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QUAD TRAP: AN ALTERNATIVE APPROACH TO INCREASE TRAPPING EFFICIENCY OF THE MALE BAGWORM, *Metisa plana* WALKER

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ABSTRACT

Mass trapping plays an important role in insect pest management strategies by effectively monitoring and controlling the pest population. Various trap designs have been developed to optimise these traps' capture efficiency and reliability. This study compares two trap designs, the Mono trap and the Quad trap, for controlling the male of bagworm in oil palm plantations. The Mono trap is made from a one-unit white transparent plastic bag with two wooden poles, while the Quad trap is a four-unit white transparent plastic bag connected with raffia rope and tied between two oil palm trunks. There is a significant difference in the mean number of male moths captured between the two traps (*P*-value = 0.0028), where Quad trap captured more male moth (594.2) than Mono trap (68.4). The results show that the Quad trap is significantly more efficient in terms of male moth capture, increasing the number of male moths caught (m^2) by 54% and reducing half installation time from 6 minutes to 3 minutes. The cost per unit trap is significantly cheaper at RM10.05 per set compared to the Mono trap (RM25.40). The Quad trap offers an alternative method of male moth control, making it easy to set up, affordable price, and requires no heavy lifting equipment. Thus, mass trapping of male moth bagworms using a Quad trap could complement other insect pest management components more effectively.

Keywords: Mass trapping, mono trap, oil palm, pheromone trapping, receptive female

ABSTRAK

Perangkap pukal memainkan peranan penting dalam strategi pengurusan serangga perosak bagi memantau dan mengawal populasi perosak secara berkesan. Pelbagai reka bentuk perangkap telah dibangunkan bagi mengoptimumkan kecekapan dan kebolehan hasil tangkapan perangkap ini. Kajian ini membandingkan dua reka bentuk perangkap, perangkap Mono dan perangkap Quad, untuk mengawal ulat bungkus jantan di ladang sawit. Perangkap Mono diperbuat daripada satu unit beg plastik lutsinar putih dengan dua batang kayu, manakala perangkap Quad terdiri daripada empat unit beg plastik lutsinar putih yang disambungkan dengan tali rafia dan diikat di antara dua batang pokok kelapa sawit. Terdapat perbezaan yang signifikan dalam purata tangkapan rama-rama jantan di antara kedua-dua perangkap (nilai-*P* = 0.0028), di mana perangkap Quad memerangkap lebih banyak rama-rama jantan (594.2) berbanding perangkap Mono (68.4). Keputusan kajian menunjukkan bahawa perangkap Quad adalah lebih efisien dari segi tangkapan rama-rama jantan, meningkatkan bilangan rama-rama jantan yang ditangkap (m^2) sebanyak 54% dan mengurangkan separuh masa pemasangan daripada 6 minit kepada 3 minit. Kos seunit perangkap adalah jauh lebih murah iaitu RM10.05 setiap set berbanding perangkap Mono (RM25.40). Perangkap Quad menawarkan kaedah alternatif kawalan rama-rama jantan, menjadikannya mudah untuk disediakan, harga berpatutan, dan tidak memerlukan peralatan mengangkat yang berat. Oleh itu, kaedah perangkap pukal rama-rama jantan ulat bungkus menggunakan perangkap Quad boleh melengkapkan komponen pengurusan serangga perosak yang lain dengan lebih berkesan.

Kata kunci: Perangkap pukal, perangkap Mono, kelapa sawit, perangkap feromon, betina reseptif

