

Illiteracy in Agroecology is the Biggest Challenge of Malaysian Rice Farmers to Practice Integrated Pest Management

J.L Tan^{1,2*}, W.C. Soh and Y.E. Leong³

¹Department of Zoology, Faculty of Science, University of South Bohemia, České Budějovice, Czech Republic

²Institute of Entomology, Biology Centre CAS, České Budějovice, Czech Republic

³Department of Entomology, National Chung Hsing University, Taichung, Taiwan (R.O.C.)

Twenty-six percent of global rice is produced in Southeast Asia, yet rice shortages remain a regional concern. Integrated pest management (IPM) has been promoted for decades to improve yields, but its adoption in Malaysia remains low. The reasons for this need to be investigated, as Malaysia aims to produce safer, higher-quality food. A survey was conducted in two paddy areas using a questionnaire to assess paddy farmers' knowledge of IPM-related topics. The study found that all respondents still rely on chemical pest control methods. Respondents scored well in their knowledge of insecticides, pest symptoms, and arthropod pests and their ecology, with average scores of 71.9%, 71.5%, and 70.2%, respectively. However, they performed poorly on topics related to natural enemies and their ecology, with an average score of 36%. The generalised linear model revealed that age, farming experience, and levels of education did not significantly affect knowledge of insecticides, pest symptoms, and arthropod pests and their ecology. However, higher levels of education were predicted to improve scores on topics related to natural enemies and their ecology. Based on these findings, farmer education is recommended to enhance their knowledge of biological control, with the hope of promoting higher adoption of IPM in Malaysia.

Keywords: farmers knowledge; farming practice; *Oryza sativa*; pest control; sustainable agriculture

I. INTRODUCTION

Many people around the world depend on rice as their staple food, and 90% of rice is produced in Asia, where China and India are the largest producers. Rice is the most important food crop for low- and low-middle-income countries; therefore, sustainable rice production is crucial to achieve food sufficiency in these regions (GRiSP, 2013). Moreover, rice agricultural residue (e.g., rice straw) are well established source for various value-added products, including paper, boards, and clean fuels such as hydrogen and/or petrochemical substitutes via pyrolysis (Fahmy *et al.*, 2020; Fahmy *et al.*, 2017). Southeast Asia contributes 26% of global rice production and 40% of exports, with Thailand and Vietnam being the main exporters (Eckert, 2022). However, rice

shortages in this region have always been a major concern. Although the 1960s Green Revolution has led to a steep increase in rice yield, this growth has not been sustainable, as the yields plateaued and, in some cases, began to decline during the 1990s (Yuan *et al.*, 2022). Several factors have contributed to this stagnation and decline, one of which is the increase in pest problems due to the prophylactic use of chemical pesticides. This practice has disrupted the pest-predator balance, leading to a resurgence of pest populations, which in turn requires more pesticide applications. Consequently, this has promoted pesticide resistance and raised environmental and health concerns. More importantly, the cost of pesticides may be equal to or greater than the

*Corresponding author's e-mail: jiunnluh@gmail.com

economic benefits gained from the use of agrochemicals, such as higher yield (Hazell, 2009).

During the 1980s, heavy reliance on chemical control led to severe outbreaks of brown planthopper (BPH), *Nilaparvata lugens* (Stål) (Hemiptera: Delphacidae), in the Southeast Asia region. This incident preceded the first success story of integrated pest management (IPM) in paddy farming in the region (Pontius *et al.*, 2002). The Food and Agriculture Organization of the United Nations (FAO), together with its partners and with the support of the Indonesian government, initiated the IPM program in Indonesia. Using the Farmer Field School (FFS) approach, IPM achieved significant successes in improving paddy production, including reducing pest damage, increasing average yields, and boosting overall returns (Thorburn, 2015). Since then, the FFS approach has spread to various continents, including seven countries in Southeast Asia: Cambodia, Indonesia, Laos, Malaysia, Philippines, Thailand, and Vietnam (Pontius *et al.*, 2002; van den Berg *et al.*, 2020; Gallagher, 2000). In 1977, Malaysia launched a field surveillance program to address BPH outbreaks, discovering that numerous effective native predators naturally suppressed the planthopper population. The feasibility of conservation biocontrol in paddy was evident, as insecticide-free plots were not damaged, while adjacent fields treated with insecticides suffered from 'hopperburn' (Ooi, 1982; Ooi, 2015). Since the initiation of the surveillance program, farmers have been trained to recognise pests and natural enemies, enabling them to make better decisions about insecticide use. Insecticides were only applied when natural control failed, as indicated by the prey:predator ratio (Ooi & Heong, 1988). However, the successes of IPM in paddy farming were short-lived in Malaysia. The failure of IPM was likely due to diminishing funding for agricultural extension services, the availability of new and cheaper pesticide formulations in Asia, and deregulation of pesticides, most of which promoted chemical-intensive rice farming (van den Berg *et al.*, 2020; Thorburn, 2015). As noted by Gallagher *et al.* (2009), obstacles to implement IPM in developing countries are often related to chemical pesticides, which are frequently underregulated and easily accessible to

farmers. In addition, agrochemical companies invest heavily in marketing campaigns that convince farmers to use pesticides as their primary pest control strategies. (Bottrell & Schoenly, 2012; Deguine *et al.*, 2021). Moreover, empowering farmers with IPM knowledge requires sustained effort, and programs like FFS are costly and time-consuming. Therefore, once supportive policies and funding were no longer available, farmers were likely to revert to chemical control, which is often perceived as less complicated (Awang *et al.*, 2019; Deguine *et al.*, 2021; Thorburn, 2015). Furthermore, securing sustainable funding for the IPM-FFS program is almost impossible, as it does not offer commercial potential, unlike the introduction of biopesticides, which has attracted support from multiple sectors due to its commercialisation prospects (Awang *et al.*, 2019).

An economic evaluation of rice production in Malaysia showed that IPM could reduce general operating expenses by decreasing the use of pesticides (Amir *et al.*, 2012). Furthermore, paddy cultivated using the System of Rice Intensification (SRI) method, which shares similarities with IPM, demonstrated that agroecological farming could lead to better plant growth and higher yields (Doni *et al.*, 2015). However, these proven economic benefits were insufficient to motivate farmers to adopt IPM due to a lack of awareness and knowledge about IPM and pesticide use, as well as limited support, training and educational programs, such as agriculture extension services and FFS-related programs (Amir *et al.*, 2012). Heong *et al.* (2021) agreed with these obstacles, stating that to overcome them, it is crucial to empower farmers with knowledge about various aspects of rice production, especially in agroecology, before promoting IPM. Farmers with a fundamental understanding of agroecology would be more likely to adopt IPM confidently and continue practicing it independently. Furthermore, various government subsidies for agrochemicals intended to boost rice yields were among the factors discouraging farmers from adopting IPM, as it was perceived as more complicated by farmers who lacked ecological literacy (Eusoff, 2018; Amin *et al.*, 2022; Fatimah, 2018). However, the results of these subsidies contradicted their intended purpose, as rice production in Malaysia remains relatively

constant for nearly three decades, from 1990 to 2016. In 2016, Malaysia's average rice yield was 2.5 metric tons per hectare (MT/Ha), which was only higher than Thailand (2.0 MT/Ha), while lower than the Philippines (2.6 MT/Ha), Indonesia (3.3 MT/Ha) and Vietnam (3.6 MT/Ha). In addition, Malaysia experienced relatively slow growth in paddy yield over these three decades (1986 – 2016). Better farm management and extension programs were identified as key factors that could help improve rice yields (Omar *et al.*, 2019). Before formulating programs to promote better farm management, it is essential to determine the reason agroecological approaches, like IPM and SRI remain unpopular, despite their demonstrated positive economic benefits in Malaysia. Understanding the current level of knowledge among farmers regarding pest management is crucial. Therefore, this study has two objectives: first, to identify the current farming practices and knowledge of pesticides among paddy farmers, and second, to assess their ability to identify pests and natural enemies and understand the ecology of these arthropods. Achieving these objectives will help researchers and policymakers understand the knowledge gaps among rice farmers and enable the design of training programs tailored to their needs, thus increasing the adoption of IPM and delivering economic, environmental and health benefits.

