Synergistic Effect of Synthetic Pheromone and Kairomone-Releasing Food Baits in Mass Trapping System of Red Palm Weevil, *Rhynchophorus ferrugineus*

*M H Muhammad Firdaus¹, T S Chuah² and A A Wahizatul¹*

¹Faculty of Science and Marine Environment, Universiti Malaysia Terengganu, 21030, Kuala Nerus, Terengganu, Malaysia
²Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA Perlis, 02600, Arau, Perlis, Malaysia
wahizatul@umt.edu.my

Abstract. The red palm weevil (RPW), *Rhynchophorus ferrugineus* is one of the most damaging pests of major cultivated palms worldwide, and is a serious threat to Malaysia’s coconut and oil palm industries. Current tactic to manage the weevils are largely based on aggregation pheromone traps. Thus, it is crucial to come up with an effective method to manage the pest based on pheromone based mass trapping system before it causes any significant economic losses. In the present study, the synergistic effect of synthetic pheromone and kairomone-releasing food baits was evaluated in highly infested area of Kuala Terengganu. Pineapple food bait was the most effective in capturing RPW with the greatest capture of weevils (12 individuals/trap), followed by oil palm petiole (10.8 individuals/trap), sugarcane (7.6 individuals/trap), and the lowest capture was coconut fruit (6.6 individuals/trap). More females (166 individuals) were trapped than males (54 individuals) with the sex ratio (1 male: 3.1 females). In terms of environmental parameters, the higher amount of rainfall and relative humidity, the lower the numbers of captured weevils were observed. In contrast, higher reading of weekly temperature influenced higher numbers of captured weevils. The inconsistency weather during monsoon season should be considered in implementing the mass trapping system of RPW. Finding from this study is important for a more effective and long-lasting method of pheromone based mass trapping in integrated RPW control strategy program.

1. Introduction
The red palm weevil (RPW), *Rhynchophorus ferrugineus* Olivier (Coleoptera: Dryopthoridae) is the major destructive insect pest of a broad range of palm trees [1]. RPW is also known as the Asian palm weevil and regarded today as one of the worst pests of coconut, *Cocos nucifera* in South and Southeast Asia [2] [3]. In India and Sri Lanka, RPW is a serious pest of oil palm [4], while in the Middle East, the RPW is the most dangerous pest of the date palm, especially in Saudi Arabia, Egypt and the United Arab Emirates [5].

RPW infestation was first detected in Malaysia in 2007 by the Department of Agriculture (DOA) in all seven Terengganu districts [6]. An intensive 3-month survey in 2011 throughout Terengganu in over 800 ha of coconut plantations, villages, parks and in the Federal Land Development Authority (FELDA) plantations in all districts indicated that RPW infested as many as 55 000 coconut trees, showing a drastic increase and rapid spread of RPW population [6]. Recently in 2016, the weevil has been found in Perlis, Kedah, Pulau Pinang, Terengganu and Kelantan which indicated a drastic increase and rapid spread of RPW population in Malaysia [7].

The symptoms of attack by RPW at the early stage of infestation are difficult to detect as RPW is a concealed tissue borer. The signs of wilting, drooping of dried leaves like an umbrella-shaped or skirting-shaped leaves showed the severely infested coconut palms [6]. Current tactics to manage RPW are largely based on insecticide applications although there are now deep concerns about environmental pollution. Now there is also a strong emphasis on the integrated pest management (IPM) strategy based on pheromone traps and biological control rather than insecticides. Pheromone trapping of RPW is an
effective method to manage populations of this palm pest [8]. The most effective and environmentally sound method is the food-baited pheromone trap [9][10].

Since RPW is a lethal pest for cultivated palms, this invasive weevil will be a threat to the coconut industry and could threaten the survival of oil palm plantations, which represents the backbone of Malaysia’s commodities market. Many studies about the management in controlling this weevil population have been reported, but few studies conducted involving Malaysia. The current method implemented by DOA Terengganu is using food baits in pheromone-based mass trapping system. Therefore, in order to improve the efficiency of pheromone-based mass trapping system of RPW, this study was designed to investigate the effectiveness of kairomone-releasing food baits (i.e. sugarcane, pineapple, coconut fruit and oil palm petiole) in the pheromone trapping of RPW; and to determine the influence of ecological factors (e.g. temperature, relative humidity and amount of rainfall) on the efficacy of different kairomone-releasing food baits.

2. Materials and Methods

2.1 Study Site
The study was conducted at Kampung Jeram, Manir, Kuala Terengganu (05°20’N 103°03’E) from August to November 2013. The study site was located in the district of Kuala Terengganu. The village location lies 12 km to the north of the state capital of Kuala Terengganu and 10 km from Sultan Mahmud Airport. The study was conducted at this village due to the coconut trees in this area exhibited signs of being under infestation by RPW.

