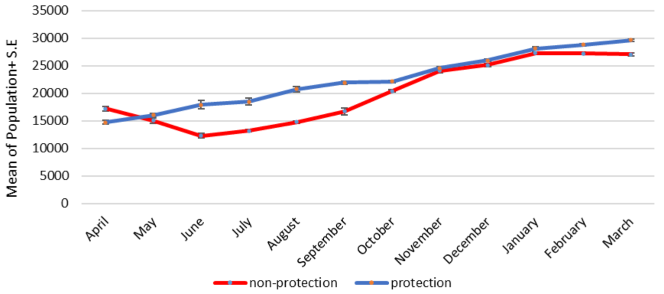

Figure 3. Comparisons mean (mean ± standard error (S.E)) of *Apis cerana* based on different method of beehives protection for sampling period

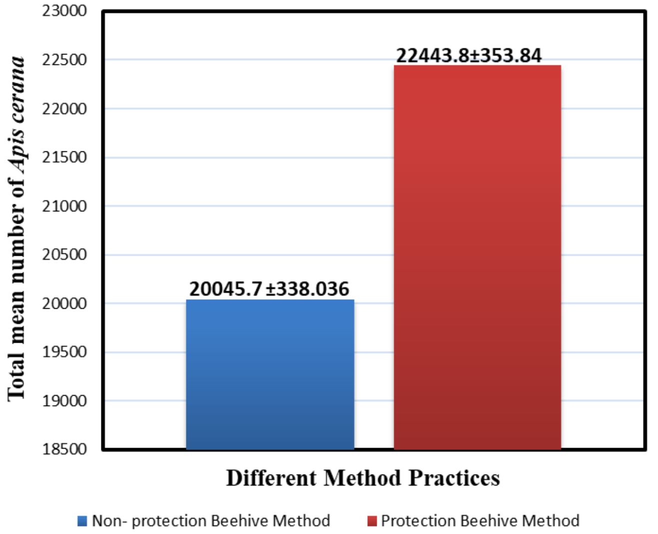

Figure 4. Comparison of total mean number of *Apis cerana* in two different method of beehives protection practices

mean of bees population abundance was recorded by the non-protection beehives method with only 20045.7 ±338.036. These indicated that the protection beehives method helped in increasing the bee population in the study area.

3.2 Relationship between the population of Apis cerana in non-protection beehive method and protection method beehives toward the amount of rainfall (mm)

In this study, the number of bee generations that appeared each year and the timing of the various insect life stages based on the amount of rainfall, which critical for scheduling mass rearing measurements. Table 1 showed the correlation between rainfall and *Apis cerana* population in the non-protection beehives box. Thus, the result showed that there was no significant correlation (Pearson correlation 0.092, P>0.05) between rainfall and the *Apis cerana* population in the non-protection beehives method.

However, in the protection beehive method, there was a significant negative correlation (Pearson correlation -0.176, P<0.05) between rainfall and the *Apis cerana* population. The result indicated that the decreasing amount of rainfall increased the *Apis cerana* population. It probably occurred because the bees were able to search for their food on a sunny day and they also preferred to stay outside of the beehive box covered by a zinc roof that served as a protection from rainfall. Based on the observation, it showed that the different method practices during mass rearing were one of the main factors that influenced the *Apis cerana* population.

Rainfall was an important factor affecting the honey bee activities as well as the distribution and development of insects. Climate change also could affect the distribution of precipitation (rainfall). The long rainfall phenomenon was found to be one of the main factors that could affect the survival of its subsequent generations. Besides, Figure 5 shows the overall mean of rainfall highly fluctuated early until the end of the sampling period. The highest mean of rainfall was 13.45 mm in May 2018 and the lowest mean of rainfall was recorded as 1.57 mm in February 2019.

Table 1. The correlation between rainfall and *Apis cerana* population in non-protected and protected beehives box methods.

