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RESEARCH ARTICLE

Determinants of Bagworms Control Practices and Smallholders' Management Towards Oil Palm Plantations

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ABSTRACT

The use of pesticides on palm oil disease such as bagworms in Malaysia by smallholders' dates to several decades. However, little research has been conducted to capture farmers' perception on pest management on palm oil. This study aims to identify the determinants of bagworm control and management of palm oil plantations in Malaysia. Key informant and focus group interviews complemented with quantitative one-on-one structured interviews of 90 farm households and observational assessments were employed. The respondents were selected from Kampar, Perak and Mempaga, Pahang. The data was analyzed using Exploratory Factor Analysis (EFA) to further investigate the determinants influencing the bagworm control and pest management practices. More than 70 percent of the respondents acknowledged that pest management control is important and the effect on the quarantine is significant. It is critical for the smallholders in terms of the knowledge on bagworm control. Five determinants discovered namely Factor 1 "General operation management, Factor 2 "Authority and peer influence", Factor 3 "Legal awareness", Factor 4 "Profit concern", and Factor 5 " Pesticide awareness". Successful intensification and diversification of organic and chemical pesticides will require increasing awareness on safer production methods, long-term harmful effects of pesticide misuse, and strengthening the capacity of regulatory agencies responsible for preventing importation of banned pesticides, alongside promoting research and investment in sustainable alternatives such as integrated pest management, biological control, and agroecological practice.

1. INTRODUCTION

The palm oil industry contributes 63% of the Gross Domestic Product (GDP) of the Malaysian economy. Palm oil product exports decreased from 24,717,610 tonnes to 24,453,699 tonnes in 2023. In Malaysia, around 5.8 million hectares (about 14.3 million acres) of land are dedicated to palm oil production, making the country one of the world's largest producers of palm oil, alongside Indonesia. Malaysia's vast palm oil plantations are crucial to its economy, although they are also associated with environmental and sustainability concerns.

Bagworm problems and outbreaks in Malaysia are not commonly faced by smallholders. Most smallholders in the country depend on technical assistance from the Malaysian Palm Oil Board (MPOB) to control this problem. The bagworm issue in Malaysia pertains to the widespread infestation of the bagworm moth (Psychidae family) larvae on various types of trees and plants. This causes economic losses to farmers and threatens the aesthetic value of landscaping in urban areas. Integrated pest management strategies are crucial to mitigate the impact of bagworms while minimizing the environmental and health risks associated with pesticide use. A study by Satendra et al. (2022) on bagworms in the Chhattisgarh and Kerala regions stated that the problem can cause ecological and economic damage in India. Bagworm outbreaks in the 1960s were caused by the use of disruptive synthetic organochlorine insecticides, which killed the bagworm's natural enemies more than it killed the pest. Stopping the use of these disruptive insecticides and using selective pesticides helped restore the natural balance and reduced the incidence of bagworm outbreaks (Wood & Kamarudin, 2019).

As a notorious pest that has wreaked havoc on palm oil plantations worldwide, the bagworm is a major concern for the industry. Known scientifically as Metisa plana Walker (one of three species), this caterpillar feeds on the leaves of oil palm trees, causing significant defoliation and stunted growth. Bagworm infestations can devastate palm oil production. Bagworm-linked defoliation can lead to lower fruit yields, ultimately affecting the profitability of palm oil producers. In addition, controlling bagworm infestations requires significant investments in pesticides, labor and other resources, which add to the overall production costs. Damaged palm trees might produce lower-quality oil, potentially impacting both the reputations of palm oil producers and market prices.

Bagworms are major pests in palm oil plantations, causing significant damage and economic losses. Bagworm infestations, particularly by Metisa plana and Pteroma pendula, significantly threaten palm oil production, potentially causing yield losses of up to 43% over two years (Kamarudin & Wahid, 2010; Thaer et al., 2021). Severe infestations can result in substantial declines in production, such as one 2.33% decline due to an attack that covered 680 hectares (Hapsani et al., 2022). Integrated Pest Management (IPM) strategies, which combine biological, cultural, and chemical methods, are essential for sustainable pest control (Sulaiman, 2021). Bagworm populations can be regulated through biological control, using parasitoids like Tetrastichus planipennisi, as well as planting nectar-producing plants such as Cassia cobanensis to support the bagworm's natural enemies (Kamarudin & Wahid, 2010; Thaer et al., 2021). Chemical controls, including trunk injections and aerial spraying, offer immediate relief, whereas pheromone traps can target male bagworms (Sulaiman, 2021).

