ASSESSMENT OF PESTS AND PREDATORS INFESTATION, AND THE PERFORMANCE OF HONEYBEE (*Apis cerana* FABR.) COLONIES IN LANGSTROTH MODIFIED BEEHIVES (LMB)

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ABSTRACT

This study was carried out from June 2016 to December 2019 at the Faculty of Sustainable Agriculture (FSA), Universiti Malaysia Sabah, Sandakan, Malaysia. The objectives of this study were to (i) assess how the prevalence of pests and predators, alongside other factors, may be causing honeybees to abscond from the existing beehives commonly used by local beekeepers; and (ii) investigate the efficacy of newly improved beehives in preventing the intrusion of pests and predators, and the potential impact this has on honeybee health performance. To determine what other factors cause bee abscondment in relation to the prevalence of pests and predators, ten new colonies of *Apis cerana* bees-all with equal health performances were examined for ten weeks in Langstroth Beehives (LBs), which are commonly used by the local beekeepers of Malaysia. To compare honeybee health performance with regard to the efficacy of beehives, ten of the same bee colonies were examined for 20 weeks, also equal in terms of health performance, were introduced to, and studied in, new Langstroth Modified Beehives (LMBs) (5 replications) and LB Beehives (5 replications). The honeybee pests and predators identified during the inspection of the LBs were wax moths, hornets, ants, cockroaches and mites. Combinations of infestation by wax moths, hornets, ants and cockroaches were found in 60% and 90% of LBs, and were determined to be the cause of honeybee abscondment. This, therefore, indicates that one of the significant challenges of beekeeping faced by local beekeepers is the existence of pests and predators in the environment. LMBs had a greater number of frames filled with more than 80% of brood combs (N = 12), honey (N = 24) and pollen storages (N = 19) than LB beehives. Low infestation rates of pests and predators in LMBs could be explained by the improvements made on the beehives' design, which prevented the intrusion of wax moths, cockroaches, and hornets into the hives.

Thus, this suggests that improving the beehives' capacity for protecting the bee colonies is crucial in reducing abscondment and increasing bee products.

Keywords: *Apis cerana*, abscondment, beehive improvement, honeybee, pest, predator

ABSTRAK

Kajian ini telah dijalankan dari bulan Jun 2016 hingga Disember 2019 di Fakulti Pertanian Lestari (FSA), Universiti Malaysia Sabah, Sandakan, Malaysia. Objektif kajian ini adalah untuk (i) menilai bagaimana kelaziman perosak dan pemangsa bersama dengan faktor lain, menjadi penyebab kepada lebah lari meninggalkan sarangnya dari sarang sedia ada yang digunakan secara meluas oleh pemelihara lebah tempatan; dan (ii) menyiasat keberkesanan sarang yang telah ditambahbaik untuk mencegah pencerobohan perosak dan pemangsa, serta potensinya dalam meningkatkan prestasi kesihatan lebah madu. Untuk menentukan faktor-faktor lain yang menyebabkan lebah lari meninggalkan sarangnya akibat prevalens perosak dan pemangsa, sepuluh koloni baru *Apis cerana* - semuanya dengan prestasi kesihatan yang sama - dikaji selama sepuluh minggu di sarang Langstroth Beehives (LB) dan sarang ini telah digunakan dengan meluas oleh pemelihara lebah tempatan Malaysia. Bagi membandingkan prestasi kesihatan lebah dan perkaitannya dengan keberkesanan sarang bagi koloni yang mempunyai prestasi kesihatan sama, keberkesanan penggunaan haif baru yang diubahsuai iaitu Langstroth Modified Beehives (LMBs) (5 replikasi) dibandingkan dengan sarang LB (5 replikasi) juga dikaji selama 20 minggu. Perosak dan pemangsa lebah madu yang dikenal pasti semasa pemeriksaan sarang LB selama 10 minggu adalah rama-rama lilin, tebuan, semut, lipas dan kutu. Kombinasi serangan perosak oleh rama-rama lilin, tebuan, semut dan lipas yang dijumpai pada sebanyak 60% dan 90% haif LB telah dikenalpasti sebagai penyebab lebah lari meninggalkan sarangnya. Oleh itu, keadaan ini menunjukkan bahawa salah satu cabaran penting pemeliharaan lebah yang dihadapi oleh pemelihara lebah tempatan adalah kewujudan perosak dan pemangsa di persekitaran. LMB mempunyai lebih banyak bingkai yang dipenuhi dengan lebih daripada 80% sisir *brood* (N = 12), dan penyimpanan madu (N = 24) dan debunga (N = 19) berbanding sarang LB. Kadar serangan perosak dan pemangsa yang rendah di LMB dapat dijelaskan oleh penambahbaikan yang dibuat pada reka bentuk sarang lebah, yang dapat mencegah pencerobohan rama-rama lilin, lipas dan tebuan ke dalam sarang. Oleh itu, ia menunjukkan bahawa peningkatan keupayaan sarang lebah bagi melindungi koloni adalah sangat penting untuk mengurangkan aktiviti lebah lari meninggal sarang dan meningkatkan produk lebah.