INTRODUCTION

The emergence of several pests that jeopardise oil palm (*Elaeis guineensis* Jacq.) productivity corresponds with Malaysia's rapid development of oil palm plantations, resulting in a significant loss in yearly oil palm crop yield (Egonyu et al. 2022; Pinnamaneni & Potineni 2023; Woittiez et al. 2017). Bagworm is one of the main insect pests of oil palm, and its outbreak can lead to significant loss to Malaysia's oil palm industry. The economic consequence of a moderate bagworm infestation of 10% to 50% foliage destruction may result in a yield reduction of 43% (Adhawiyah et al. 2023; Basri et al. 2022; Enting & Latip. 2021; Pinnamaneni & Potineni 2023; Wood & Norman 2019). The recurring outbreak of bagworms in the oil palm industry has resulted in significant economic losses exceeding USD 25 million per year, and immediate control measures should be undertaken (Mazmira et al. 2022). *Metisa plana, Pteroma pendula,* and *Mahasena corbetti* are the three most destructive leaf defoliators in oil palm plantations (Syarif et al. 2023; Wood & Norman 2019). On November 15, 2013, bagworm was declared a dangerous pest under Malaysian Act 167, the Plant Quarantine Act 1976. Oil palm planters who fail to control the bagworm infestation after receiving the notice will be charged RM 10,000 or face imprisonment for two years under this act (Attorney General's Chambers 2013). Numerous controls were implemented to suppress the bagworm population, such as biological, parasitoids and predators; mechanical, mass trapping and attract-and-kill technique; and chemical control (Ikhsan et al. 2024; Zahir et al. 2021). Most of the earlier studies focused on selecting and applying chemicals, resulting in better population control. Chemical insecticides, despite their effectiveness and immediate results, come at a high cost. Moreover, they lead to resistance, resurgence, the emergence of secondary pests, the

death of non-target organisms, the accumulation of pesticide residues, and environmental damage (Ikhsan et al. 2024).

Alternative approaches to monitor and manage bagworms are required, and reduced insecticide usage is environmentally preferable (Barzman et al. 2015). The idea of mass trapping was introduced to provide an environmentally friendly approach to reduce the pest population. This approach has been included as one of the key elements in bagworm's integrated pest management programme. Pheromone trapping is a technique or tool that can help oil palm planters and scientists track the movement and activity of their target insects (Ikhsan et al. 2024; MPOB 2016; Najib et al. 2017). Fruit borer, *Leucinodes orbonalis*; sugarcane wireworm, *Melanotus okinawensis*; and white spotted tussock moth, *Orgyia thylellina;* nettle caterpillars, *Setothesea asigna, Amathusia phidippus, Setora nitens, Darna trima*, and bagworms, *M. plana*, *Mahasena corbetti* are pests that have been successfully managed using mass pheromone trapping (Ikhsan et al. 2024; Nahar et al. 2020; Ryan 2002). Several pheromone trap designs were developed for mass trapping the winged adult males of the bagworms in oil palm. Norman and Othman (2006) conducted a field trial using three types of traps (Delta, Open-Delta and Vane) to evaluate each trap design's effectiveness. More bagworm male moths were observed in the Vane trap baited with four females compared to two other traps, Delta and Open-Delta traps (Norman & Othman 2006). Later in 2016, Najib et al. reported that custom-made transparent plastic known as Mono trap had successfully increased the number of male moth captures (by 28%) and reduced the cost per unit of the trap (by 53%) as compared to the Vane trap. According to Norman et al. (2010; 2011), mass capturing of adult male bagworms reduces their chances of mating with females and propagating the next generation. This simple approach was proven to reduce the next bagworm generation (Norman et al. 2019; Najib et al. 2017).

Insect sex pheromones are crucial elements of monitoring and pest control methods aimed at agricultural crop pests. In the case of bagworm pests, sex pheromones are produced by females to attract males. Interestingly, the Psychidae pheromone may have a chemical composition that differs from the sex pheromones of other Lepidoptera - all psychid species studied so far use esters of long-chain fatty acids as sex pheromones (Rahmani et al. 2020). Unfortunately, no effective sex pheromone of the bagworm, *M. plana* and *P. pendula*, has yet been isolated, identified, and synthesised (Norman & Othman 2006). As an alternative, the live receptive wingless females were used as a lure to attract the winged adult males (Fauziah et al. 2012; MPOB 2016; Najib et al. 2017).

In this study, a comparative study between two trap designs: the Mono trap and the Quad trap for controlling the winged male moth of the bagworm in terms of capture rate, cost efficiency, and ease of use in oil palm plantations by using live receptive wingless females as pheromone sources has been conducted.

MATERIALS AND METHODS

Study Site

This study was conducted in bagworm infested oil palm area located in Chamek, Johor, Malaysia (2° 3'43.36"N; 102°57'58.22"E). This block (8 hectares) is a smallholder's plot that has not been treated with chemical pesticides. The palms are about 12 years old.