Bagworms present a formidable challenge to agriculture due to their wide-ranging impact and adaptability. As polyphagous pests, they cause defoliation and economic damage to various crops such as avocados and guayules (Bhagat et al., 2022.; Rhainds & Cabrera-La Rosa, 2010). Smallholders face challenges in managing bagworm infestations because of their limited knowledge and resources compared to those of larger plantations (Desa et al., 2021). Successful IPM implementations have been reported, including introducing natural predators and manual eradication, but bagworm outbreaks remain frequent, with attack rates of 38-76% (Mulyani et al., 2024).

Effective management of bagworm infestations is critical for maintaining sustainable palm oil production and minimizing economic losses. Recent advancements in pest control offer promising solutions for managing these resilient pests. Sustainable management methods include pheromone trapping combined with Bacillus thuringiensis spraying, which has been effective in reducing bagworm populations by up to 94% (Ahmad, 2017). New insecticides and the push-pull farming system also offer promising alternatives (Rhainds & Sadof, 2009; Akeme et al., 2021). Despite this progress, enhancing smallholder education and promoting sustainable practices are crucial for effective and long-term control (Desa et al., 2021; Göldel et al., 2020).

However, there is a gap in the existing research on bagworm management. Based on previous studies, the challenges specific to smallholders in terms of implementing control strategies are substantial, and studies are needed on the long-term sustainability of chemical control methods, as well as the development of more selective or reduced-risk insecticides. This paper could benefit both smallholders and large-scale producers while mitigating the ecological impacts of the bagworm problem in palm oil plantations. This study aimed to identify the determinants of bagworm control and management on palm oil plantations in Malaysia. The study was carried out in Malaysia in 2024.

MATERIALS AND METHODS

Study area

The study area in Fig.1 comprised three areas identified as being affected by bagworms. They included Kampung Air Kuning (Seri Iskandar) and Kampung Air Kuning (Kampar) in the state of Perak and FELDA Mempaga 1 in Pahang. Kampung Air Kuning (Seri Iskandar) has a majority population of Malay senior citizen residents who own small-scale oil palm plantations of less than five acres. Meanwhile, Kampung Air Kuning (Tapah) is populated with multi-racial residents. FELDA Mempaga 1 is populated with Malay residents who have been designated as group settlers of oil palm plantations under the Federal Land Development Authority (FELDA). These three areas have been identified by the Malaysian Palm Oil Board (MPOB) as being affected by bagworms. In 2018, the MPOB conducted 13 series of awareness programs on bagworm eradication. These involved talks and demonstrations about how smallholders could control bagworm outbreaks on their oil palm plantations. Perak was the state most visited by these awareness programs (seven times). Other states included Pahang (twice), Selangor (twice), Negeri Sembilan (once), and Kelantan (once). The awareness programs were part of an IPM project for controlling bagworms in Peninsular Malaysia. Since Perak smallholders were involved the most in the awareness programs, they were the most suitable participants for this new research survey (Malaysian Palm Oil Board, 2019).