		Non-protection	Protection
Rainfall	Pearson Correlation	0.092	-0.176**
	Sig. (2-tailed)	0.155	0.006
	N	240	240

**Correlation was significant at the 0.01 level (2-tailed), r = Pearson's correlation coefficient, p = significance (2 tailed).

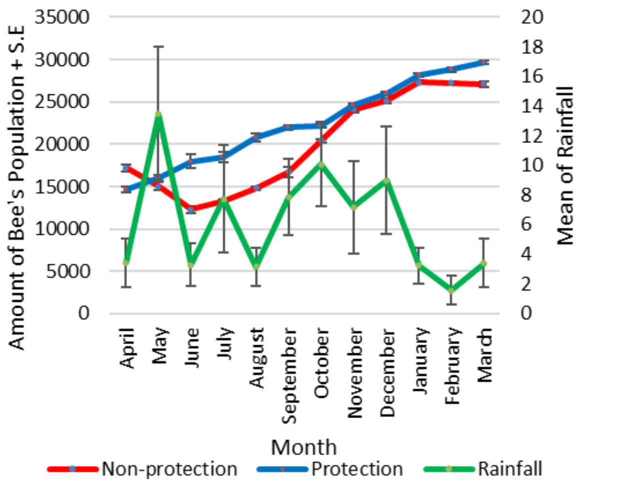

Figure 5. Relationship between population of *Apis cerana* in non-protection and protection methods beehives toward rainfall.

3.3 Relationship between the population of Apis cerana in non-protection and protection methods beehives toward temperature (°C) and relative humidity

Table 2 shows there was no correlation (Pearson correlation 0.047, P>0.05) between temperature and the *Apis cerana* population in the non-protection method. Similarly, in the protected beehive method, there was no correlation (Pearson correlation -0.123, P>0.05) between

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temperature and the population of *Apis cerana.* Figure 6 shows the overall mean temperature fluctuated in a moderate way. In general, the mean temperature for the overall 12 months did not much fluctuate as it stayed within the range of 26.36°C to 28.5°C as a minimum and maximum temperature respectively.

Table 3 shows there was no correlation between humidity and *Apis cerana* bee population in non-protection (Pearson correlation –0.033, P>0.05) and protection (Pearson correlation –0.003, P>0.05) methods. Figure 7 shows the overall relationship between the *Apis cerana* population with the mean of relative humidity fluctuating in a moderate way.

4. Discussion

4.1 Comparison between population abundance of Apis cerana at non-protection method beehives and protection method beehives practices

Apiculture is known as beekeeping activities, it is important to the forest and agro-based industry and it that can give benefits to humans, particularly the interaction of pollination between plants and bees (Ramachandra *et al.,* 2012; Muli *et al.,* 2014). Honey beekeeping means managing bee products such as honey, beeswax, and others for commercial and personal purposes (Khan and Khan, 2018). In other words, the previous study done by Mengistu *et al*. (2016) reported to encourage beekeeping interventions throughout the world is an important component of agriculture and rural development programs, the useful small-scale efforts should be done in many countries.

In this study, *Apis cerana* colonies were reared in non-protected beehive boxes and protected beehive box method in the smallholder's oil palm areas. The population of beehive colonies were observed for over a year from April 2018 until March 2019. The population growth of *Apis cerana* continuously increased in the number of population at early in the year. Statistically, the population of *Apis cerana* over a year of sampling found a highly significant difference between both non-protection and protection methods rearing. The non-protected beehive box techniques contributed 80.21% of the bee's population growth and the protection method contributed to 99.10% of the bee's population growth. Thus, when comparing between population *Apis cerana* in each method practice, this study revealed the population of bees in the protection method were significantly increased by preventing the colonies from being attacked by natural enemies.

The total mean population of the bees with the application of the protection method had the highest mean number of 22443.8±353.84 when compared to the mean number of bees in the non-protection beehive box method with 20045.7±338.036. It could be concluded that the protection method in the mass rearing of *Apis cerana* contributed to a higher bee population. On the other hand, Abou-Shaara (2013) also reported modified beehives could increase honey bee survival. However,

Table 2. The correlation between temperature and *Apis cerana* population in non-protection and protection methods.