II. MATERIALS AND METHODS

A. Design of Questionnaire

A trilingual (English, Mandarin, and Malay) survey questionnaire consisting of three major sections was developed. The first section was designed to collect the demographic information from the respondents, while the second section focused on gathering general information about their current paddy farming practices. The third section was designed in a simple quiz format, consisting of four categories. The first category assessed the respondents' knowledge and understanding of commonly used insecticides in paddy farming. The second category tested their ability to identify or recognise symptoms of pest damage in paddy fields. The third and fourth categories evaluated their knowledge of

identifying or recognising paddy arthropod pests and natural enemies, as well as their respective ecology in the paddy field. Furthermore, within each of the four categories in the third section, respondents were asked about their confidence level in their knowledge and understanding of the respective topics. The questionnaire was designed to be concise, with a maximum of 10 questions in each section or category and took approximately 10 minutes to complete. This design aimed to encourage more respondents (i.e., paddy farmers) to participate in the survey without taking up too much of their time. The respondents' private information, including, names, contact details, and other identifying information, was not collected throughout the questionnaire.

B. Pilot Test

A pilot test was carried out to ensure that the language used in the questionnaire was at an appropriate level, allowing the targeted respondents to properly understand the questions. The test was conducted using a convenience sampling method, with a total of 15 Malaysian paddy farmers from Selangor and Perak participating. Their feedback was considered, and the questionnaire was revised before the actual survey.

C. Survey

The survey was conducted in two paddy areas in Malaysia (Table 1), from February 2022 to September 2022. The Integrated Agriculture Development Area Barat Laut Selangor (IADA BLS) paddy area was selected as one of the survey sites because it is one of the highest yield paddy production areas in Malaysia, with an average of approximately 4.34 metric tons per hectare in 2021 (IADA Barat Laut Selangor, 2022). The Langkap paddy area was selected alongside IADA BLS because it is recognised by many paddy farmers as another high yield paddy production area in Malaysia, even though the production statistics of that area were not available. Participants were selected using a convenience sampling method, where they were approached either in the paddy fields or at local agriculture shops. Participants who were technology-

savvy received an electronic version of the questionnaire through Google Forms, while those less familiar with technology were provided with a printed version. In this survey, the electronic questionnaire was encouraged to align with global sustainability trends and promote the use of less papers. All participants also received verbal guidance, if necessary, in the local dialect to ensure they fully understood all the questions.

Table 1. The survey was carried out in the following areas

| Malaysia States | Area | Estimated coordinate |
|-----------------|----------------|----------------------|
| Selangor | Tanjong Karang | 3.456937, 101.204511 |
| | Sekinchan | 3.516331, 101.121178 |
| | Sungai Besar | 3.698399, 101.008621 |
| Perak | Langkap | 4.032262, 101.160041 |

D. Statistical Analysis

The data collected were analysed using the R statistical program, version 4.2.1 (The R Foundation, <https://www.r-project.org/>). A pairwise comparison test, either a t-test (parametric data) or a Mann-Whitney *U* test (non-parametric data), was used to test for differences in the respondents' knowledge of the tested topics between the two paddy areas.

The Poisson generalised linear model (GLM) was used to determine the effects respondents' age, farming experience, and educational level on the respondents' current knowledge of the topics tested in the survey. The model was initially created using the *glm* function, with the respondents' scores as the response variable and age, farming experience and educational level as the independent variables, specifying the family as *poisson*. The best-fitting model was selected using backward elimination method with the *drop1* function, and Chi-

square (χ^2) as the test statistic. The independent variables which were indicated as significant in the Chi-square test (χ^2 , $p < 0.05$) remained in the final model, while those that were not significant were removed. A new model, containing only the significant independent variables, was created for the analysis.

III. RESULTS

A. Demographic Information

A total of 101 paddy farmers participated in the survey, with 56 of them from Selangor and 45 of them from Perak. Among the Selangor participants, most were from Sekinchan and Sungai Besar, with only two from Tanjong Karang (Figure 1). In Perak, most participants were from the Langkap area, and three were from other surrounding paddy areas. Demographic information of the respondents is summarised in Table 2.

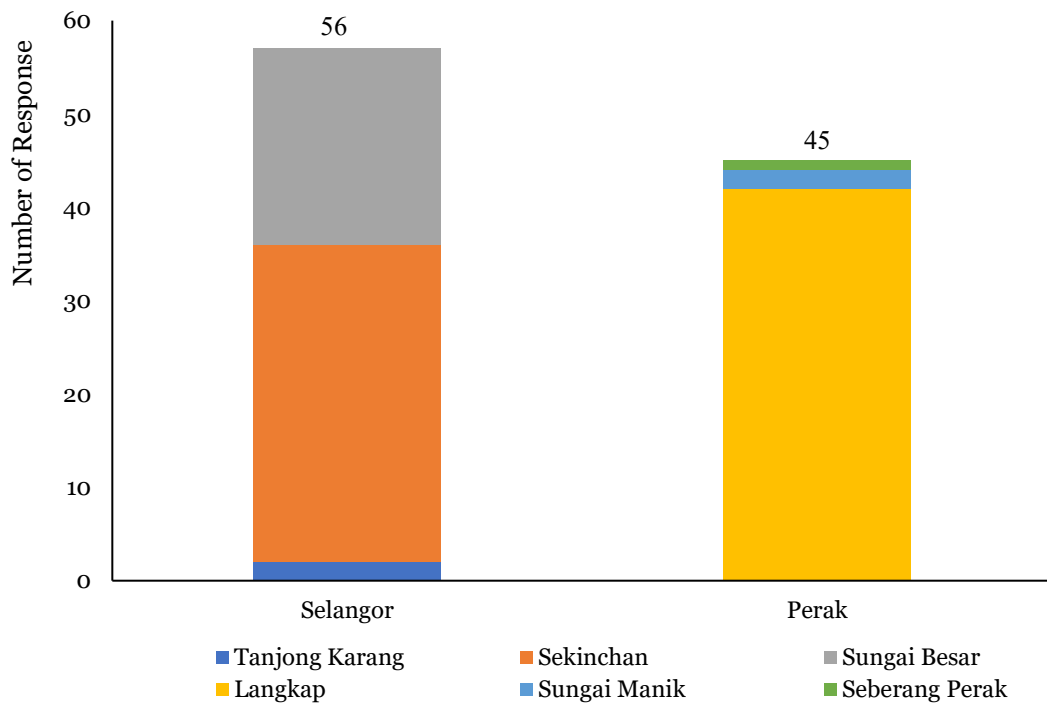


Figure 1. The farming locations of the respondents

Table 2. Demographic information of the respondents

| | | Selangor N ¹ (in %) | Perak N ¹ (in %) | Overall N ¹ (in %) |
|------------------|---------|--|---------------------------------------|---|
| Gender | Male | 55 (98.2) | 44 (97.8) | 99 (98.0) |
| | Female | 1 (1.8) | 1 (2.2) | 2 (2.0) |
| Ethnicity | Malay | 20 (35.7) | 5 (11.1) | 25 (24.8) |
| | Chinese | 35 (62.5) | 40 (88.9) | 75 (74.3) |
| | Indian | 1 (1.8) | 0 (0.0) | 1 (1.0) |
| | Others | 0 (0.0) | 0 (0.0) | 0 (0.0) |
| Age | ≤ 20 | 0 (0.0) | 0 (0.0) | 0 (0.0) |
| | 21 – 30 | 2 (3.6) | 3 (6.7) | 5 (5.0) |
| | 31 – 40 | 5 (8.9) | 7 (15.6) | 12 (11.9) |
| | 41 – 50 | 9 (16.1) | 17 (37.8) | 26 (25.7) |
| | 51 – 60 | 18 (32.1) | 12 (26.7) | 30 (29.7) |
| | ≥ 61 | 22 (39.3) | 6 (13.3) | 28 (27.7) |