Kata kunci: *Apis cerana*, meninggalkan sarang, penambahbaikan sarang lebah, lebah, perosak, pemangsa

INTRODUCTION

Many studies have shown that the livelihood of rural communities is highly dependent on subsistence agriculture, as they provide substantial additional income security (Bernama 2020; Mohd Mansor 2014), for example the agriculture and beekeeping. Honeybees provide a vast range of products for humans to enjoy; from honey to other bee produce, such as pollen, beeswax, royal jelly, venom and more. There was a study on the resin collection behavior of the stingless bees in the rural area to enhance the meliponiculture (Mohd Fahimee et al. 2019). In Sabah, *Apis cerana* (Hymenoptera: Apidae) is the most common species of honeybee being domesticated in the rural areas (Koeniger et al. 2010). The modern beekeeping practices were being promoted by Department of Agriculture Sabah, Malaysia (Sabah DOA) and Rural

Development Corporation (KPD) since the 1990s, which mainly operates in the northern areas of the Sabah via contract farming. Despite tremendous local demand, the yield of bee products, like honey obtained from the apiary industry, is still less than the potential of the state of Sabah (Ministry of Agriculture & Food Industry, Sabah 2015). The yield of domestic honey in Sabah has drastically dropped during the past few years, which has been attributed to population declines in honeybee colonies operated by rural beekeepers (Bernama 2017). Thus, it is crucial to assess the beekeeping production system in Sabah to identify the primary constraints on community beekeeping and possible hive modifications that would be suitable for local bee species and their habitat requirements.

Nowadays, bees such as *Apis cerana* and *A. mellifera* are commercially valuable as essential plant pollinators, and for the high demand of their products, like honey and wax. The decline in the population of honeybees due to agricultural chemicals, pests, predators and diseases is of great concern to many countries around the world, including those in Asia (Abdulhay & Yonius 2020; Kajobe et al. 2016; Norowi et al. 2010; Shimanuki & Knox 2000). In the tropical regions, beekeeping is threatened by various pests, predators and diseases, which often lead to economic losses (Abdulhay & Yonius 2020; Kajobe et al. 2016). In most cases, these pests, predators and diseases can also interact with each other, which in turn affects the health performance of the honeybee colonies, and reduces the yield of bee produce (Forfert et al. 2015). Therefore, it is vital to maintain a healthy honeybee population to ensure the supply of honey and other bee products is adequate enough to meet the domestic market demand. Despite the high potential of Sabah for beekeeping, its beekeeping practices and involvement in the development of beehive technology require improvement.