2.2 Trap Design and Trap Contents
The trap design is based on previous report with minor modifications [11]. The pheromone traps was designed by using 7 L of dark blue polypropylene bucket with four holes cut below the upper rim of the bucket. The distance between the holes was 10 cm. The bucket was covered with a lid that has a small handle on the upper surface, functioning as to ease opening the trap and the lower side has a small hook functioning to hold the pheromone dispenser. The outer surface of the bucket was rubbed by copper brush to make the outer surface become rough, so that the weevils can climb up easily into the bucket. Each pheromone trap was containing the following materials:
   i. 300 g of different type kairomone-releasing food baits (i.e. sugarcane, pineapple, coconut fruit and oil palm petiole) respectively
   ii. 600 mL of tap water
   iii. 10 mL of ethanol
   iv. 10 mL of ethyl acetate in a small bottle that hook under the lid of bucket
   v. dispenser of male produced aggregation pheromone of R. ferrugineus
   vi. half spoon of detergent instead of insecticide
For control purpose, pheromone trap was containing:
   i. 600 mL of tap water
   ii. 10 mL of ethanol
   iii. 10 mL of ethyl acetate in a small bottle that hook under the lid of bucket
   iv. dispenser of male produced aggregation pheromone of R. ferrugineus
   v. half spoon of detergent instead of insecticide.
Water was added every week to maintain the moisture in the trap and to increase the rate of fermentation of food baits in pheromone traps. Detergent was used to kill the trapped RPW. Food baits was replaced for every two weeks.

2.3 Experimental Design and Trap Installation
This study was designed with randomized complete block design (RCBD) with 5X5 level of factorial design. There were five types of food baits treatment and each treatment was replicated five times. Overall, a total 25 pheromone traps were installed at the study site. The distance between the traps was about 100 m and each trap was 3 m away from coconut tree. All traps were placed on ground level under
shady tree and less disturbance area. The captured RPW in the trap were collected weekly during the morning session. All the traps locations were recorded by the Global Positioning System (GPS) (Model: Garmin Gecko 201).

2.4 Ecological Parameters
The relative humidity (%) and temperature (°C) were recorded by using 3 in 1 Hygrometer. The amounts of rainfall data (mm) during the period of study were obtained from Department of Meteorology to relate the influence of rainfall on the total catches of RPW.

2.5 Statistical Analysis
All the data obtained from this study were analyzed using statistical software produced by IBM Statistical Package for the Social Sciences (SPSS) version 21.0. One-way analysis of variance (ANOVA) was used to evaluate the differences of total numbers of RPW in traps between different kairomone-releasing food baits. Correlation coefficient was tested to determine the relationship between total catches of RPW with ecological parameters (relative humidity, temperature and amounts of rainfall).

3. Results and Discussion

3.1 Weekly Trap Catches of RPW
Results showed that the weekly mean weevil catch per trap in 14 weeks of samplings were fluctuated throughout the study period (Figure 1). A total number of 220 weevils were successfully collected from August until November 2013. In general, the weekly trap catches increased gradually from week 1 to reach the peak catch in week 2, but decreased gradually until week 4. The traps caught more weevils in week 2 (1.48 individuals/ trap) while in week 13 the lowest catches of weevils was obtained (0.16 individuals/ trap).

![Figure 1. Weekly mean weevil catch per trap from August until November 2013. (Note: *sign shows the week of changing food baits every two weeks).](image)

The captured weevils in week 2 recorded the highest captures just after 2 weeks of introducing the pheromone traps at the study site. This is most probably due to the production of kairomone odour that occurs as a result of fermentation process of food baits after one week. The mass trapping for Rhynchophorus spp. is often improved by the presence of synergistic palm volatiles in the pheromone-baited traps [12]. The combination of synthetic pheromone and kairomone will attract the weevils to enter the traps. The catches of weevils in week 5, 7, 9 and 11 were higher compared with the
other weeks. The replacement of new food baits was probably influenced the total catches of weevils. The lowest catches was obtained in week 13 (0.16 individuals/ trap) due to the influence of monsoon season that brought heavy rainfall and limited the mobility of RPW. The uncertainty weather during the monsoon period caused the fluctuated numbers of captured weevils.

3.2 Effectiveness of Kairomone-releasing Food Baits
All five types of kairomone-releasing food baits were attractive to the weevils. Pineapple traps collected the most captures of weevils (12 individuals/ trap), followed by oil palm petiole, sugarcane, control and coconut fruit (Figure 2). There was a significant difference of total captured weevils between five types of kairomone-releasing food baits, (F(4,158) = 1.422, p<0.05).