Pheromone Source

Metisa plana population sampling was conducted in the infested field one week earlier before the installation of the trap to determine the duration from the formation of pupae until reaching the receptive female stage. The live receptive female bagworms were used as a lure to attract the winged adult males. According to Norman and Othman (2006), adult females are mature when an opening appears at the back of the case. The phase from the pupal stage to the mature adult female occurs around 11 days after pupation begins (Norman & Othman 2006). Live receptive females were collected from fronds number 17 and above. The female pupae were separated from the male pupae based on size since female pupae are significantly larger than male pupae (Norman et al. 2011). The sign of female maturity is based on the colour of the crushed eggs (Figure 1A). When the colour of the crushed eggs is milky yellowish (Figure 1B), it shows that the female is suitable to be used as a pheromone source. According to Subchev (2002), bagworms displayed no distinct calling behaviour or posture. The receptivity of the female *M. plana* was therefore identified by the anterior end opening of the pupal bag and the intermittent protrusion of the female's head and thorax from the opening (Basri & Kevan 1995) (Figure 2). The sign of the ideal time for a sex pheromone to be released is when the anterior end opens, and this female will remain receptive for about an average of nine days till the hole at the anterior end closes (Norman & Othman 2006).

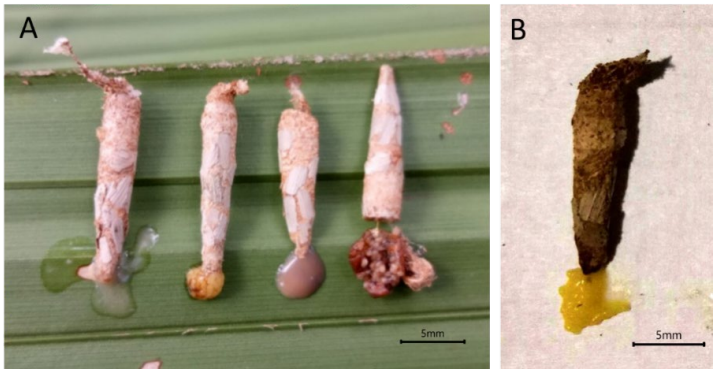

Figure 1. Different stages of egg maturity in female adults (A) and the suitable stages for lures (B)

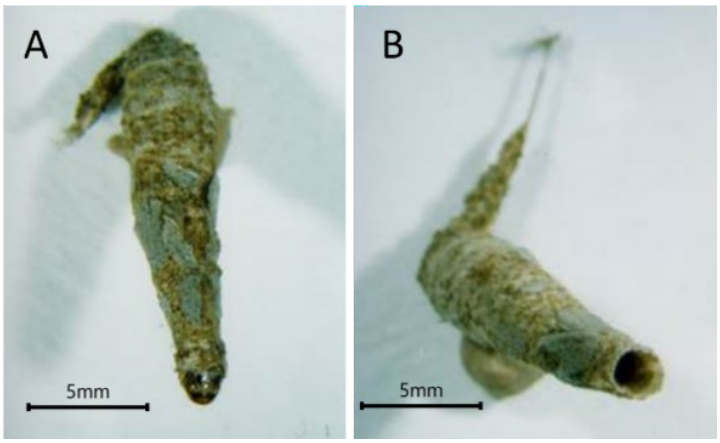

Figure 2. Head's protrusion (A) of the *M. plana* receptive female and anterior opening (B) at the pupal bag

Trap Design and Trap Construction.
This study evaluated two sticky trap designs (Mono and Quad traps), as shown in Figure 3. Pheromone traps were fixed in the hot spot areas in the smallholder's area to capture bagworm male moths in the infested area. The main material for both traps is white transparent colour plastic sheet. The Mono trap is made from a one-unit white transparent colour plastic sheet with two wooden poles, while the Quad trap consists of a four-units white transparent colour plastic sheet connected with raffia rope.

Figure 3. Type of pheromone traps used in this study; Mono trap (A) and Quad trap (B)

Mono trap. For the treatment plot, a Mono trap was custom-made by inserting and stretching a white transparent colour plastic sheet (0.5-metre width x 0.8-metre length) in between two-metre-long wooden poles. Two square-shape holes were made in each trap (3cm x 3cm). The plastic was evenly sprayed with polybutene glue (Chemi Bond, Malaysia) and baited with four receptive bagworm females, two females at each hole on the plastic surface. Traps were then placed along the non-harvesting paths within a hectare of the bagworm-infested plot. Each trap was placed two palms apart in distance (approximately 20 metres) (MPOB 2016; Norman et al. 2011). The same procedure was applied to the Mono trap for the control plot, except that no lures (receptive females) were attached to the traps. The trap density for the treatment and control plots was 30 units per hectare (ha) each and placed for 21 days in the field. The assessment for the winged adult males captured was taken 21 days after treatment (DAT) in both treatment and control plots. The number of winged adult males captured at both sides of the plastic trap was recorded.