In Asia and Southeast Asia, the most damaging pests and predators identified in beekeeping are the wax moths and hornets, which often cause honeybee colonies to abscond their hives (Chantawannakul et al. 2016; Koeniger et al. 2010; Oldroyd & Nanork 2008). Despite the extensive growth of the apiculture industry in Malaysia, studies on the prevalence of pests and predators in beekeeping are limited. The wax moth (Lepidoptera: Pyralidae), is the primary pest of *A. cerana*, and was first recorded in Asia before spreading to Africa, Europe, America and New Zealand (Kwadha et al. 2019). Two species of wax moths, namely the greater wax moth (*Galleria mellonella*) and lesser wax moths (*Achroia grisella*) are the most devastating pests to beekeeping (Ellis et al. 2013; Sarwar 2016). The damage caused by *G. mellonella* larvae is severe in tropical countries, and it is this pest that is responsible for the decline in the honeybee population (Kwadha et al. 2019). The economic loss incurred by beekeepers from wax moths stems from the larvae of these moths infesting and destroying the bee combs, including the bee products within them, such as wax, pollen and honey. In Southeast Asia, hornets, such as *Vespa* sp., pose a severe threat to honeybees. Hornet worker bees hunt honeybee guards and returning bee foragers by waiting on the landing boards or hovering in front of the latter's hives (Sarwar 2016). The honeybee colonies generally become weak after such pests and predators attack, experiencing a decline in the number of bee workers looking after the queen, which in turn leads to a suspension of brood rearing and foraging, before ultimately absconding (Ellis et al. 2013; Sarwar 2016). Abscondment in beekeeping is defined as the complete abandonment of the beehive by the whole colony, which indicates that the beehive is incompatible with the bees' habitat requirements (Pokhrel et al. 2006). Therefore, regular monitoring of the health of a beehive and early diagnosis on possible infestations of pests and predators can greatly reduce honeybee absconding behaviour, however, such data is limited.

There have been many innovations in beekeeping worldwide, and one of the most famous beehives designed for beekeeping of the *A. mellifera* was made by Lorenzo Langstroth in 1851. The Langstroth hive has removable frames, which allows beekeepers to inspect and remove each frame individually. Due to the differences in colonies and the sizes of bees, the size of Langstroth hives for *A. cerana* in the tropical region, including the state of Sabah, were built smaller than usual. Since 1990, there have been no initiatives undertaken in Sabah to improve the design of beehives to possibly control the abscondment of bees by reducing the intrusion of pests, even though beekeepers within the state of Sabah are interested in rearing honeybees to increase their income. A study conducted by Tulu et al. (2020) in Southwestern Ethiopia corroborates that frequent pest and predator intrusion into beehives have led to bee colony abscondment, and that the reduction in the amount of honey yielded was among the major incentives for improving upon the condition of beehives used by local beekeepers. Hence, it is important to evaluate whether the existing Langstroth hives have had an effect on the high absconding rates of honeybees, as well as examine the prevalence of pests and predators plaguing Sabah's beekeeping practices. This study, therefore, was initiated with the following objectives: (i) to assess the prevalence the pests and predators, and other factors causing honeybees to abscond from the existing beehives used by local beekeepers; and (ii) to investigate the efficacy of newly improved beehives in preventing the intrusion of pests and predators, and the potential impact this has on honeybee health performance.

MATERIALS AND METHODS

Study Sites and Beekeeping Research Designs

The field diagnostic data on the factors affecting honeybee abscondment and the testing of the newly designed beehives' efficiency were carried out from June 2016 to December 2019. The study was conducted at the Faculty of Sustainable Agriculture, Universiti Malaysia Sabah (UMS), Malaysia located in the district of Sandakan.

Data Sources and Methods of Data Collection

Prevalence of pests and predators, and the determination of factors causing honeybee abscondment in Langstroth Beehives (LBs)

To determine the factors causing bee abscondment in relation to the prevalence of pests and predators, ten colonies were kept in Langstroth beehives (LBs), which were then placed under the shade of trees and were studied for ten weeks. LBs are commonly used by the local beekeepers of Sabah, and consist of eight movables frames. In this study, each beehive contained five empty frames and three frames filled with combs covered by healthy bees. The numbers and types of pests and predators, such as wax moths, wasps, ants and cockroaches that had infested the colonies were counted three times a day, every day, for ten weeks. The abscondment rate of bee colonies from each hive were also recorded, after an acclimatisation period of two weeks had passed. The research method performed in this study was modified from Pokhrel et al. (2006).

Efficacy of Langstroth Modified Beehives (LMBs) in preventing the intrusion of pests and predators, and honeybee health performance

Ten new bee colonies of *A. cerana*, all of equal health performance, were placed in both Langstroth modified beehives (LMBs) and standard Langstroth beehives (control); with each hive containing five colonies, respectively. The LBs, which are the kind most commonly used by local beekeepers, were used as control beehives. All colonies in the LMB and LB beehives consisted of five empty frames and three frames containing combs covered by healthy bees,

stored food, a brood and a queen. All colonies were placed in shade to avoid the direct impact of scorching sunlight.