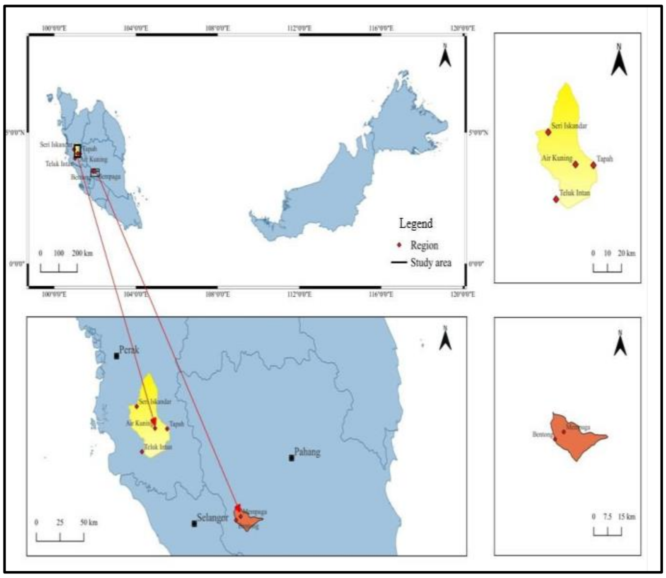

Fig. 1 : Geographical location of the study area in Perak and Pahang , Malaysia

Bagworm control has been conducted by air in certain states of Malaysia. Aerial spraying using airplanes, unmanned aerial vehicle (UAV) drones, and fog spraying is the most common method of controlling bagworm outbreaks by air. In 2018, the biological pesticide (Bt) Ecobac-1 was sprayed in Pahang, Johor, Selangor, Pulau Pinang, and Perak. The largest area sprayed with Ecobac-1 (6032.1 hectares, ha.) was in Pahang, followed by Johor (322.44 ha.), Perak (135.59 ha.), Selangor (76.44 ha.) and Pulau Pinang (24.88 ha.) (Malaysian Palm Oil Board, 2019). Therefore, feedback from smallholders in Pahang state was chosen for sampling purposes as their state represented the largest area (per hectare) that was subject to the controlling measures.

Survey method and data analysis

The smallholders were selected purposely. Smallholders were gathered in a local hall and volunteered to participate in the study. A total of 90 smallholders were interviewed (27 from Seri Iskandar, 23 from Kampar, and 40 from Mempaga) using a structured questionnaire. This was developed and adopted from the questionnaire devised by Greiner (2015), with additional statements and modifications to determine the awareness of smallholders about bagworm attacks. The questionnaire was content-validated by social scientists and translated into the languages spoken by the smallholders, which were Malay and Chinese. Pre-testing was conducted with smallholders who were not study respondents to ascertain whether the questionnaire was understandable. The questionnaire was modified accordingly after the pre-testing. The questionnaire also included the socio-demographic and socio-economic profiles of the smallholders, their control mechanisms and practices, as well as their yield management. The socio-demographic and economic data recorded such details as gender, age, education, oil palm land ownership, land area, oil palm yields, and other plantation details. Gross profit and yearly revenue were recorded based on information given by the smallholders since most were financially literate regarding their own plantations. The control practices and mechanisms related to bagworm eradication were determined by a set of statements explaining the control operation in each oil palm plantation. The same applied to yield management, where a set of statements was developed explaining yield management and legal awareness about controlling bagworms on their plantations. According to the set of statements, the smallholders chose from "strongly agree", "agree", "not sure", "disagree", and "strongly disagree" when responding to each statement. Focus group interviews were also conducted with small groups of smallholders to facilitate the survey process.

Statistical analysis

Statistical analysis was performed using the SPSS statistical software to find the determinants of bagworm control practices. Statistical calculations such as means, standard deviations, and averages were used to analyze and report the smallholders' responses. A prominent multivariate statistical analysis technique that reduces many connected variables to a small number of independent factors is factor analysis. By simplifying the dataset's variables into a smaller number, it clarifies the cause of their mutual dependency. The first step is to test the data to determine whether it is suitable for factor analysis. Bartlett's Test of Sphericity is deployed to examine the correlation coefficients between variables. The chance that the variables will form common factors increases with the degree of correlation between them. (Gie Yong & Pearce, 2013). Meanwhile, the Kaiser-Meyer-Olkin (KMO) test compares the observed correlation coefficients' magnitudes. It is recommended that the Kaiser-Meyer-Olkin (KMO) ratio be higher than 0.5. A dataset is more appropriate for factor analysis when its KMO ratio is larger. Accordingly, a KMO ratio of 0.90 is regarded as ideal, 0.80 as excellent, 0.70 as decent, 0.60 as moderate, 0.50 as weak, and less than 0.50 as inadequate. (Yong & Pearce, 2013). To decide the number of factors, the eigenvalue scree test and variance are the important criteria. They show the overall amount of variance that each factor explains; during implementation, the factor with an eigenvalue greater than one would be chosen. To improve the comprehension of the data, the principal components approach was utilized for factor analysis after the varimax method for the factor loading procedure had been implemented for maximizing the factor variances.

Sample size

The sample size of the survey was based on the suggestion by Winter et al. (2009). The total number of respondents (90) was sufficient according to the criteria that needed fulfilling, which were the levels of loading (λ), number of factors (ḟ), and number of variables (p). Table 1 shows why the 90 participants formed a sufficient sample size as the number of factors involved was five, with 22 variables, and the factor loading chosen was above 0.6. A sample size of between 78 and 99 was considered reliable.

Table 1 . Estimated N (sample size) for Satisfactory Factor Recovery for Different Factor Loading (λ) , Numbers of Factors (ḟ), and Number of Variables (p).