![Figure 2. Mean weevil catch per trap on the efficacy of different types of kairomone-releasing food baits.](image)

Previous study done Wahizatul et al. [11] in Terengganu showed that pineapple traps caught significantly higher numbers of weevils compared to sugarcane and sago. In this study, the use of oil palm petiole and coconut fruit as food baits were tested since the food baits were never been used before. The oil palm petiole traps appeared to collect more weevils (10.8 individuals/ trap) higher than the weevils collected in sugarcane traps (7.6 individuals/ trap). This result of study could be used as an important information that petiole of oil palm is also preferred by RPW. Currently, the weevil poses a threat to the coconut industry and threatens the survival of oil palm plantations [6]. The coconut traps caught fewer weevils (6.6 individuals/ trap) than the control traps (7 individuals/ trap) because the usage of coconut fruit as food baits are less effective instead of petiole and coconut’s cabbage. Coconut petiole is the most economically and easily available food bait in countries where coconut is grown [12]. To improve the efficacy of pheromone trapping, the combination of ethyl acetate and ethanol were added to the traps in this study. The weevil captures were significantly increased (2-3 times) when ethyl acetate was added to food baited pheromone traps [8]. It is worth mentioning that ethyl acetate is not a substitute for food baits, but it should be added to food in RPW pheromone traps to enhance weevil captures [10]. Water also play essential role in maintaining kairomone effects by slowing down the drying process of food baits and keeping the trap cool. By replenish the water even if the traps were not serviced beyond 15 days, the trapping efficiency was sustained.

3.3 Influence of Ecological Factors on the Total Numbers of Captured Weevils
Lower numbers of trapped weevils were obtained when high reading of relative humidity was recorded (Pearson Correlation, r = -0.137). The numbers of captured weevils was greater during less amount of
rainfall (mm). There were negative correlations between the numbers of captured weevils collected with the amount of rainfall (Pearson Correlation, $r = -0.182$) and relative humidity (%). However, a significant positive correlation (Pearson Correlation, $r = 0.179$) was found where the numbers of captured weevils collected was directly proportional to the reading of temperature ($^\circ$C).

The ecological factors and weather seasonally can be associated with weevil’s mobility and pheromone mass trapping performance. Physical parameters such as relative humidity (%), amount of rainfall (mm) and temperature ($^\circ$C) play important roles in implementation of pheromone mass trapping of captured weevils. The total numbers of captured weevils showed negative correlations with relative humidity and amount of rainfall. The higher the relative humidity and amount of rainfall, the lower the numbers of weevils collected. The numbers of captured weevils was directly proportional to the reading of temperature. The higher temperature in week 5 (28.34$^\circ$C) captured more weevils compared to the lowest temperature (26.11$^\circ$C) in week 14. The fluctuating pattern of captured weevils were subjected to monsoon season brought a huge amount of rainfall and high relative humidity. Al-Saoud et al. [14] stated that seasonal changes in temperature, rainfall and other weather parameters also reflected the temporal variation in numbers of weevil’s catches.

3.4 Sex Ratio of Captured Weevils
Both males and females were attracted to enter the traps. However, the capture rates of female were nearly 3.1 times greater than the rate of male captures. About 75.45% of captured weevils were females, while 24.55% of the captured weevils collected were males (Figure 3). The pineapple traps caught more female weevils (9.2 individuals/ trap) than sugarcane and control traps. The captured weevils of female in oil palm petiole traps were intermediate between coconut fruit and pineapple traps (Figure 4).

The weevil’s catches also differed in sex ratio between males and females (Figure 4.3). The number of captured females was greater than the numbers of males in all the treatments tested with the value different from the sex ratio of 1 male: 3.1 females. However, the pineapple traps recorded the highest mean captures (9.2 females/ trap and 2.8 males/ trap). Similar proportion of higher females than males was also recorded from the previous research like Kaakeh et al. [15] and El-Garhy (1996) who collected twice females than male’s weevils. The male-aggregation pheromone that used in this study was able to attract more female weevils. The females active in their movement and disperse more than males in order to find their partner for mating to produce the offsprings.
Figure 4. Mean weevil catch per trap on the efficacy of different types of kairomone releasing food baits.

4. Conclusion
As a conclusion, the results demonstrated that pineapple trap was the most effective food baits to be used in the future in Malaysia. The uncertainty weather during the monsoon season should be considered in implementing the mass trapping programme that involves progressive tactics to manipulate the influence of season. The implementation of trapping programme also should to give more attention to ecological factors (amount of rainfall, relative humidity and temperature) as the environmental parameters will influence to the total numbers of weevils collected and the efficacy of the food baits used.

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