Langstroth Modified Beehives **(LMBs)**

The LMB, which was constructed out of plywood, had three small holes, each with a diameter of one cm, cut into the back of the hive for ventilation purposes; and a circular entrance with the diameter of two cm (Figure 1). A knitted wire mesh was used to cover the three holes and the top of the LMB, in order to prevent pest intrusion into the hive (Figure 1). For the hive entrance, a 1 cm x 1 cm wire mesh was installed as fence that would prevent wasp infestation, but could easily be entered by the bees.

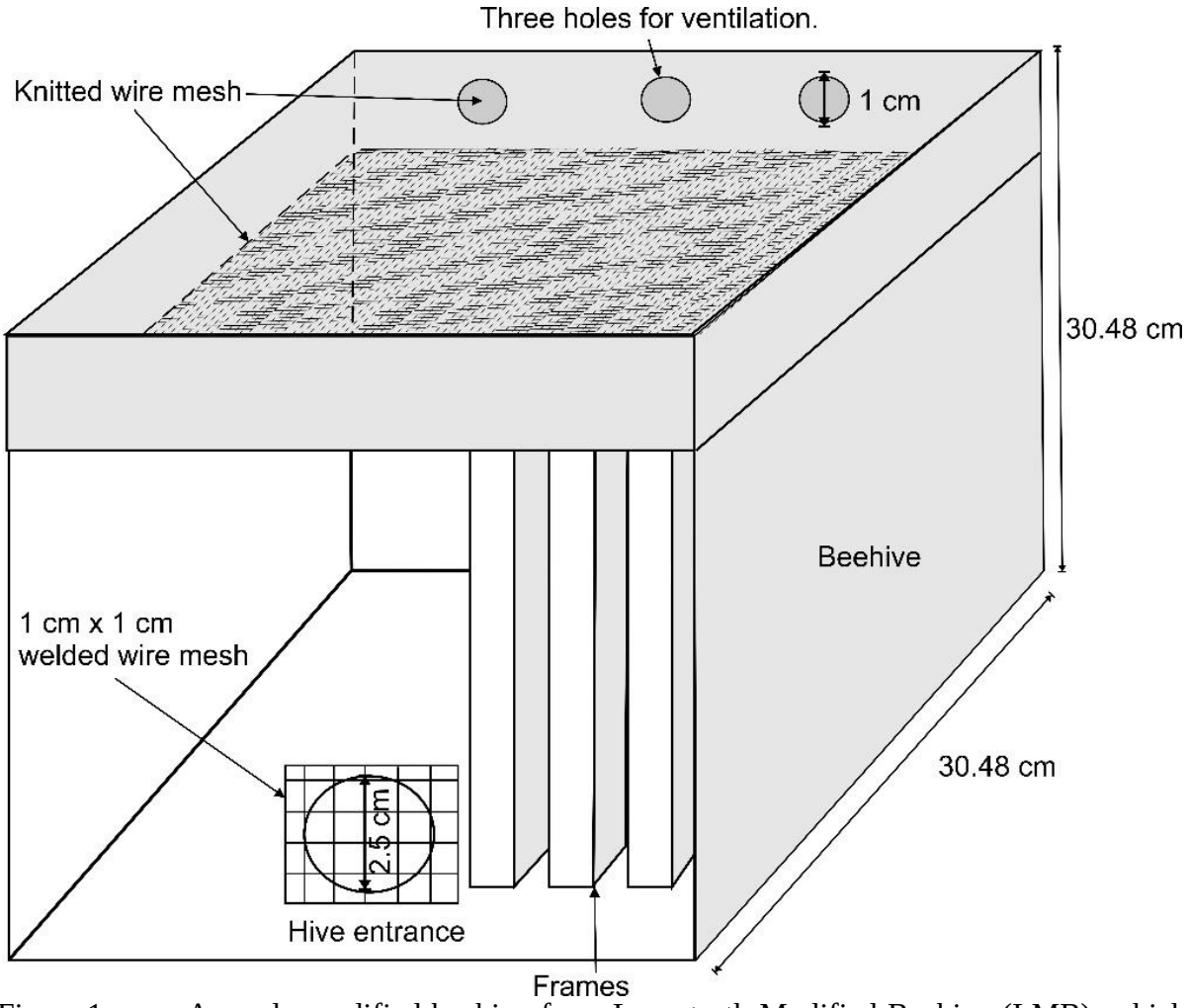

Figure 1. A newly modified beehive from Langstroth Modified Beehive (LMB), which was constructed out of plywood