		Non-protection	Protection
	Pearson Correlation	0.047	-0.123
Temperature	Sig. (2-tailed)	0.467	0.056
	N	240	240

**Correlation was significant at the 0.01 level (2-tailed), r = Pearson's correlation coefficient, p = significance (2 tailed).

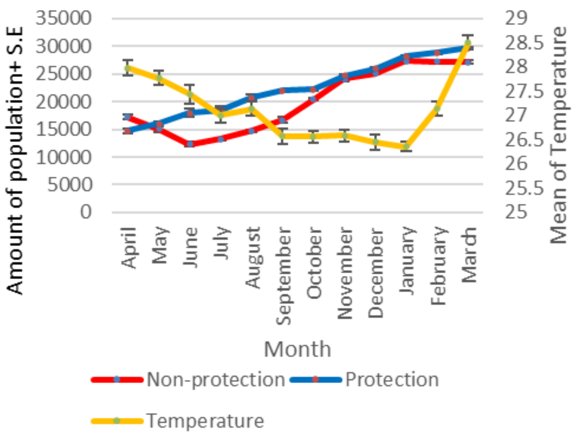

Figure 6. Relationship between population of *Apis cerana* in non-protected and protected beehive box methods toward temperature rate

Table 3. The Correlation between humidity and *Apis cerana* population in non-protected and protected beehive box methods.

		Non-protection	Protection
	Pearson Correlation	-0.033	-0.003
Humidity	Sig. (2-tailed)	0.608	0.960
	N	240	240

**Correlation was significant at the 0.01 level (2-tailed), r = Pearson's correlation coefficient, p = significance (2 tailed).

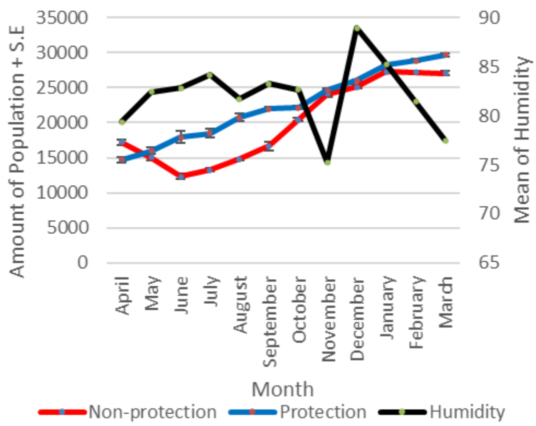

Figure 7. Relationship between population of *Apis cerana* towards humidity

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the efficiency of the honey bee production also depends on their genotype, internal hive factor, and external hive factors like temperature and humidity (Abou-Shaara *et al.* 2013; Tan *et al.* 2012).

A study supported by Abbott (2016) appropriates beehive conditions could increase the production of brood and later on promote an increment in the number of adult bees. A previous study by Erdoğan (2019) reported the population of bees in the insulated hives was 19.03% higher than the average of other types of hives such as wooden and polystyrene. In the findings of Abou-Shaara (2013), the population of the bee with modified hives through an insulating cover hive had better results compared to other hives in the case of the honey bee. Thus, the use of modified beehives was recommended for keeping honey bees under harsh environmental conditions and current ecological threats to beekeeping. Mujuni (2012) also reported minimizing space by building each house accommodating at least five (5) hives on a square meter area, this innovation ensures enough warmth inside the hives, and absconding of bee colonies was minimal. Five to ten years ago, many threats were faced by honey bees from pests and diseases in the world (Suresh, 2013).