| | | | | |
|---------------------------------------|----------------------------------|-----------|-----------|-----------|
| Educational level² | No formal | 6 (10.7) | 5 (11.1) | 11 (10.9) |
| | Primary | 24 (42.9) | 13 (28.9) | 37 (36.6) |
| | Lower Secondary | 11 (19.6) | 13 (28.9) | 24 (23.8) |
| | Upper Secondary | 10 (17.9) | 12 (26.7) | 22 (21.8) |
| | Pre-university | 1 (1.8) | 0 (0.0) | 1 (1.0) |
| | Higher | 4 (7.1) | 2 (4.4) | 6 (5.9) |
| Farming experience (years) | ≤ 10.00 | 3 (5.4) | 12 (26.7) | 15 (14.9) |
| | 10.01 – 20.00 | 20 (35.7) | 10 (22.2) | 30 (29.7) |
| | 20.01 – 30.00 | 10 (17.9) | 13 (28.9) | 23 (22.8) |
| | 30.01 – 40.00 | 5 (8.9) | 5 (11.1) | 10 (9.9) |
| | ≥ 40.01 | 18 (32.1) | 5 (11.1) | 23 (22.8) |
| Size of farming area (hectare) | ≤ 1.00 | 1 (1.8) | 0 (0.0) | 1 (1.0) |
| | 1.01 – 5.00 | 13 (23.2) | 3 (6.7) | 16 (15.8) |
| | 5.01 – 10.00 | 13 (23.2) | 5 (11.1) | 18 (17.8) |
| | 10.01 – 15.00 | 17 (30.4) | 12 (26.7) | 29 (28.7) |
| | 15.01 – 20.00 | 10 (17.9) | 10 (22.2) | 20 (19.8) |
| | 20.01 – 25.00 | 1 (1.8) | 8 (17.8) | 9 (8.9) |
| | ≥ 25.01 | 1 (1.8) | 7 (15.6) | 8 (7.9) |
| Paddy field tenure | Owned land | 10 (17.9) | 6 (13.3) | 16 (15.8) |
| | Private leased land ³ | 28 (50.0) | 25 (55.6) | 53 (52.5) |
| | Gov-leased land ⁴ | 0 (0.0) | 0 (0.0) | 0 (0.0) |
| | Owned and private leased land | 18 (32.1) | 13 (28.9) | 31 (30.7) |
| | Owned and gov-leased land | 0 (0.0) | 1 (2.2) | 1 (1.0) |
| | Others | 0 (0.0) | 0 (0.0) | 0 (0.0) |

¹ N: the number of responses

² Education level: Lower Secondary represent Form 1 to 3 (age 13 – 15); Upper Secondary represent Form 4 to 5 (age 16 – 17); Pre-university include Form 6, matriculation, A level, foundation (age 18 – 19); Higher education represent diploma, first degree or higher (≥ age 19)

³ Private leased land: lease from another person or private company; ⁴Gov-leased land: Government-leased land, lease from the government

B. Current Farming Practices

All respondents depended on synthetic agrochemicals for pest management, but 18.8% of them also

incorporated natural and organic products, and 6.9% included biopesticides in their pest management approach (Table 3). Mixing multiple agrochemicals for applications was practiced by almost all respondents,

with about 13% of them mixing seven or more agrochemicals at a time. Only nearly half of the respondents practiced field monitoring before pesticide application, while about 74% of them practiced calendar spraying. About 67% of respondents will increase the frequency and dose of pesticides if they notice any unhealthy symptoms while practicing their routine pest management approach. However, almost all respondents assessed their plant health solely based on their own or their peers' past experiences. Only about 36% of respondents perceived their current pest management strategy as being more than 80% effective. The most common reasons given for their current pest management approach were the influence of other farmers in the community, trial-and-error experiences gained in the past, and the influence by licensed pesticide dealers and sales representatives (Figure 2). Not surprisingly, their top three advisers for pest management were licensed pesticide dealers, other farmers and friends, and sales representatives (Figure 3).

Table 3. Current farming practices of farmers

| | | The Number of Response(s), N | | |
|---|------------------------------|-------------------------------------|--------------|----------------|
| | | Selangor | Perak | Overall |
| | | N (in %) | N (in %) | N (in %) |
| Types of products used in their respective paddy field¹ | Synthetic agrochemicals | 56 (100.0) | 45 (100.0) | 101 (100.0) |
| | Natural and Organic products | 10 (17.9) | 9 (20.0) | 19 (18.8) |
| | Biopesticides | 5 (8.9) | 2 (4.4) | 7 (6.9) |
| | Biological control agents | 0 (0.0) | 1 (2.2) | 1 (1.0) |
| Practice of mixing pesticides and/or liquid fertilisers | Yes | 54 (96.4) | 45 (100.0) | 99 (98.0) |
| | No | 2 (3.6) | 0 (0.0) | 2 (2.0) |
| Number of chemicals in the mixture at a time² | ≤ 3 | 16 (29.6) | 4 (8.9) | 20 (20.2) |
| | 4 – 6 | 34 (63.0) | 32 (71.1) | 66 (66.7) |
| | ≥ 7 | 4 (7.4) | 9 (20.0) | 13 (13.1) |
| Field monitoring before pesticides application | Yes | 25 (44.6) | 23 (51.1) | 48 (47.5) |
| | No | 31 (55.4) | 22 (48.9) | 53 (52.5) |
| Practice calendar spraying | Yes | 42 (75.0) | 33 (73.3) | 75 (74.3) |
| | No | 14 (25.0) | 12 (26.7) | 26 (25.7) |
| Increase the frequency and dose of pesticides against unhealthy symptoms | Yes | 36 (64.3) | 32 (71.1) | 68 (67.3) |
| | No | 20 (35.7) | 13 (28.9) | 33 (32.7) |
| | Yes | 54 (96.4) | 43 (95.6) | 97 (96.0) |

| | | | | |
|--|----------|-----------|-----------|-----------|
| Assess plant health solely based on past experiences³ | No | 2 (3.6) | 2 (4.4) | 4 (4.0) |
| Perceived effectiveness of current pest management practice⁴ | ≤ 20% | 1 (1.8) | 0 (0.0) | 1 (1.0) |
| | 21 – 40% | 0 (0.0) | 0 (0.0) | 0 (0.0) |
| | 41 – 60% | 3 (5.4) | 8 (17.8) | 11 (10.9) |
| | 61 – 80% | 32 (57.1) | 20 (44.4) | 52 (51.5) |
| | ≥ 81% | 20 (35.7) | 17 (37.8) | 37 (36.6) |

¹The respondents were able to choose more than one option in these questions

² This question is only applicable to respondents who practiced mixing of pesticides/liquid fertilisers

³ past experiences refer to both self and peers' experiences

⁴ the level of effectiveness is assessed based on the experiences and perception of the respondents

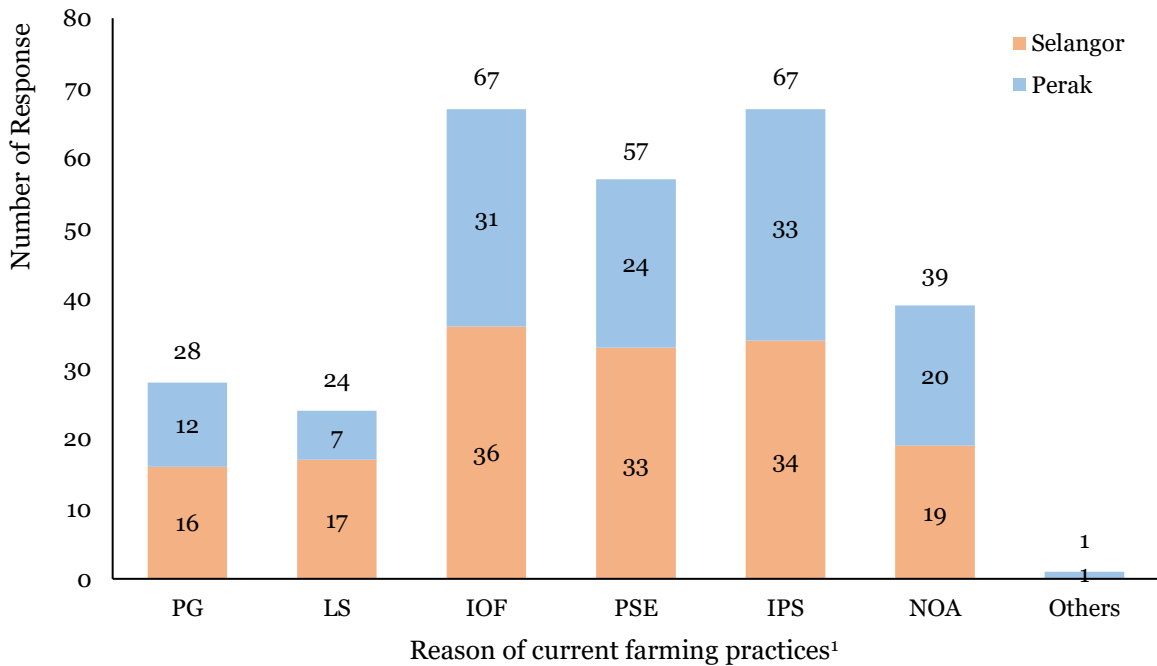


Figure 2. The reason(s) of the respondents for their current farming practices

¹The respondents were able to select and provide more than one reason. PG, continue the practice of past generations; LS, more sense of livelihood security due to previous successes; IOF, influence of other farmers in the community; PSE, more confident due to previous self-experience; IPS, influence by licensed pesticide dealers and sales representatives; NOA, no other known alternative practice is available; Others, other reason: trying to be a model farm for other farmers