Determination of honeybee health performance and pest intrusion into the LMBs and LBs

Observations on pest intrusion and the health performance of the honeybees were conducted for twenty weeks. For the assessment of the efficacy of the beehives in preventing pest and predator intrusion, the number and type of pests and predators, such as wax moths, hornets, ants and cockroaches, were counted thrice every day, after a two week acclimatisation period for the bee colonies had passed. Furthermore, the pest and predator activity outside each hive was monitored for approximately two minutes a day every week. For assessment on brood

performance, pollen and honey storages, the bee combs were ranked and categorized as shown in Figure 2, Figure 3 and Figure 4. This system was adopted from Pirk et al. (2013). Excluding the three frames containing bee combs provided previously, the tabulation for colony performance in each of the hives were only performed on frames that had new weekly brood, honey or pollen developments.

Figure 2. Frame filled with > 80% of bee comb and containing brood cells /pollen /honey, which was given Rank 1

Figure 3. Frame filled with > 51% of bee comb and containing brood cells /pollen /honey, which was given Rank 2

Figure 4. Frame filled with < 50% of bee comb and containing brood cells /pollen /honey, which was given Rank 3

Statistical Analysis

Data frequencies, tables and graphs were generated using Microsoft Excel 2017. Means and standard error (SE) were calculated for the number of pests and predators and the percentage efficacy of the hives. All statistical analyses were conducted using SPSS version 26. A non-parametric Mann-Whitney U test was performed to investigate differences in rank categories of brood performance, pollen and honey storages between LMBs and LBs ($p \leq 0.05$).

RESULTS AND DISCUSSION

Prevalence of Pests and Predators, and the Factors Causing Honeybee Abscondment in Langstroth Beehives (Lbs)

The honeybee pests and predators identified during the inspection of the beehives commonly used by local beekeepers in Sabah were wax moths, hornets, ants, cockroaches, and mites (Table 1). Domestic honeybee species were subjected to many types of pests and predators, with some attacking the adult bees and stored food in the hives (Monceau et al. 2018; Pokhrel et al. 2006; Tan et al. 2013). Nearly all countries in the tropical region reported that wax moths, hornets and ants are significant enemies of the honeybee, which frequently cause colonies of *A. cerana* to become weak and abscond (Gela et al. 2017; Kebede et. al. 2015). From the ten hives inspected in this study, 90%, or 9 out of 10, of the colonies were emptied due to abscondment caused by pests and enemies of the bees (Table 1). Wax moths, hornets and cockroaches had infested almost all studied beehives, totalling to 90% of all the hives becoming infested (Table 2). This finding was also in line with many studies that have indicated that one of the significant detriments to beekeeping were the existence of local pests and predators (Gela et al. 2017; Jatema & Abebe 2015; Kebede et al. 2015; Monceau et al. 2018; Pokhrel et al. 2006; Tan et al. 2013).

In tropical and subtropical Asia, the greater wax moth is said to be the most destructive pest of *A. cerana* (Ambaw et al. 2020; Hanumantha Swamy 2007; Sarwar 2016; Vijayakumar et al. 2019). In India, the wax moth attacks on honeybee colonies have caused massive

economic losses, which can reach up to a 70% financial loss for beekeepers every year (Vijayakumar et al. 2019). The wax moth larvae damages both honeybee colonies and bee products (Ellis et al. 2013; Kwadha et al. 2019). In this study, the presence of wax moths in the colonies were identified by checking the occurrences of larvae and silken galleries on the brood and honeycombs in the hives. The overall total of hives with at least one colony infested by wax moths was 90% (Table 1 and Table 2). Wax moths are attracted to combs that had been previously used by brood, and contained old stored pollen. They laid eggs in the cracks and crevices of the hives, which they had entered at night. Once their eggs hatched, the larval stages of wax moths were responsible for causing extensive damage to both bee combs and the brood frames of the hives. Then, they quickly destroyed the stored beeswax, particularly in weaker colonies with many unattended combs. The continuous infestation caused the colonies to be weakened and absconded. This study also observed that the feeding habits of the wax moth larvae also reduced the wax combs to debris and silk.