4.2 Relationship between the population of Apis cerana in non-protection and protection methods beehives toward the amount of rainfall (mm)

The honey bee has a number of natural stress inducers and enemies including climatic, biological pests, predators, and diseases (Guyo and Solomon, 2015). Taha and AL-Kahtani (2019) mentioned that the honey bee activities depended on several factors that emerged simultaneously with some environmental conditions. In this study, the rainfall affected and contributed to the *Apis cerana* population. Meanwhile, the amount of rainfall in this study also highly fluctuated. The result showed a minimum rainfall of 1.57 mm in February 2019 and maximum rainfall of 13.45 mm in May 2018. A previous study by Kjøhl *et al*. (2011) reported that increasing temperatures, droughts and more frequent extreme events affected the plant-pollinator interactions. Additionally, weather parameters played a significant role in the development of the *Apis cerana* population.

In this study, the correlation between the population of *Apis cerana* toward the amount of rainfall as abiotic factors showed a significant negative correlation in the protection beehive box. This scenario explained that decreasing rainfall encouraged the bee population due to favourable conditions where bees were able to search for food. They also preferred to stay outside the beehive box safely. However, there was no correlation observed between *Apis cerana* and rainfall in non-protective beehives.

Rainfall was an important factor affecting the activity, distribution, and development of insects. The result of the present studies was parallel to the previous study by Kumar *et al.* (2015), the bees reduced the number of flights per day for foraging was influenced by rainfall because rainfall and strong wind tended to reduce the ground speed of bees. The observation regarding the population of *Apis cerana* towards the amount of rainfall was a negative correlation and significantly resulted in the protection method. It occurred because the beehives box has a zinc roof that protected the beehives from rainfall. Hemalatha *et al*. (2018) also reported that rainfall affects bees' activities because individual bees had not performed the foraging process. Climate change also affected the type and distribution of precipitation (rainfall). The long rainfall phenomenon was a crucial time for the bees and influenced the survival of its subsequent generations.

This study was aligned with the previous study by Puškadija *et al.* (2007) that during rainy days the honey bees stayed inside their beehives. The distribution and composition of the flower species surrounding the hives could have been affected by climate and subsequently caused changes in bee activities particularly searching (Le Conte and Navajas, 2008). According to Reddy *et al.* (2015), a negative correlation was observed that contributed to the decrease in the number of bees moved out from beehives and had increment to the death of bees during the heavy rain. Additionally, flight activity by *Apis cerana* and *Apis mellifera* dropped drastically during rain and preferred to be in their hives during rain (Abou-Shaara *et al.,* 2012). The excessive dry climate also leads to food shortage, reduced pollen production and impoverished nutritional quality (Stokstad, 2007). For instance, in a study by Mattila and Otis (2006), the pollen diet was a very important thing in mass rearing future bee workers. Meanwhile, the environmental changes gave negative effects on the immature stage of bees including the larva and migratory stages (Chagnon 2008). Furthermore, when the environment worsens, bees took an alternative way to stop brood rearing then prepared to abscond and migrate to an alternative seasonal nesting site (Woyke *et al*., 2012). When the bees swarmed, they did not return to the original nest but to a new nest in a closer area (Woyke *et al*., 2012).

The population of *Apis cerana* in non-protection beehives did not provide any significant effect which is probably due to high rainfall distribution, tropical forest and the site near with river. Water resource is important for all the life in the world (Falkenmark, 2020).

Previously, Nicolson (2009) and Seeley (2014) had mentioned that the honey bees used water for two reasons which are for cooling of the brood area by evaporation process on hot days and for feeding the larval brood when foraging is limited on cool days. Honey bees collect water, then distribute it around the hive, particularly on the cells consisting of eggs and larvae. Under extreme climatic conditions, the bee can load 44 mg of water. Despite all explanations, the results above showed that there was no relationship between rainfall (mm) with a non-protective method of the population of bee in the field and vice versa for protection method.