Quad trap. For the treatment plot, a Quad trap was constructed by stretching and combining four units of white transparent colour plastic sheet (2.0-metre width x 0.8-metre length) using raffia rope (10 metres long) and tied between oil palm trunks. Two square-shape holes were made in each trap (3cm x 3cm). Similarly, each plastic was evenly sprayed with polybutene glue (Chemi Bond, Malaysia) and was baited with four receptive bagworm females, with two females at each hole on the plastic with a total of 16 baits for one set of Quad traps. The traps were placed along the non-harvesting paths within a hectare of the bagworm-infested plot. Each trap was placed five palms apart in distance (approximately 45 to 50 metres). The same procedure was applied to the Quad trap for the control plot, except no lures (receptive females) were attached to the traps. The proposed trap density for the treatment and control plots was eight set traps per ha each and placed for 21 days in the field. The assessment for the winged

adult males captured was taken at 21 DAT in both treatment and control plots. The number of winged adult males trapped at both sides of the plastic trap was recorded by visual counting.

Data Analysis

Mean number of male moths captured was analysed using analysis of variance (ANOVA) (SAS version 9.4). T-test analysis was used to compare the Mono and Quad plots. A probability of $P<0.05$ is considered statistically significant. The data for male moths captured for control plots were excluded from the analysis due to no variance in the results of zero catches.

RESULTS AND DISCUSSION

The results of the t-tests (Table 1) showed that there is a significant difference in the mean number of male moths captured between the two traps (*P*-value = 0.0028). Table 2 shows Quad trap captured significantly more male moths (mean of male moths = 594.2) than the Mono trap (mean of male moths = 68.38), indicating that it is a more effective tool for trapping male moths.

Table 1. T-test analysis on the number of male moths captured by different trap designs

Equality of Variances				
Method	**Num DF**	**Den DF**	**F Value**	**Pr>F**
Folded F	89	23	3.14	**0.0028**

Note: Numbers in bold font indicate significant difference ($P<0.05$)

Table 2. Total male moths of *Metisa plana* captures at 21 DAT according to trap designs

Treatment	Mean Total Captures (Mean±SE)
Mono	68.38±10.00
Quad	594.20±10.90

Note: ±indicate standard error

Norman and Othman (2006) in his study also found that trap baited with more receptive females captured higher than the other trap baited with less number of receptive females. Thus, this also suggests that the high concentration of sex pheromones released by the 16 receptive females attached to the Quad trap were responsible for the high capture rate of a male moth and extend the radius of attractant. Nevertheless, it's important to remember that high male moth catches were also influenced by the timely collection of receptive females during the trap-fixing session (Norman & Othman 2006). According to Norman and Othman (2006), the effect of live virgin females on attracting male moths lasted for two weeks, after which their effect decreased drastically. According to Rizuan et al. (2011), the receptive female (unfertilised/virgin stage), female with yellowish eggs (fresh eggs of gravid female) and female with brownish eggs (matured eggs of gravid female) mated twice in a period between 7.45–8.21 am. Thus, to ensure the success of mass trapping, these important factors must be considered.

The findings of this study have important implications for pest management practices in agriculture. Male moths are often targeted in pest control programs because they are

responsible for mating with female and thus contribute to population growth. The use of effective trapping methods can help to reduce the population of male moths, which in turn can limit the damage caused by this pest. The results of this study suggest that the use of Quad traps could be integrated with Mono trap to enhance the effectiveness of mass trapping, especially in immature and high palm areas.

Productivity and Cost Analysis

In term of the productivity and cost analysis, Table 3 shows the comparison for several parameters regarding catches productivity, male moth captured per square metre (m^2), cost per unit, time for a trap set in the field and surface area between two trap designs of pheromone trapping.