λ	f	p	$N_{estimate}$
.4	8	24	977
		48	678
		96	541
.6	1	6	18
		12	15
		24	13
		48	12
		96	12
	2	6	59
		12	39
		24	34
		48	31
		96	30
	3	6	208
		12	67
		24	55
		48	50
		96	49
	4	12	99
		24	78
		48	71
		96	68
	8	24	179
		48	156

Source: (Winter et al., 2009)

RESULTS

Smallholders' sociodemographic profile

The survey revealed (as shown in Table 2) that slightly more males than females (54.4%) were engaged on oil palm plantations in the three selected study areas of Perak and Pahang. This supported the idea that women are involved in plantation activities, even though they face certain challenges in male-dominated industries like oil palm plantations (Roslam et al., 2023). The involvement of female planters in Malaysia starts with the task of collecting loose fruit on the plantation to help their husbands, but they are not involved in the tools and technology of plantation operations (Ahmad & Ismail, 1998). Aged smallholders (above 60 years old) dominated the surveys, with 59% being in this age group. Few young individuals (those aged between 31 and 40 years old) were involved in oil palm plantations since most of this group choose jobs that are not classified as involving dirt, danger, and difficulty (the 3Ds) (Norlida, 2023). The majority of the respondents (36.7%) had only completed primary school. This indicates that smallholder literacy is low. Most smallholder respondents had worked for many years on oil palm plantations (more than 30 years). The data suggests that most had started at an early age, not completing secondary school, and continued plantation work until the age of 60 or above. They tended not to stop operating their plantation, even when they reached the retirement age of 60.

Table 2 : Socio-demographic characteristics of smallholders in three areas of study in Malaysia

Characteristic	Response frequency	Response (%)
Sex		
Male	49	54.4
Female	41	45.5
Age		
31-40	10	11.1
41-50	11	12.2
51-60	16	17.7
Above 60	53	59.0
Education		
No schooling	5	5.5
Primary school	33	36.7
Lower Secondary school	17	18.9
Upper Secondary school	18	20.0
College / University	17	18.9
Experiences		
1-5	14	15.6
6-15	20	22.2
16-25	20	22.2
26-30	11	12.2
More than 30 years	25	27.8

Smallholders' socio-economic profile

Smallholders might have their own plantation, rent a plantation, or be involved in a plantation held by another party (Table 3). Most were oil palm plantation owners (82.2%). Some smallholders owned theirs through inheritance. Others used the plantation to gain an additional income, having another full-time job such as being a teacher, a clerk, or an entrepreneur. The oil palm plantation tenants usually shared the profits with the landowner. Most plantations covered an area of between 5 and 10 acres (48.9%) or less. Smaller plantations are easier to manage than large plantations. Variable gross profits were recorded. Most smallholders gained RM 10,001 to 20,000 of gross profit per year, which ranged between low and medium in terms of per oil palm profit yields. The range was equal to between RM 833.40 and RM 1,666.67 per month, which is considered a low income and below the poverty line in Malaysia (Applanaidu et al., 2020). The majority of the smallholders in the three study areas received no financial aid (96.7%). Most were funding their plantation with their own money through the profits gained month by month. Financial aid like subsidies is very important for smallholders as it can affect the productivity of the oil palm plantation yields (Jingjing et al., 2024). Furthermore, association membership - like belonging to a cooperative - is important for smallholders since it can advance the rights of members, eradicate poverty, and resolve sensitive issues that affect the members (Jaafar et al., 2017). A slightly small proportion of smallholders became association members (48.9%) compared to those who did not (51.1%). Smallholders in Malaysia usually join associations such as the Malaysian Palm Oil Association (MPOA), the Malaysian Estate Owners' Association (MEOA), and the National Association of Smallholders (NASH).