Sarwar (2016) reported that the frequent attacks of hornets on the beekeeping of *A. cerana* often caused colonies to abscond in many tropical countries. The hornet was one of the most common predators of honeybees found in this study (Table 1 and Table 2). In Malaysia, there are twenty-three species of hornets of *Vespa* sp. and *Provespa* sp., which are considered to be the most prevalent predators for domestic honeybees (Martin 1995). In this study, the most frequent attacks on honeybees by the hornets was recorded on week six, when the attackers began to realise that food sources were plentiful in the apiary area (Table 1). Hornet workers frequently hunted honeybee foragers that were returning to their hive by hovering around the beehives and staying on the landing boards in front of the hives. The strong jaws of the hornets mauled the bees, and dropped the carcasses to the ground. The repeated attacks of the hornets on the hive could have caused the bees to lose too many of their soldiers, thus leading to colony abscondment. During the study, the hornet invasion on the *A. cerana* colonies observed in the sixth week caused the bees to abscond by the seventh week (Table 2). Once the hornet entered into a beehive, they would kill the developing larvae and pupae of the honeybee before bringing their prey to their nest to feed their young larvae.

All types of ants have been reported to be a nuisance to the beekeeping of *A. cerana* in the tropical region of Asia (Sarwar 2016). In this study, the ants entered the beehive to establish their nesting site, or to steal honey and pollen, particularly those of bees with weaker colonies. Sometimes they attacked the bee colonies by taking the adult bees and brood, regardless of whether they were dead or alive. Some studies have reported that ants were often challenging to control once they had established their colonies in the beehives, where they often destroyed the weak bee colonies (Aryal & Dhakal 2020).

Minor pests and predators of honeybees, which can be periodically controlled using cultural or chemical techniques, were grouped as non-severe threats. This includes mites and cockroaches (Table 1 and Table 2). Although this study reports that cockroaches were found in nine out of ten hives, they did not cause severe damage to the bee combs or beehives (Table 1). The cockroaches were observed to be inside beehives that contained bees of weakened colonies, and they mainly fed on pollen, wax and debris discarded by the bees. Two species of mites that were identified in this study were the *Periplaneta americana* and the *Blattella germanica*. This study found that only a small number of mites infested the beehives, and only those with weakened or underpopulated bee colonies.

Table 1. Prevalence of bee pests and predators among Langstroth beehives, which are commonly used by local beekeepers, as observed over the course of 10 weeks

Pests and predators	No. of infested hives (N = 10)	Week that pests and predators began to attack the colonies (in or outside the hives)	The proportion of infected hives (%)
Wax moths	9	Week 2	90
Hornets	9	Week 6	90
Ants	1	Week 5	10
Cockroaches	9	Week 4	90
Mites	1	Week 7	10

Pests and predators were observed at 8am, 12pm and 3 pm in a day / daily / weekly.

Table 2. Pest and predator combinations causing bee abscondment, observed for 10 weeks

Pest and predator combinations in infected hives	Langstroth beehives (N = 10)	Colony abscondment observed during the study period	Proportion (%) of hives affected by a combination of pests and predators
Mites,	1	No abscondment	-
wax moths, cockroaches, ants & hornets	3	Week 7	30
Wax moths, cockroaches & hornets	3	Week 7	30
Wax moths & cockroaches	3	Week 7	30

Colonies health performance and the efficacy of Langstroth Modified Beehives

There was a significant difference between the LMBs and LBs for the brood combs development (Mann-Whitney U test; $U = 182$, $N = 50$, $p < 0.01$), honey storages (Mann-Whitney U test; $U = 128$, $n = 50$, $p < 0.001$) and pollen storages (Mann-Whitney U test; $U = 645$, $N=50$, $p<0.001$). Table 3 shows that the LMBs had more frames filled with over 80% of brood combs (N = 12), honey (N = 24) and pollen storages (N = 19) than the LBs. This finding was consistent with previous studies showing that innovative beehive conditions increase the efficiency of beekeeping by increasing colony health performance (Tan et al. 2013). Tarekegn & Ayele (2020) also reported that the adoption of improved beehive designs, by beekeepers in Ethiopia, had a positive and significant effect on the production efficiency of honeybees.