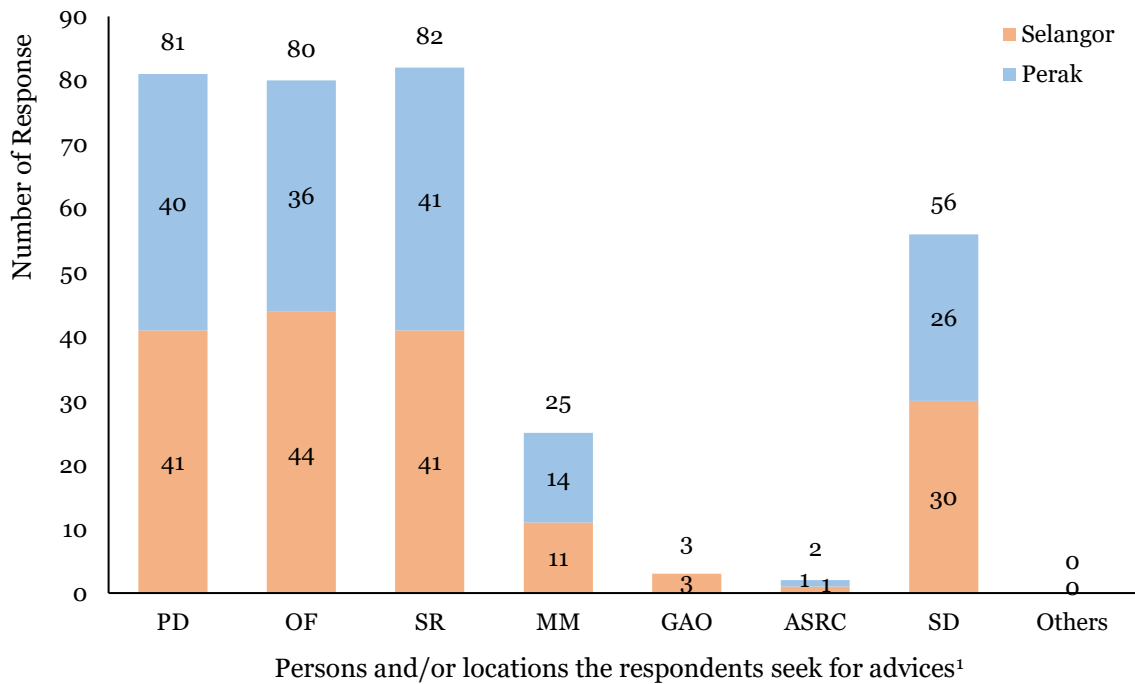


Figure 3. The person and/or locations to which the respondents usually refer for agricultural advice
¹The respondents were able to select more than one option in this question. PD, licensed pesticide dealers; OF, other farmers and friends; SR, sales representatives; MM, mass media; GAO, local government agency and agriculture officers; ASRC, agricultural scientist, researchers, and consultants; SD, self-dependent, self-experiences, trial-and-error approach; Others, other not listed channels

C. Knowledge and Understanding of Selected Topics in Integrated Pest Management (IPM)

Most respondents were confident in their knowledge and understanding of insecticides, their ability to recognise symptoms of pest damage, and their ability to identify arthropod pests in the paddy field (Table 4). Nearly half of them were also confident that they understood the basic ecology of common arthropod pests. However, most of them think they are either unable to or lack confidence in differentiating arthropod

natural enemies from pests and perceive themselves as lacking understanding of the ecology of natural enemies.

Since all data violated the assumption of normality ($P < 0.05$), as tested using Shapiro-Wilks (S-W) W tests, Mann-Whitney U test was used for pairwise comparisons. The pairwise comparison indicated no significant difference in the scores of respondents from the two paddy areas (Table 5). The average of the respondents score was 70% and above for topics on insecticides, pest damage symptoms, and arthropod pests of the paddy field. However, the scores for topics on natural enemies was only about 36%.

Table 4. The respondents' perception of their knowledge and understanding of various IPM topics

| C. ¹ | | | The Number of Response(s), N | | |
|-----------------|--|----------|------------------------------|-------------------|---------------------|
| | | | Selangor N (in %) | Perak N (in %) | Overall N (in %) |
| 1 | Possessed general knowledge and understanding of insecticides | Yes | 35 (62.5) | 31 (68.9) | 66 (65.3) |
| | | No | 11 (19.6) | 11 (24.4) | 22 (21.8) |
| | | Not sure | 10 (17.9) | 3 (6.7) | 13 (12.9) |
| 2 | Ability to recognise symptoms of pest damage(s) | Yes | 43 (76.8) | 37 (82.2) | 80 (79.2) |
| | | No | 9 (16.1) | 3 (6.7) | 12 (11.9) |
| | | Not sure | 4 (7.1) | 5 (11.1) | 9 (8.9) |
| 3 | Ability to recognise or identify any arthropod pest in the paddy field | Yes | 40 (71.4) | 35 (77.8) | 75 (74.3) |
| | | No | 12 (21.4) | 5 (11.1) | 17 (16.8) |
| | | Not sure | 4 (7.1) | 5 (11.1) | 9 (8.9) |
| | Understand the basic ecology of common arthropod pest in the paddy field | Yes | 27 (48.2) | 21 (46.7) | 48 (47.5) |
| | | No | 19 (33.9) | 20 (44.4) | 39 (38.6) |
| | | Not sure | 10 (17.9) | 4 (8.9) | 14 (13.9) |
| 4 | Ability to differentiate natural enemies from arthropod pest in the paddy field | Yes | 22 (39.3) | 16 (35.6) | 38 (37.6) |
| | | No | 17 (30.4) | 17 (37.8) | 34 (33.7) |
| | | Not sure | 17 (30.4) | 12 (26.7) | 29 (28.7) |
| | Understand the basic ecology of common natural enemies in the paddy field | Yes | 10 (17.9) | 13 (28.9) | 23 (22.8) |
| | | No | 22 (39.3) | 22 (48.9) | 44 (43.6) |
| | | Not sure | 24 (42.9) | 10 (22.2) | 34 (33.7) |

¹ C., category

Table 5. The score of respondents from the two paddy areas in each category

| Malaysia states | The mean percentage of the score (100%±SE) ^{1,2} | | | |
|-----------------|---|-----------------------|-----------------------|-----------------------|
| | C1 | C2 | C3 | C4 |
| Selangor | 70.8±2.4 ^a | 72.0±2.4 ^a | 71.2±2.6 ^a | 34.4±3.2 ^a |
| Perak | 73.3±3.1 ^a | 70.7±2.4 ^a | 68.9±3.0 ^a | 38.1±3.5 ^a |
| Average | 71.9±1.9 | 71.5±1.7 | 70.2±2.0 | 36.0±2.4 |

¹ SE represent the standard error

² C1, knowledge and understanding on insecticides; C2, ability to recognise symptoms of pest damage; C3, paddy arthropod pests and their ecology; C4, natural enemies in the paddy field and their ecology; the different superscript alphabets indicate a significant difference in the Mann-Whitney *U* test within the same column

D. The Effect of Age, Farming Experience and Education Level on the Score

The effects of age, farming experience, and education level were not significant on the respondents’ score in the topics of knowledge and understanding on insecticides, the ability to recognise symptoms of pest damage, and paddy arthropod pests and their ecology. The effects of age and farming experience were also not significant on the respondents’ score in topic of natural enemies in the paddy field and their ecology, but educational level was a significant variable that can affect the score in this topic. Although six education

levels were offered as options in the questionnaire, only five levels were used in the GLM analysis. The pre-university level was removed because it had only one respondent, making it unsuitable for the analysis. The GLM analysis indicated that respondents’ scores in the topic of ‘natural enemies in the paddy field and their ecology’ would improve with any education level higher than no formal education, which was predicted to have the lowest score (Table 6). The largest predicted improvement in score was associated with higher education, where an increase of 175% was predicted based on the data from this study.