Table 3: Socioeconomics characteristics of smallholders in the three-study area of Malaysia

Characteristic	**Response frequency**	**Response**
Land ownership		
Tenant	5	5.6
Owner	74	82.2
Others	11	12.2
Area of plantation		
1 to 5 acres	42	46.7
5 to 10 acres	44	48.9
10 acre and more	4	4.4
Gross Profit (RM)		
1000 to 10000	16	17.8
10001 to 20000	52	57.8
20001 to 30000	13	14.4
30001 to 40000	8	8.9
40001 to 50000	1	1.1
Financial aid		
Receiving financial aid	3	3.3
Not receiving financial aid	87	96.7
Association Membership		
Member	44	48.9
Non-member	46	51.1

Analysis of the determinants of bagworms control practices and smallholders' management towards oil palm plantations via Exploratory Factor Analysis

The number of factors was determined by selecting components with eigenvalues greater than 1. The factor loads were found using the varimax rotation analysis approach. When analyzing the analysis results, variables having a factor loading value higher than 0.4 were taken into effect. As can be seen in Table 4, the Kaiser-Meyer-Olkin test (KMO) value statistics were calculated as 0.709. This suggests that factor analysis could have been applied to the variables found. Furthermore, two factors were eliminated to improve the analysis's dependability. A modification to the initial judgment was made appropriately for factor analysis for each omitted variable.

Table 4: Kaiser-Meyer-Olkin (KMO) and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		**.709**
Bartlett's Test of Sphericity	Approx. Chi-Square	866.280
	df	231
	Sig.	.000

Fig. 2 presents the graph for the six factors affecting the measurement of the determinants of bagworm control practices and smallholders' management on oil palm plantations. The eigenvalues are plotted against each of the elements in a scree plot. The eigenvalues are displayed on the Y-axis, while the factors or determinants are indicated on the X-axis. This graph was used to determine how many factors should be included. In the analysis, the components that were present up until the curve began to turn horizontal were included, while those that were not included were removed. As seen in Fig. 3, the curve began to turn horizontal at the sixth component. As a result, factors following the sixth were eliminated from the study, but the first six were included. The omitted components had eigenvalues less than 1, though the first six factors had eigenvalues larger than 1.

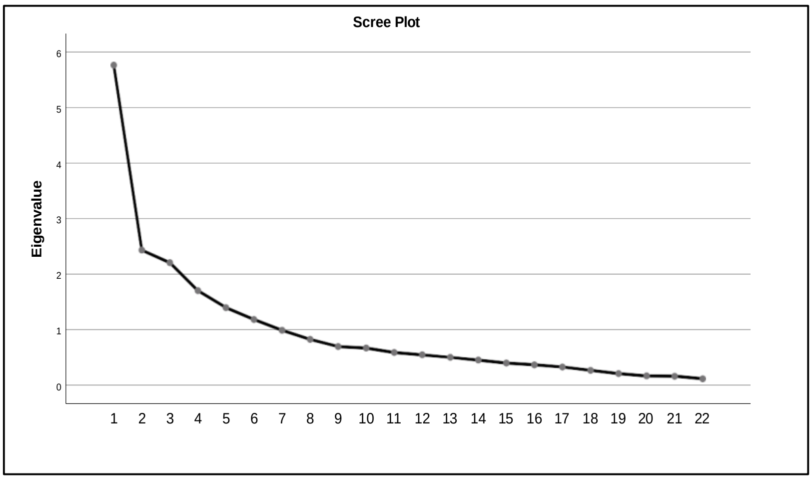

Fig 2. Factors of bagworms control practices and smallholders' management towards oil palm plantations

Table 5: Factor analysis initial solution statistical results

Total Variance Explained									
		Initial Eigenvalues		**Extraction Sums of Squared Loadings**			**Rotation Sums of Squared Loadings**		
Factor	Total	% of Variance	Cumulative %	Total	% of Variances	Cumulative %	Total	% of Variance	Cumulative %
1	5.762	26.193	26.193	2.950	13.410	13.410	3.513	15.966	15.966
2	2.433	11.058	37.251	3.384	15.382	28.792	2.816	12.802	28.768
3	2.207	10.033	47.284	1.949	8.858	37.650	2.249	10.222	38.990
4	1.704	7.746	55.030	1.777	8.079	45.792	1.510	6.862	45.852
5	1.398	6.356	61.386	1.100	5.001	50.730	1.125	5.115	50.967
6	1.185	5.384	66.770	0.967	4.396	55.126	0.915	4.159	55.126
7	0.992	4.509	71.279	-	-	-	-	-	-

Table 5 presents the statistical results for the factor analysis solution. As a result, it was determined that six factors would be adequate to describe the variables, considering the eigenvalues, variance, and additive variance criterion. After rotation, these six key components contribute to 55.13% of the total variance. The first component represents 15.97% of total variance, the second for 12.80%, the third for 10.22%, the fourth for 6.86%, the fifth for 5.12%, and the sixth for 4.16%.