Table 3. Total number combs concerning honey and pollen categories measured in the LMBs and LBs, as observed over the course of 20 weeks

Food storage	Beehive types	Median Rank	N	Rank categories (n)			IQR
				>80%	>51%	<50%	
Honey	LMB	18.12	25	19	2	4	1-1.5
	LB	32.88	25	1	14	10	2-3
Pollen	LMB	15.58	25	24	0	1	1
	LB	35.42	25	4	4	17	2-3
Brood	LMB	20.28	25	12	7	6	1-2.5
	LB	30.72	25	4	8	13	2-3

Note: LMB= Langstroth Modified Beehive, LB=Langstroth Beehive. IQR = Interquartile Range

The results in Table 4 also show that the LBs contained more pests and predators than the LMBs, and that pest infestation in the LBs began in the third week, whereas it only began

in the LMBs in the seventh week. The lower and later infestation rates in the LMBs could be explained by the installation of the 1 cm x 1 cm wire mesh at the entrance of the hive, which acted as fence that prevented the entry of hornets (Figure 1 and Table 4). Hornet activity in each colony were monitored for about two minutes per day every week, and they were often seen trying to unsuccessfully enter the LMBs, which had their entrances covered by wire mesh, something the LBs did not. In addition to this, several bees guarding the front and direct behind of the fence were also observed in most LMBs, which probably discouraged other pests, like wax moths and cockroaches, from trying to enter the hive. The guard bees play an important role in colony defense, which includes ensuring colony brood survival (Nouvian et al. 2016). Breed et al. (2004) found that hive guarding is performed by bees to check whether the incoming bees are their nestmates, and to detect any signs of threat by pests and predators. This study also found that bees colonies' abscondments were more common in LBs, but not recorded for LMBs (Table 5). A study in Saudi Arabia by Abou-Shaara et al. (2013) found that improving beehives' conditions had increased the size of bee colonies and stored pollen areas due to less intrusion of pests and predators into the beehives. Thus, this suggests that improving the beehives' capacity for protecting all bee combs is very important in ensuring the survival of bee colonies.

Table 4. Prevalence of bee pests and predators in LMBs and LBs, observed for 20 weeks

Beehive Type	Pests and predators	No. of infested hives	Week of pests and predators observed in the beehives	The proportion of infected hives (%)
LB (N=5)	Wax moths	3	Week 3	60
	Hornet	4	Week 4	80
	Ants	2	Week 5	40
	Cockroaches	1	Week 5	20
	Mites	1	Week 6	20
LMB (N = 5)	Wax moths	1	Week 7	20
	Hornet	0	-	0
	Ants	1	Week 15	20
	Cockroaches	0	-	0
	Mites	0	-	0
	Wax moths	0	-	0

*Note: LMB= Langstroth Modified Beehives, LB=Langstroth Beehive

Table 5. Pest and predator combinations causing bee abscondment that were observed in LMBs and LBs for 20 weeks

Beehive Type and total hive (N)	Pest and predator combinations in infested hives	Total beehives	Colony abscondment observed during the study period	Proportion (%) of hives affected by a combination of pests and predators
LB (N=5)	Mites	1	No abscondment	-
	Wax moth & hornet	3	Week 5	90
	Wax moth, cockroaches & hornet	3	Week 7	60
	Wax moth & ants	3	Week 7	90
LMB (N = 5)	No data	No data	No data	No data

CONCLUSION

Although the present findings did not detect any diseases affecting the health of bee colonies, frequent and high intrusion rates by pests and predators into the beehives led to bee abscondment, and may pose a severe threat to the beekeeping industry of Sabah. This study also found that bees colonies' abscondment were more common in existing LBs, which are currently being widely used by the local beekeepers. Overall, the results of this study suggest that improving the design of beehives, such as the LMB model, reduces the intrusion of pests and predators into the hives, thus enhancing the amount of bees' colonies, stored pollen and honey storages.

ACKNOWLEDGEMENTS

This study was funded by the University of Malaysia Sabah's internal grants of SDK0068-2018 and SBK0285-STWN-2015. We are thankful to the Sabah Rural Development Corporation (KPD) for their assistance during fieldwork. We would also like to thank the Faculty of Sustainable Agriculture, UMS that made this study possible.

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