Table 6. GLM analysis of the effect of education level on the respondents’ score in the topics of natural enemies in the paddy field and their ecology

| Predictors ¹ | β coefficient | Standard error | Odd ratio |
|-------------------------|---------------------|----------------|----------------|
| Intercept | 0.4925 | 0.2357 | |
| Primary | 0.5971 | 0.2543 | 1.817 (181.7%) |
| Lower secondary | 0.6470 | 0.2625 | 1.910 (191.0%) |
| Upper secondary | 0.5274 | 0.2682 | 1.695 (169.5%) |
| Higher | 1.0116 | 0.3043 | 2.750 (275.0%) |

¹ The predictors are the education level, with the intercept being the reference level of the model

IV. DISCUSSION

The demographic information revealed several key insights, including that males still dominate paddy farming in these areas, with more than 50% of the respondents being above 50 years old. This is not surprising, as females are generally less involved in farm management tasks, and youth with rural background are more likely to pursue urban careers, which they perceive as more lucrative, especially amid the reduction of agricultural land due to urban growth (Fatimah, 2018; Amran & Abdul Fatah, 2020; Abdullah *et al.*, 2012; Makhtar *et al.*, 2022; Murdad *et al.*, 2022; Marzuki & Jais, 2020). Most of the respondents were Chinese, followed by Malay and Indian, due to the presence of

‘New Villages’ in Sekinchan and Langkap, which are predominantly Chinese (Wang, 1988). The level of education was also reflected in age, as older individuals in Malaysia were less likely to have received higher education. Furthermore, those with tertiary education were often reluctant to pursue an agricultural career, as it is typically perceived as a physically demanding job (Hussin & Peredaryenko, 2022). The respondents comprised individuals with varying years of farming experience and different sizes of farmland. In general, paddy farmers in Perak tend to have larger farming areas due to the predetermined allocation of land size for each paddy plot. In Perak, each paddy plot is standardised to approximately two hectares, while in

Selangor, it is one hectare per plot. Most respondents farm on privately leased land, which is becoming increasingly common in Malaysian paddy farming. Many younger generations who inherit land from their parents do not venture into paddy farming. As a result, these young landowners tend to rent their land to existing paddy growers who intend to expand their farming areas.

A. Current Paddy Farming Practices

It is well within expectations that all respondents still depend heavily on agrochemicals, such as chemical pesticides and mineral fertilisers. However, some growers have begun to incorporate natural and organic products (e.g., organic fertilisers, manure compost, amino acid-based bio-stimulants, and seaweed extracts) and biopesticides (e.g., mineral oils, pheromones, botanicals, and entomopathogenic microbes) into their farming regime. Although the use of organic-based fertilisers and bio-stimulants has varying results depending on the type of plants, they generally have a positive effect on growth, quality, and yield (Ali *et al.*, 2021; Liu *et al.*, 2021; Salam *et al.*, 2021; Leogrande *et al.*, 2022). Furthermore, organic fertilisers can help revitalise the soil and have potential to reduce or substitute the use of inorganic fertilisers in the long run (Liu *et al.*, 2021; Tan *et al.*, 2020). The respondents mainly depended on biopesticides available at their local pesticide dealers. Currently, typical commercially available biopesticides in Malaysia include products based on neem (azadirachtin), *Bacillus thuringiensis*, *Metarhizium anisopliae*, *Bacillus amyloliquefaciens*, *Beauveria bassiana* and several species of *Trichoderma* (Sivapragasam, 2022). Despite using these products, the respondents were found to associate them with chemical pesticides or target pests, without understanding the actual mechanism of these biological products. Since crop protection companies usually focus solely on promoting products for profit, raising awareness about IPM or the mechanisms of the products is not typically among the main objectives (Awang *et al.*, 2019). Conversations with sales representatives indicated that many do not have a biology background, making it

difficult for them to convey accurate information about the products to farmers. Additionally, some respondents purchased products through online platform that were often unregulated and typically lacked proper information on the packaging. As a result, farmers used these products based on their own interpretations, leading to low efficiency, likely due to poor quality or incorrect usage. Consequently, farmers have become sceptical about the effectiveness of biologically based products. Needless to say, the situation is even worse for biological control agents, such as parasitoids, predators, and beneficial nematodes, as farmers have lacked exposure to information about them.

Conventional practices, such as mixing of pesticides and calendar spraying, remained routine for most respondents. Most of them still believe that increasing the frequency and dosage of pesticides is the way to overcome any worsening of pest and disease infestations. In fact, it has been proven that the opposite is true, as such practices hasten resistance in pests and negatively affect both the applicators and agroecology (Georghiou & Taylor, 1986; Farina *et al.*, 2016; Rudzi *et al.*, 2022). Almost all respondents assess their plant health based solely on their own and their peers' past experiences, which can be subjective and inaccurate. Heong (1984) reported that farmers' assessments of pest damage were inconsistent, and as a result, their ability to make sensible decisions about pest management is doubtful. The top three reasons behind the respondents' current farming practices are the influence of other farmers in the community, influence by licensed pesticide dealers and sales representatives, and personal past experiences. Additionally, their top three advisers are also licensed pesticide dealers, other farmers and friends, and sales representatives. This is not surprising, as recommendations from other farmers may also stem from licensed pesticide dealers and sales representatives, who are often considered experts by farmers. However, farmer-proclaimed experts are typically profit-oriented and tend to recommend solutions that benefit their businesses through promotions, incentives, and training programs that motivate farmers to use their products, often of agrochemical origin (Heong *et al.*, 2015). When the recommended solutions were not effective, the

respondents claimed to practice a trial-and-error approach, which, in desperate situations, included the use of illegal pesticides that often contain higher concentrations of active ingredients and various combinations of pesticides. Consequently, this strategy led to resistance and resurgence of pest populations, negatively affecting the environment and human health, including poisoning of applicators (Shepard *et al.*, 2009). The respondents also cited the lack of known alternative practice as one of the reasons for their current farming practice, although they were introduced to conservation biocontrol during the 1970s outbreak of brown planthopper (Ooi, 1982). Even though the local government has made efforts to introduce sustainable agriculture through programs, such as Malaysian Good Agriculture Practice (MyGAP) and Rice Check guidelines, the lack of awareness has led most paddy farmers to continue farming unsustainably (Mohamed *et al.*, 2016). This is reflected in their responses, as local government agencies, agriculture officers, and agricultural scientists were among the least sought for advises. The respondents claimed that there are low trust and confidence, or a lack of ways to contact these experts. Farmers were often asked to reach out to these officers and scientists, while these officers and scientists rarely visited them in the field. Given the packed schedules of farmers during paddy season, it is taxing for them to make such efforts. The almost non-existing extension services visitation failed to act as a bridge between farmers' problems and researchers' solutions. Furthermore, the respondents noted that some officers in the local agriculture department offered solutions similar to those of licensed pesticide dealers. As a result, they lost confidence and ended up preferring to consult pesticide dealers and sales representatives, who were more easily accessible.

B. Knowledge and Understanding of Integrated Pest Management (IPM)

In general, the respondents' perceptions of their knowledge and understanding of the various topics corresponds to their score in the respective topics. There is no significant difference in the scores of respondents from the two paddy areas. The average score of the

respondents indicated that they have a decent level of knowledge and understanding of the topics related to insecticides, symptoms of pest damage, and arthropod pests in paddy fields. The respondents' knowledge and understanding of these topics can be attributed to their experience, as well as the occasional talks and workshops organised by agrochemical companies in collaboration with local pesticide dealers, which typically share information on target pests and symptoms of pest damage associated with their respective products, including insecticides. Additionally, it is also part of the marketing strategies of sales representatives and pesticide dealers to provide services that assist farmers in identifying pests and symptoms, as well as to offer information on their products, such as the spray rate, mode of actions, target pests, and active ingredients, with intention of promoting their products. However, based on our communications, many sales representatives and licensed pesticide dealers have relatively poor knowledge of insecticides and arthropod pests, yet they remain one of the primary sources of information for many farmers. Besides programs organised by agrochemical companies, the Malaysian Department of Agriculture has also made efforts to educate farmers on pesticide use through various initiatives, including the implementation of the Malaysia Good Agricultural Practice Scheme (myGAP), aimed at promoting sustainable agriculture (Department of Agriculture Malaysia, 2024). However, the respondents still show weakness in several areas related to responsible pesticide usage. This is particularly evident as many respondents are unaware that the IRAC code represents the insecticide mode of actions (IRAC, 2024). This aligns with the findings of Chang *et al.* (2021), which noted that farmers were unfamiliar with modes of action and often confused switching between different active ingredients and trade names with changing the mode of action. This is crucial because the rotation of insecticides remains one of the most important methods for managing insecticide resistance (Madgwick & Kanitz, 2024). Furthermore, some respondents still disagreed with the idea that insecticides should be applied strictly according to the recommended dosage. More often, they apply higher

doses when faced with resistance issues, citing the lack of alternatives. Applying insecticides in amounts other than those specified on the label can promote the development of resistance, whether the dose is higher or lower (Muniz-Junior *et al.*, 2023). This also applies to some bio-insecticides, such as *Bacillus thuringiensis* toxins (Siegwart *et al.*, 2015). Therefore, it is vital for farmers to understand the consequences of using doses other than the recommended amount, not only for environmental and health concerns but also to prolong effectiveness of pest management products.