The factor analysis rotation results based on the varimax method are shown in Tables 6.1 to 6.5. Each factor had a related construct or supporting variable with a value of more than 0.4. The sixth factor was eliminated because of the low loading factors (less than 0.4). The factor load is a coefficient that explains the correlation between items and factors. From the survey, five groups of factors influenced the bagworm control practices and management of the smallholders (Table 6). These factors were named as follows: Factor 1 "General operation management, Factor 2 "Authority and peer influence", Factor 3 "Legal awareness", Factor 4 "Profit concern", and Factor 5 "Pesticide awareness".

Table 6.1: Exploratory Factor Analysis of Factor 1 ,General Operation Management

Statements	**General Operation Management**
I am aware that pheromone usage to control the bagworm problem is better than pesticide usage.	0.781
I must use alternative ways to overcome the bagworm problem.	0.705
I will make a report if there are bagworms infected plantation in my nearest area.	0.684
Palm oil related technology contributes to the increasing of yields.	0.627
I am responsible to make sure that my oil palm plantation yield keeps increasing.	0.594
Palm oil yield increasing tremendously after I received consultation with MPOB yearly	0.576
Plant quarantine for bagworm infected plant is effective and succeed to increase my plantation yield.	0.500

Factor 1, "General operation management", explains 15.97% of the total variance and concerns the basic knowledge that smallholders possess about operating their plantation. The most related knowledge is their awareness that pheromone usage is better than pesticide usage (0.781). Smallholders also agreed that using alternative approaches like non-chemical pesticides was essential (0.705). Besides, smallholders tended to report the bagworm problem nearest to them, if there were any (0.6684). Moreover, they were aware of the role of technology in increasing yields (0.627), accepted responsibility for plantation yield (0.627), agreed about engaging the MPOB in consultation over increasing yields (0.576), and agreed about the effectiveness of plant quarantine when a bagworm outbreak occurred (0.500).

Table 6.2 : Exploratory Factor Analysis of Factor 2, Authority and Peer Influence

Statements	**Authority and Peer Influence**
If my oil palm plantation effected by bagworms, I am ready to follow the instruction from authority so no further problem will occur.	0.904
I am aware the bagworms problem will be worst if late action taken.	0.807
I am aware on the responsibility of supplying palm oil sufficiently	0.684
I am competing with other oil palm plantation smallholders positively.	0.635

Factor 2, "Authority and peer influence", concerns the bagworm control practices followed by smallholders. It explains 12.80% of the total variance. They were ready to follow instructions from the authorities (0.904) and aware that fast action should be taken (0.807). Smallholders were also aware of the responsibility to supply sufficient oil palm (0.684), and they positively competed with other smallholders in producing palm oil (0.635).

Table 6.3 : Exploratory Factor Analysis of Factor 3, Legal Awareness

Statements	**Legal Awareness**

I am aware if I am not reporting the bagworms problem in my plantation, I can be charged by law enforcement	0.653
I am aware the unreported bagworm problem is wrong by the law enforcement.	0.653
I am aware the usage of biology pesticide (Bt) is safer and can control the bagworms as suggested by MPOB.	0.574
I am agreeing with the implementation of Plant Quarantine Act 1976 towards infected oil palm plantation for the continuity of palm oil industry in Malaysia.	0.457

Factor 3, "The legal awareness", of smallholders was one factor in controlling and managing bagworm attacks. It explains 10.22% of the total variance. The smallholders were aware that legal action could be taken against them if they did not report a bagworm outbreak on their land (0.653), just as they understood that an unreported bagworm incident is wrong according to the law and can be subject to law enforcement (0.653). Moreover, the smallholders were aware that biological pesticides (Bt) were safer and can control bagworms, as suggested by the MPOB (0.574).

Table 6.4 : Exploratory Factor Analysis of Factor 4, Profit Concern

Statements	**Profit Concern**
The yield weight decreasing because of bagworms attack in my oil palm plantation.	0.639
Plant quarantine method will give negative impact to my monthly income.	0.552
My oil palm plantation has used drone techniques for air spraying the pesticide to control the bagworm problem efficiently.	0.527

Factor 4, "Profit concern", was one of the identified determinants. It explains 6.86% of the total variance. The smallholders were concerned that the yield weight would decrease due to bagworm attacks on their oil palm plantation (0.639). They were aware that the plant quarantine method would negatively impact their monthly income (0.552). They were also aware that oil palm plantations can use drone techniques for air-spraying pesticide to control bagworm problems efficiently (0.527).