4.3 Relationship between the population of Apis cerana in non-protection and protection methods beehives toward the amount of temperature (°C)

This study was carried on to evaluated the relationship between the population of *Apis cerana* in different method practices toward the temperature. The result showed that temperature did not show a significant relationship with the bee population and this contradicted the previous study by Reddy *et al.* (2015). The temperature did not give any significant effects on the presence of *Apis cerana* population in both non-protection or protection beehive methods. In this study, the temperature did not give significant effects on the bee population. It was potentially due to the surrounding temperature that is suitable for their body temperature and could regulate the internal temperature of the beehives because the research site was conducted in tropical forest country. However, other studies mentioned that temperature was the most important abiotic factor that influenced honey bee activities (Corbet *et al*., 1993). The important factor of temperature could have caused the limiting bee flight and pollen availability (Jasmi *et al*., 2014) and a previous study by Chagnon (2008) reported that light intensity, rain, and relative humidity could also be a factor. Koetz (2013) also mentioned the greatest challenge in the mass rearing of *Apis cerana* was the high tendency of bees to abscond which was exaggerated by the warm, favourable conditions of tropical areas.

Another study found that the climatic factor such as ambient air temperature significantly influenced the honey bees' temperature precisely ectothermic honey bees because their body temperature closely followed the changes of ambient temperature (Reddy *et al*., 2015). Reddy *et al.* (2015) also claimed that an individual bee is unable to control its body temperature but a population of a honey bee colony are able to regulate the internal temperature of the beehives. Nevertheless, the nest of a normal colony is maintained at a constant temperature of 32°C. During foraging activity, honey bees were exposed to a broad range of temperatures which affected the thermoregulatory ability of individual bees (Kovac and Stabentheiner, 2011). In higher relative temperatures, a higher number of honey bees were found in nectar collection compared to pollen collection but more honey bees were found in pollen collection compared to nectar collection (Gebremedhn, 2014). A previous study by Hemaltha *et al*. (2018) also reported that the bee had positive relation toward maximum temperature by generating with pollen, nectar, and outgoing bee and the optimum air temperature was helping for effective bee foraging activity.

According to Stanbentheiner *et al.* (2010), larvae and pupae of the bee were strongly dependent on the accurate regulation of brood nest temperature for proper growth. If the bees were under extreme conditions, they had to put extra effort to maintain and regulate their body as well as colony temperature which impacted foraging efficiency. Puškadija *et al*. (2007) claimed that the flight activity of worker honey bees influenced the temperature in hives. Bees could resist to high temperatures as 45°C-50°C but if the temperature drops below 35°C, it caused drastically lower down foraging activity and halted the activity when the environmental temperatures reached 40°C, while their thoracic temperature reached a maximum of 45.3°C. The ideal temperature for bees according to Manoj *et al.* (2017) and Subbiah (1956) reported that the maximum day temperature of 34.4°C, long diurnal hours of sunshine and partly sunny were the ideal weather for good brood rearing activity of bees.

A previous study done by Reddy *et al.* (2015) revealed that some of the honey bees had the ability to forage above 30°C range of air temperature but it depended on their behavioural and physiological mechanism of regulating the temperature. In addition, the low humidity and higher temperature affected the flight activity of honey bees (Alqarni, 2006; Stanbentheiner *et al.*, 2010; Reddy *et al.,* 2015). As a result, the number of pollen collectors was little compared to the nectar and water collectors at high temperatures. During ambient temperatures, pollen foraging was decreased and carried relatively little fluid as a reaction in higher thoracic temperatures of pollen collectors along with water and nectar collectors (Alqarni, 2006). A previous study found that higher thoracic temperature was also detected due to incremental insolation in bee workers after foraging activity (Cena and Clark, 1972; Heinrich, 1979; Cooper *et al*., 1985) and during nectar (Kovac and Stabentheiner, 2011) and water collecting.

Additionally, the activity of foraging was low during late afternoon hours because of higher temperatures. Therefore, to maintain the colony temperatures in the beehive, a higher number of bees are needed in the beehives but the number available for foraging was less. The finding in the present study was important to the point of view of climate change. The changes in global temperatures were lead to disrupting the relationship between flowers and bees (Wang *et al*., 2009). The increase in global temperature would reduce the number of bees foraging activity which affected the pollination efficiency.