Many respondents were able to recognise common pest symptoms, including damage from the brown planthopper, stem borer, and rice leaf folder. Most of them were also able to recognise rice lodging, a relatively common phenomenon in paddy farming, often caused by strong winds, accumulated rainfall, and plant height resulting from excessive nitrogen fertilisers use (Wu *et al.*, 2022). The respondents were noted to have difficulty differentiating between nutrient deficiency symptoms and pest damage symptoms, which is understandable since these symptoms often overlap, such as yellowing, brown spots, and necrosis. In the field, it is also challenging for experts to accurately determine based solely on these common symptoms, and therefore, diagnostic tools and systems are developed to help field identification of such symptoms (Xin *et al.*, 2018; Taylor, 2018; Mrisho *et al.*, 2020; Jose *et al.*, 2021). During the interview, most respondents were very confident in their diagnostic abilities, citing their years of experiences on paddy farming, which was also reflected in the results (Table 4). More experienced farmers also mentioned that, on occasion, sales representatives from agrochemical companies consulted them about certain symptoms, which further boosted their confidence. Some respondents even provided examples of creative theories based on their experience, though many of these theories were far removed from the actual science behind the phenomenon. This kind of behaviour is psychologically referred to by Chabris and Simons (2010) as the 'illusion of confidence' and the 'illusion of knowledge', where individuals mistakenly equate their routine experience with a true understanding of a topic. This may become an obstacle for farmers in seeking

professional assistance when facing pest and disease problems, unless the situation becomes desperate. Therefore, it highlights the importance of scientific experts being proactive in approaching farmers and educating them with the accurate, scientifically proven information. This, in turn, will help in the adoption of sustainable agricultural practices.

Almost all respondents understand the concept of complete metamorphosis and can recognise pests they can easily observed, such as the brown planthopper. However, the understanding of the ecology of these pests still requires strengthening among general paddy farmers, despite the relatively high average scores in the section on arthropod pests. Some of the more important concepts that some respondents still lack knowledge of include the fact that brown planthoppers undergo incomplete metamorphosis and are sap-sucking pests. Their feeding does not result in defoliation but causes drying, wilting, and, in severe cases, 'hopperburn' (Sogawa & Cheng, 1979; Wang *et al.*, 2021). Additionally, some respondents failed to recognise the adults of common rice stemborers in Malaysia, namely *Chilo auricilius* Dudgeon, *Scirpophaga incertulas* (Walker), and *Sesamia inferens* (Walker) (Yaakop *et al.*, 2020). Due to complete metamorphosis, they often only notice the larvae, which damage the crops, while the adults of these species look completely different. This concurs with the findings of Awudzi *et al.* (2021), where farmers had difficulty identifying the adults of pests with complete metamorphosis. The population of rice leaf folder, *Cnaphalocrosis medinalis* Guenée, can increase with high nitrogen usage, rainfall, and relative humidity, with rainfall and relative humidity also positively correlated with rice stemborer populations (de Kraker *et al.*, 2000; Gangwar, 2015; Baskaran *et al.*, 2017; Zainab *et al.*, 2017). Although both pests are key pests of paddy, many respondents are still unaware of this. Knowing the basic ecology of the pests is equally important as the ability to recognise the pest itself, especially when some respondents claimed to monitor and spray for the control of adult rice stemborers during the day, despite these moths being nocturnal in nature. This knowledge is vital for adopting an integrated pest management approach. Even though information on pest ecology is

presented to farmers during various exhibitions and training programs, some may forget it as they tend to prioritise profit for their livelihood. Therefore, consistent efforts to visit and refresh farmers on this information on-site may lead to better outcome.

The respondents generally have poor knowledge of natural enemies and their ecology, with an average score of only 36%. Although almost all respondents recognised adult dragonfly as generalist predators, most were unaware that their larvae live in the water and are also predators. Most respondents also do not recognise common natural enemies present in paddy fields, such as the wolf spider (*Pardosa pseudoannulata* (Bösenberg & Strand)), the common ladybeetle (*Micrapis discolor* (Fabricius)), parasitoid (*Tetrastichus schoenobii* Ferriere), and the meadow grasshopper (*Conocephalus longipennis* (Haan)) (Zhong *et al.*, 2019; Ooi, 2015; Rothschild, 1971). Furthermore, most respondents were unaware that *P. pseudoannulata* is a webless, ground-inhibiting spider that is very effective in controlling brown planthoppers and green leafhoppers; *M. discolor* preys on rice pests; *T. schoenobii* is an effective egg parasitoid of the yellow rice stemborer; and *C. longipennis* is an egg predator of the yellow rice stemborer (Mala *et al.*, 2009; Hagen *et al.*, 1999; Ooi, 2015; Rothschild, 1971). Although information, such as the wolf spider being an effective predator and recommendations on ways to protect them, like avoiding early insecticide spray, was once promoted to Malaysian paddy farmers by the National Agricultural Research and Extension Agencies (Sigsgaard, 2000), most respondents have no recollection of this information. Some respondents claimed ladybeetle as pests. In fact, *M. discolor*, the most commonly seen ladybeetle in the two paddy areas, is known as pollinivorous. However, this does not negate their role as effective predators of several key rice pests, including brown planthoppers, green leafhoppers, aphids, and thrips (Shanker *et al.*, 2013; Razali *et al.*, 2015). It is no surprise that most respondents think *C. longipennis* is an herbivore, as they are unaware of grasshopper species that are predators. Needless to say, most of them also did not know about the existence of parasitoids, which are often too small to notice. Such information must be shared verbally,

possibly more effectively through live demonstrations, such as an insect zoo (Saul-Gershenz, 2009), especially with illiterate and elderly farmers who may be reluctant to accept information about 'good' insects. As Wongsiri *et al.* (1980) reported, there were a long list of natural enemies of rice insect pests in Thailand, and being in the same region, Malaysia should also have a huge diversity of natural enemies. Research on currently available natural enemies should be conducted, and such information should be shared with farmers to encourage the adoption of conservation biological control. Given that some farmers still ignorant of alternative pest control methods and continue to rely solely on chemical insecticides, this indicates a major gap in the dissemination of research findings on biological control to farmers in Malaysia.

C. Higher Level of Education can Improve Respondents' Score on the Topic of Natural Enemies

Respondents with higher levels of educations were predicted to score better on the topic of natural enemies, while age and farming experience were not significant. Education level has previously been reported to be positively correlated with the adoption of new technology and IPM (Shrestha *et al.*, 2024; Dinpanah & Nezhadhosseini, 2013). In line with the findings of this study, it is likely that a farmer with more formal education is better equipped to gain professional knowledge (Hou & Wu, 2010). Additionally, respondents mentioned gaining new farming information through mass media platforms, such as TikTok and Facebook. This is particularly advantageous for literate farmers, as they can compare the content with scientific readings, such as journal articles, and are less likely to be misled. Scientific articles are mostly in English, and illiterate farmers, due to language barrier, are excluded from this information. Respondents also raised the issue of language barriers during training and seminar organised by research institutions and universities. For example, many illiteracy farmers do not understand English and cannot grasp the meaning of scientific jargon. As a result, many of them shy away from such programs, because they do not understand

them and consider them a waste of time. However, specific programs designed to cater to farmer education, such as farmer field schools and educational-extension activities, have proven to improve farmers' knowledge and increase the adoption of IPM (Dinpanah & Nezhadhosseini, 2013; Waddington *et al.*, 2014). Therefore, it is highly recommended that such activities be carried out to help more farmers, especially those who are illiterate, understand natural enemies and their ecology, with the hope of increasing the adoption of sustainable agriculture approaches, such as IPM, in Malaysian paddy farming.