Table 3. Comparison between two trap designs of pheromone trapping

Parameters	Trapping technique		Differences
	Mono trap	Quad trap	%
Productivity (male moth catches/trap/day)	3.26±0.90	28.29±0.40	88
Male moth captured per square metre (male moth/m^2)	85.37	185.68	54
Cost (RM per unit)	25.40	10.05	60
Time of setting/ trap (minutes)	6	3	50
Sticky surface area (m^2)	0.80	3.20	75

In terms of male moth catches, the Quad trap increased male moth catches by up to 88.0% compared to the Mono trap as the sticky surface area (m^2) increased by 75%. In comparison to the Mono trap, the Quad trap captured 54% more male moths per square metre. These results have proven that the Quad trap not only improves the catches' productivity but also significantly attracts more male moths due to the strong attractant from the lures. In addition, the installation time for the Quad trap was improved, reducing the installation time by 50% from 6 to 3 minutes compared to the Mono trap. This improvement can increase the productivity of pheromone trapping activity and set up in the field. The Quad trap can be prepared ahead of time in the laboratory or office before the operation, thus reducing the set-up time in the field. Additionally, because no wooden poles need to be brought to the trial plot, the worker's burden is less than the Mono trap.

This study revealed that the cost of material for the Quad trap was significantly reduced by 60% compared to the Mono trap. The cost for a Mono trap is RM25.40 per unit, while the effective cost for a Quad trap is RM10.05 per set per unit. Furthermore, the resources involved in preparing the Quad trap were cheaper and readily available in the market. As for impact and productivity, the Quad traps were cost and time-saving for installation, where one unit installation of the Quad trap is comparable to two units of the Mono trap. According to the results, the Quad trap is noticeably more efficient than the Mono trap. The Quad trap has an innovative feature in that it is simple to set up, affordable, and efficient in capturing significantly more wing male moths. Furthermore, this biological approach is environmentally friendly and safe for humans and the environment, including oil palm pollinating weevil, *Elaeidobius kamerunicus* and other beneficial insects.

This kind of mass trapping has been proven effective based on a previous study conducted by Najib et al. in 2017 where two consecutive rounds of pheromone trapping application successfully reduced the bagworm population by approximately 94% in Kg. Temehel and 85% in Kg Seri Sepakat in Johor, when incorporated with the aerial spraying control using *Bacillus thuringiensis* bioinsecticide. The bagworm population was reduced in the range of 77% to 89% when the pheromone traps were used alone. According to Wood and Norman (2019), these findings appear to indicate the prospect of a practical technique for control in bagworm-infested plantings.

Metisa plana can be controlled using various techniques, including an attract-and-kill technique. In this scenario, the male bagworm moth was lured by pheromones emitted by sexually receptive females. While seeking out these females, the males were trapped on a sticky plastic surface (MPOB 2016; Najib et al. 2016; Norman et al. 2010; Norman et al. 2011). The efficacy of the Quad trap monitoring approach in managing male moth bagworms has been established due to its cost-effectiveness, convenience, and reduce worker's burden since there is no requirement to transport wooden poles.

CONCLUSION

A Quad trap has successfully increased the number of male moths captured per square metre (by 54%), saved up the installation time (by 50%) and reduced the cost per unit of the trap (by 60%) as compared to the Mono trap. Therefore, this Quad trap is recommended as an alternative trap design for use in oil palm plantations to control bagworm. Mass trapping of male moth bagworms using a Quad trap could complement other insect pest management components more effectively. Further studies on the correlation between the number of male moths caught and the reduction in the subsequent bagworm population need to be carried out to evaluate the effectiveness of this trap.

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AUTHORS DECLARATIONS

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Conflict of Interest
The authors declare that they have no conflict of interest.

Ethics Declarations
No ethical issue required for this research.

Data Availability Statement
My manuscript has no associated data.

Authors' Contributions

The conceptualization of this study was carried out by Noorhazwani Kamarudin (NK), Siti Nurulhidayah Ahmad (SNA), Mohd Najib Ahmad (MNA), Mohd Fahmi Keni (MFK), Nur Robaatul Adhawiyah Mohd Ali Napiah (NRAMAN), Shamsilawani Ahamed Bakeri (SAB), Mohamad Rosman Sulaiman (MRS) and Mohamed Mazmira Mohd Masri (MMM). The methodology was developed by NK, SNA, MNA, MFK, NRAMAN, SAB, MRS and MMM. NK and SNA also conducted the formal analysis and investigation. NK prepared the original draft of the manuscript, while the writing, review, and editing process involved contributions from SNA, MNA, MFK, NRAMAN, SAB, MRS and MMM. All authors read and approved the final manuscript.

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