Table 6.5 : Exploratory Factor Analysis of Factor 5, Pesticide Awareness

Statements	**Pesticide Awareness**
My knowledge towards the pesticides law affects the yield of my plantation	0.765
I am aware the usage of chemical pesticide is fast and efficient but hazardous.	0.564

Factor 5, "Pesticide awareness", also determined the bagworm control practice and management. It explains 5.12% of the total variance. The smallholders demonstrated knowledge that the pesticides law affected the yield of their plantation (0.765). They were aware that using chemical pesticides is fast and efficient but hazardous (0.564).

Smallholders' responsibility towards oil palm plantation yield

Fig. 3 shows the responsibility taken by smallholders for their oil palm plantation yield. Bagworms can be one reason for the decreasing yield of an oil palm plantation. As leaf-eating insects, bagworms could reduce the productivity yield by up to 50% (Woittiez et al., 2017). Over 60% of the smallholders agreed that they were responsible for ensuring their oil palm plantation yield kept increasing yearly. Less than 20% were unsure (14.4%) or disagreed (3.3%) regarding their responsibility for this aspect. Some smallholders depended on subsidies to increase their yield, which was likely to make them unsure or disagree that they themselves had total responsibility for their yield productivity. The initiatives that help planters to increase their productivity include the Oil Palm Replanting

Scheme (TSSPK), the New Planting Scheme (TBSPK), the Quality Oil Palm Seedlings Assistance Scheme (SBABB), and the Oil Palm Smallholder Agricultural Input Soft Loan Scheme (IPPKS). These initiatives provide features like high-quality seedlings, fertilizers, pesticides, cash for land preparation, and other agricultural inputs for smallholders (Jingjing et al., 2024). In the context of bagworm eradication, the responsibilities of smallholders included the management of pest control to ensure the sustainability of oil palm yields. This included using the IPM suggested by the MPOB (Desa et al., 2021). The majority of the smallholders totally agreed to take responsibility for managing their plantation and ensuring the yield increased yearly with or without government intervention. Smallholders face barriers to increased yields, mostly involving unsuitable ground vegetation, pests, and diseases, while yields may be close to zero in cases of severe infestation (Woittiez et al., 2017). With smallholders' self-accountability and government intervention, the productivity of oil palm plantations would develop accordingly.

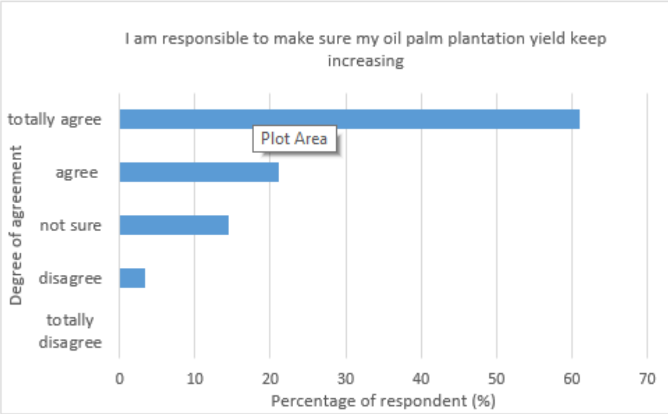

Fig 3: Responsibility of smallholders towards oil palm plantation yield

Awareness of bagworm control practice

Sixty-eight percent of all the respondents were aware of the urgent need for fast action regarding the bagworm problem (Fig. 4). This shows that the majority of them recognized the severe impact of a bagworm attack on their plantation. Bagworms will have the greatest impact on oil palm in Peninsular Malaysia. Since it is the major pest of oil palm, an outbreak can cause major losses of up to 40% of the crops (Robaatul et al., 2023). The smallholders took outbreaks seriously and expected the fastest action to be taken to shield them from major losses. The best action taken would be through the IPM practices that the MPOB has recommended to smallholders. However, based on field observation, most smallholders were using chemical pesticides rather than IPM practices because of a lack of knowledge about controlling bagworm infestations (Desa et al., 2021).