D. Perspectives and Recommendations

Farmers were often blamed to be reluctant in the low adoption of IPM in Malaysia, but it was found that the main obstacle is the lack of awareness and understanding about IPM and biological control. Farmers were found to have positive opinions toward the adoption of IPM and expressed a strong willingness to learn about it. However, without suitable guidance, programs, and training, reducing pesticide use and practicing IPM without prior fundamental knowledge is perceived as risky and non-incentivising (Chang *et al.*, 2021; Leong *et al.*, 2022). Farmers often compare biological control with chemical control, citing the lack of available products. However, biological control is not limited to introductions through classical biological control or mass-released, but there is also conservation biological control, which can be achieved by improving and conserving agroecology (Leong *et al.*, 2022; Fairuz *et al.*, 2017). There have been several successful examples of conservation biological control in Malaysian paddy farming, due to the high species diversity in the region (Rothschild, 1970; Ooi, 1982; Ooi, 1988; Ooi, 2015). Farmer education is a key activity that can help increase awareness of biological control practices and promote the adoption of IPM (Mkenda *et al.*, 2020). It is recommended that the government strengthen the knowledge of extension service officers in relevant areas to provide advice and assistance to farmers to transition from conventional practices to IPM. Programs such as the farmer field schools and model

farms can be established to facilitate the dissemination of information. Besides knowledge, farmers are most concerned about sustaining their livelihoods when deciding to adopt new practices. Therefore, government policies to support farmers during the transition from conventional practices to IPM are necessary to reduce the risk of losses that could affect their livelihoods during this period. Some of the suggested government efforts can take the form of subsidies and incentives through marketing programs in collaboration with various government-linked organisations. This can help farmers obtain a more stable and better selling price for IPM products, thereby motivating them to adopt this practice.

V. CONCLUSIONS

All respondents still practiced conventional farming approaches, including heavy reliance on chemical pesticides, calendar spraying, mixing of 'cocktail' pesticides, and increasing dosage and frequency to overcome severe pest infestation. The respondents identified their peers, licensed pesticide dealers, and sales representatives as the main influencers and advisors behind their farming practices and problems. Most respondents scored well on the topics of knowledge and understanding of insecticides, recognising symptoms of pest damage, and arthropod pests and their ecology. However, several areas of understanding vital for the adoption of IPM still need improvement. The respondents scored the worst on the topics of natural enemies and their ecology, with most only recognising dragonfly as generalist predators, which is alarming given the global urgency for sustainable practices. According to the GLM, age, farming experience, and levels of education do not significantly affect the scores on the topics of knowledge and understanding of insecticides, the ability to recognise symptoms of pest damage, and arthropod pests and their ecology. However, levels of education can improve the scores on topics of natural enemies and their ecology. It is recommended that relevant government agencies provide support through extension services and programs, such as farmer field schools, to

improve farmers' knowledge, especially for the illiterate, on topics of biological control with the hope of increasing the adoption of IPM. Additionally, financial support for farmers during the transition from conventional to IPM is suggested to motivate farmers in adopting this practice, as sustaining livelihoods is most concerning to them.

VIII. REFERENCES

- Abdullah, FA, Samah, BA & Othman, J 2012, 'Inclination towards agriculture among rural youth in Malaysia', *Journal of Basic and Applied Scientific Research*, vol. 2, no. 11, pp. 10892-10894.
- Ali, O, Ramsuhag, A & Jayaraman, J 2021, 'Biostimulant properties of seaweed extracts in plants: Implications towards sustainable crop production', *Plants*, vol. 10, no. 3.
- Amin, RM, Ahamat, H & Hassan, MS 2022, 'Regulatory framework of rice fertiliser subsidy management to attain sustainable development goals: Malaysia's perspective', *Journal of Sustainability Science and Management*, vol. 17, no. 8, pp. 175-195.
- Amir, HM, Shamsudin, MN, Mohamed, ZA, Hussein, MA & Radam, A 2012, 'Economic evaluation of rice IPM practices in MADA, Malaysia', *Journal of Economics and Sustainable Development*, vol. 3, no. 9, pp. 47-55.
- Amran, FNF & Abdul Fatah, F 2020, 'Insights of women's empowerment and decision-making in rice production in Malaysia', *Food Research*, vol. 4, no. S5, pp. 53-61.
- Awang, J, Norton, G & Larochelle, C 2019, 'Obstacles to widespread diffusion of IPM in developing countries: Lessons from the field', *Journal of Integrated Pest Management*, vol. 10, no. 1.
- Awudzi, GK, Adu-Acheampong, R, Avicor, SW, Bukari, Y, Yeboah, MA, Boateng, EKO & Ahadzi, SK 2021, 'Farmers' knowledge and perception of cocoa insect pests and damage and the implications for pest management on cocoa in Ghana', *Journal of Plant Protection Research*, vol. 61, no. 2, pp. 145-155.
- Baskaran, RKM, Sharma, KC & Kumar, J 2017, 'Seasonal and relative abundance of stem-borer and leaf-folder in wet land rice eco-system', *Journal of Entomology and Zoology Studies*, vol. 5, no. 2, pp. 879-884.
- Bottrell, DG & Schoenly, KG 2012, 'Resurrecting the ghost of green revolutions past: The brown planthopper as a recurring threat to high-yielding rice production in tropical Asia', *Journal of Asia-Pacific Entomology*, vol. 15, no. 1, pp. 122-140.
- Chabris, C & Simons, D 2010. *The Invisible Gorilla*, Glasgow, United Kingdom, HarperCollins Publishers Ltd.
- Chang, YY, Tan, J & Tan, JL 2021, 'Knowledge and attitude of Malaysian fruit growers on integrated pest management (IPM)', *ASM Science Journal*, vol. 16.
- de Kraker, J, Rabbinge, R, van Huis, A, van Lenteren, JC & Heong, KL 2000, 'Impact of nitrogenous-fertilization on the population dynamics and natural control of rice leaffolders (Lep.: Pyralidae)', *International Journal of Pest Management*, vol. 46, no. 3, pp. 225-235.
- Deguine, J-P, Aubertot, J-N, Flor, RJ, Lescourret, F, Wyckhuys, KAG & Ratnadass, A 2021, 'Integrated pest management: good intentions, hard realities. A review', *Agronomy for Sustainable Development*, vol. 41.
- Department of Agriculture Malaysia 2024. Official Portal of Department of Agriculture, Ministry of Agriculture and Food Security, Department of Agriculture Malaysia, viewed 28 November 2024, <<https://www.doa.gov.my/index.php/pages/view/1053?mid=12>>.
- Dinpanah, G & Nezhadhosseini, SM 2013, 'Factor influence on adoption of integrated pest management (IPM) by vine owner of Iran', *International Journal of Agronomy and Plant Production*, vol. 4, no. 10, pp. 2514-2519.
- Doni, F, Sulaiman, N, Isahak, A, Mohamad, WNW, Zain, CRCM, Ashari, A & Yusoff, WMW 2015, 'Impact of System of Rice Intensification (SRI) on paddy field ecosystem: Case study in Ledang, Johore, Malaysia',

VI. ACKNOWLEDGEMENT

The authors thank all the participants in this study.