Extreme climatic conditions caused another implication where honey bees collected and loaded more water used for cooling of the brood when foraging was limited on cool days. Meanwhile, on cold days at environment temperatures of 5°C, the honeybees started collecting water, whereas their thoracic temperature was in between 37°C, and 38.5°C even under an ambient temperature of 30°C. Honeybee started to collect the nectar when the ambient temperature was close to 13°C (Kovac and Stabentheiner, 2011).

Based on the explanation above, it clearly showed that temperature plays a direct role in foraging activities of bees mainly on external beehives where it supports the results above in which temperature does not have any relationship in the population of *Apis cerana* particularly in the beehives box because this study more focusing the outside temperature or surrounding area but not measuring temperature inside the box. Probably because the outside temperature in the tropical condition is suitable with their body temperature, bees are able to adapt and regulate the inside temperature of the beehives. Based on the explanation above, the foraging activity of bees are also influenced by surrounding temperature of beehives where the experiment was precise on.

4.4 Relationship between the population of Apis cerana in non-protection and protection methods beehives toward the amount of relative humidity (%)

This study evaluated the relationship between the population of *Apis cerana* and the humidity in non-protection and protection method practices. The result showed that relative humidity was recorded with a minimum of 75.27% and a maximum of 88.96%. According to Reddy *et al*. (2015) and Human *et al.* (2006), one of the important factors in the growth of brood and egg hatching was relative to humidity. In this study, there was no correlation between the population of *Apis cerana* and relative humidity. Relative humidity did not give any significant effects on the presence of *Apis cerana* in non-protection or protection methods. The result of this study aligned with a previous study done by Polatto *et al.* (2014), whereby relative humidity values in the field were not extreme enough to be considered as factors to affect the bees activities. The present study also contradicted the previous study (Reddy *et al*., 2015) where the relationship between relative humidity and foraging activity was significant and found to have positive correlations.

According to Reddy *et al*. (2015) and Joshi and Joshi (2010), relative humidity gave little effect on the flight activity of *Apis* species but the combination of humidity and temperature affected the availability of pollen. Therefore, high humidity and low temperature increased bee activities but slowed down the release of pollen. Thus, it contradicted with this study which could be compared to another study done by Gebremedhn and Tadesse (2014), revealing the air temperature had a positive correlation with the number of nectar collecting bees and relative humidity which had a negative correlation with the number of nectar collecting bees. This statement clearly showed that relative humidity played a critical role in the foraging activity of bees mainly at external beehives, however, relative humidity did not influence the population of *Apis cerana* in the beehive box.

5. Conclusion

This study concludes that the protective beehive box method is able to reduce predators' attack and subsequently reduce the mortality rate of bee colonies which contributed to the significant increase of colonies growth. Obviously, the protected beehive box could enhance the performance of the bees colony in the beehive box compared to the unprotected beehive box. As a result, the income of farmers would increase considerably and consistently due to the protection beehive box methods that would enhance the performance of colonies for the whole rearing process. There was also no obvious significant relationship between the population of *Apis cerana* with their abiotic factors whether in non-protected method or protected method except rainfall in protection beehives. For unprotected beehive box methods also showed that the increasing amount of rainfall would decrease the number of *Apis cerana* population. However, this study found that with the increase of rainfall, the *Apis cerana* population in the protection beehives box still increases. Even though, rainfall affects bee activities as well as the distribution and development of bees' colony, the protected beehive box method is able to protect the colonies. On top of that, other beekeepers facing similar problems in the mass rearing of *Apis cerana,* particularly in the beehive box in relation to climatic factors and predatory's problems could follow and develop the

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protection beehive box method practices. By doing so, the main problems and issues can be resolved and encourages the apiculture industry.

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