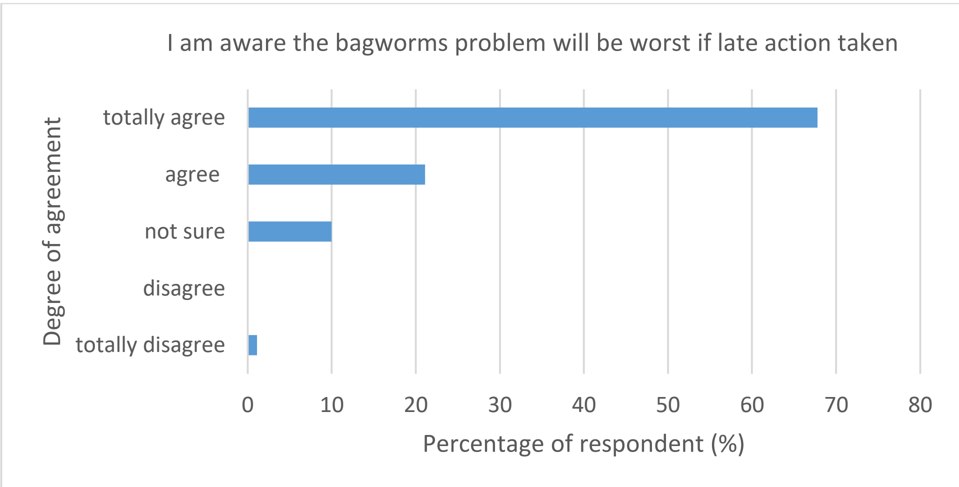

Fig 4: Awareness of the fast action towards bagworms problem

DISCUSSION

This study on the bagworm control practices among smallholders of Malaysian oil palm plantations highlights the significant impacts of pest infestations on productivity and profitability. Through a combination of qualitative and quantitative methods, including structured interviews with 90 smallholders, this paper identifies key factors influencing bagworm management. The EFA results revealed that the primary determinants include general operation management, authority and peer influence, legal awareness, profit concern, and pesticide awareness. The smallholders generally acknowledged the importance of pest management, but they face challenges related to their limited knowledge and resources. This paper reinforces the need for advanced education on sustainable practices, integrated pest management, and the risks of chemical pesticide misuse. Strengthening the regulatory frameworks and promoting safer alternatives, such as biological control methods, are important for effective and sustainable pest management. The findings suggest that increased awareness and capacity among smallholders could significantly contribute to a higher productivity growth rate within the Malaysian palm oil sector. Measures could include the intensification and diversification of organic and chemical pesticides, which would require greater awareness of safer production methods and the long-term harmful effects of pesticide misuse. Other potential steps involve strengthening the capacity of the regulatory agencies responsible for preventing the importation of banned pesticides, as well as promoting research on and investment in sustainable alternatives like integrated pest management, biological control, and agro-ecological practices.

AUTHOR CONTRIBUTIONS

Dr RHM Radzil , the main author, participated in conceptualization of research , prepared maps and figure , formal data analysis , interpreted the results, and preparing the manuscript. Dr HZ Hamzah prepared the writing of initial draft, interpretation of the results and proofreading. Dr H Ahamat participated in project administration and financial acquisition. Dr M Hassan, writing the research framework, review and editing the manuscripts.

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ETHICS APPROVAL

The UKM Ethics Review Committee at Malaysian National University approved our interviews (approval: JEP-2023-550) on November, 2023. Respondents gave written consent for review and signature before starting interviews.

CONFLICT OF INTEREST

The author declares that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

ABBREVIATIONS

EFA	Exploratory factor analysis
FELDA	Federal land development authority
GDP	Gross domestic product
IPM	Integrated pest management
IPPKS	Oil palm smallholder agricultural input soft loan scheme

KMO	Kaiser-meyer-olkin
MEOA	Malaysian estate owners' association
MPOA	Malaysian palm oil association
MPOB	Malaysian palm oil board
NASH	National Association of Smallholders
SBABB	Quality oil palm seedlings assistance scheme
TBSPK	New planting scheme
TSSPK	Oil palm replanting scheme

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HIGHLIGHTS

- The determinants found includes Factor 1 "General operation management, Factor 2 "Authority and peer influence", Factor 3 "Legal awareness", Factor 4 "Profit concern", and Factor 5 " Pesticide awareness".
- Factor 1, "General operation management", explains the most (15.97 percent)of the total variance and concerns the basic knowledge that smallholders possess about operating their plantation.
- Most of the smallholders totally agreed to take responsibility for managing their plantation and ensuring the yield increased yearly with or without government intervention.
- Majority of smallholders recognized the severe impact of a bagworm attack on their plantation.