VII. CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

- Journal of Pure and Applied Microbiology, vol. 9, no. 2, pp. 927-933.
- Eckert, P 2022. Southeast Asia remains world rice bowl as pockets of region suffer crop disasters, Radio Free Asia (rfa), viewed 7 December 2022, <<https://www.rfa.org/english/news/cambodia/south-eastasia-rice-10302022114716.html>>.
- Eusoff, NS 2018. Paddy farmers calls on new govt to raise subsidies, The Edge Markets, viewed 08.12 2022, <<https://www.theedgemarkets.com/article/paddy-farmers-calls-new-govt-raise-subsidies>>.
- Fahmy, TYA, Fahmy, Y, Mobarak, F, El-Sakhawy, M & Abou-Zeid, RE 2020, 'Biomass pyrolysis: past, present, and future. ', Environment, Development and Sustainability, vol. 22, pp. 17-32.
- Fahmy, Y, Fahmy, TYA, Mobarak, F, El-Sakhawy, M & Fadl, MH 2017, 'Agricultural residues (wastes) for manufacture of paper, board, and miscellaneous products: Background overview and future prospects', International Journal of ChemTech Research, vol. 10, no. 2, pp. 425-448.
- Fairuz, K, Idris, AG, Syahrizan, S & Mohammad Noor, AH 2017, 'Knowledge, attitude, awareness, communication and practice among farmers towards empowerment of natural enemies in rice field in Melaka, Malaysia', International Journal of Academic Research in Business and Social Sciences, vol. 7, no. 11, pp. 1225-1235.
- Farina, Y, Abdullah, MP, Bibi, N & Kalik, WMAWM 2016, 'Pesticides residues in agricultural soils and its health assessment for humans in Cameron Highlands, Malaysia', Malaysian Journal of Analytical Sciences, vol. 20, no. 6, pp. 1346-1358.
- Fatimah, BK 2018. Evaluation of Agricultural Subsidies and the Welfare of Rice Farmers, Kuala Lumpur, Malaysia, IDEAS Policy Research Berhad.
- Gallagher, KD 2000. Community Based Rice IPM Programme Development: A Facilitator's Guide, Jakarta, Indonesia, United Nation Food and Agriculture Organization.
- Gallagher, KD, Ooi, PAC & Kenmore, PE 2009, 'Impact of IPM Programs in Asian Agriculture', eds R Peshin & AK Dhawan, in Integrated Pest Management: Dissemination and Impact, Springer, Dordrecht, pp. 347-358.
- Gangwar, RK 2015, 'Life cycle and abundance of rice leaf folder, *Cnaphalocrocis medinalis* (Guenee) - A review', Journal of Natural Sciences Research, vol. 5, no. 15, pp. 103-105.
- Georghiou, GP & Taylor, CE 1986, 'Factors Influencing the Evolution of Resistance', in Pesticide Resistance: Strategies and Tactics for Management, National Academy Press, Washington, D.C., pp. 157-169.
- GRiSP (Global Rice Science Partnership) 2013. Rice almanac, Los Baños, Philippines, International Rice Research Institute.
- Hagen, KS, Mills, NJ, Gordh, G & Mcmurtry, JA 1999, 'Terrestrial Arthropod Predators of Insect and Mite Pests ', eds TS Bellows & TW Fisher, in Handbook of Biological Control: Principles and Applications of Biological Control, Academic Press, San Diego, California, pp. 383-503.
- Hazell, PBR 2009. The Asian Green Revolution, Washington, D. C., International Food Policy Research Institute (IFPRI).
- Heong, K-L, Lu, Z-X, Chien, H-V, Escalada, M, Settele, J, Zhu, Z-R & Cheng, J-A 2021, 'Ecological engineering for rice insect pest management: the need to communicate widely, improve farmers' ecological literacy and policy reforms to sustain adoption', Agronomy, vol. 11.
- Heong, KL 1984, 'Pest control practices of rice farmers in Tanjong Karang, Malaysia', International Journal of Tropical Insect Science, vol. 5, no. 3, pp. 221-226.
- Heong, KL, Wong, L & Reyes, JHD 2015, 'Addressing Planthopper Threats to Asian Rice Farming and Food Security: Fixing Insecticide Misuse', eds KL Heong, J Cheng & MM Escalada, in Rice Planthoppers, Springer, Dordrecht, Netherlands, pp. 65-76.
- Hou, B & Wu, L 2010, 'Safety impact and farmer awareness of pesticide residues', Food and Agricultural Immunology, vol. 21, no. 3, pp. 191-200.
- Hussin, R & Peredaryenko, M 2022. Future of agriculture sector lies in our youths, Star Media Group Berhad, viewed 15.12 2022, <<https://www.thestar.com.my/opinion/columnists/comment/2022/10/19/future-of-agriculture-sector-lies-in-our-youths>>.
- IADA Barat Laut Selangor 2022. Pencapaian hasil dan pengeluaran padi IADA Barat Laut Selangor, IADA Barat Laut Selangor, viewed 14.12 2022, <<https://iadabls.mafi.gov.my/>>.
- IRAC International MoA Working Group 2024. Mode of Action Classification Scheme, Insecticide Resistance

- Action Committee, viewed 28 November 2024, <<https://irac-online.org/documents/moa-classification/>>.
- Jose, A, Nandagopalan, S, Ubalanka, V & Viswanath, D 2021, 'Detection and classification of nutrient deficiencies in plants using machine learning', *Journal of Physics: Conference Series*, vol. 1850.
- Leogrande, R, Chami, DE, Fumarola, G, Carolo, MD, Piegari, G, Elefante, M, Perrelli, D & Dongiovanni, C 2022, 'Biostimulants for resilient agriculture: A preliminary assessment in Italy', *Sustainability*, vol. 14, no. 11.
- Leong, YE, Tan, JL & Kwong, PJ 2022, 'Knowledge and acceptance level of vegetable farmers on organic farming and biological control in Kampar, Perak', *ASM Science Journal*, vol. 17.
- Liu, J, Shu, A, Song, W, Shi, W, Li, M, Zhang, W, Li, Z, Liu, G, Yuan, F, Zhang, S, Liu, Z & Gao, Z 2021, 'Long-term organic fertilizer substitution increases rice yield by improving soil properties and regulating soil bacteria', *Geoderma*, vol. 404.
- Madgwick, PG & Kanitz, R 2024, 'What is the value of rotations to insecticide resistance management?', *Pest Management Science*, vol. 80, no. 4, pp. 1671-1680.
- Makhtar, S, Abidin, ISZ & Islam, R 2022, 'The impact of rice productivity in Malaysia: Econometric analysis', *International Journal of Business and Economy*, vol. 4, no. 3, pp. 21-32.
- Mala, M, Jahan, M & Islam, KS 2009, 'Comparative prey consumption of a predatory spider, *Pardosa pseudoannulata* (Bosenberg and Strand) on three different diets', *Progressive Agriculture*, vol. 20, no. 1 & 2, pp. 57-62.
- Marzuki, A & Jais, AS 2020, 'Urbanisation and the concerns for food security in Malaysia', *PLANNING MALAYSIA*, vol. 18, no. 3, pp. 202-217.
- Mkenda, PA, Ndakidemi, PA, Stevenson, PC, Arnold, SEJ, Darbyshire, I, Belmain, SR, Priebe, J, Johnson, AC, Tumbo, J & Gurr, GM 2020, 'Knowledge gaps among smallholder farmers hinder adoption of conservation biological control', *Biocontrol Science and Technology*, vol. 30, no. 3, pp. 256-277.
- Mohamed, Z, Terano, R, Shamsudin, MN & Latif, IA 2016, 'Paddy farmers' sustainability practices in granary areas in Malaysia', *Resources*, vol. 5, no. 2.
- Mrisho, LM, Mbilinyi, NA, Ndalaha, M, Ramcharan, AM, Kehs, AK, McCloskey, PC, Murithi, H, Hughes, DP & Legg, JP 2020, 'Accuracy of a smartphone-based object detection model, PlantVillage Nuru, in identifying the foliar symptoms of the viral diseases of cassava - CMD and CBSD', *Frontiers in Plant Science*, vol. 11.
- Muniz-Junior, G, de Oliveira Roque, F, Pires, APF & Guariento, RD 2023, 'Are lower pesticide doses better? An evolutionary perspective on integrated pest management', *Ecological Modelling*, vol. 482.
- Murdad, R, Muhiddin, M, Osman, WH, Tajidin, NE, Haida, Z, Awang, A & Jalloh, MB 2022, 'Ensuring urban food security in Malaysia during the COVID-19 pandemic - Is urban farming the answer? A review', *Sustainability*, vol. 14, no. 7.
- Omar, SC, Shaharudin, A & Tumin, SA 2019. *The Status of the Paddy and Rice Industry in Malaysia*, Kuala Lumpur, Malaysia, Khazanah Research Institute.
- Ooi, PAC 1982, 'Attempts at forecasting rice planthopper populations in Malaysia', *Entomophaga*, vol. 27, no. S1, pp. 89-98.
- Ooi, PAC 1988, 'Ecology and Surveillance of *Nilaparvata lugens* (Stal) - Implications for Its Management in Malaysia', Doctor of Philosophy Ph.D. Thesis, University of Malaya.
- Ooi, PAC 2015, 'Biological control of agricultural pests', *UTAR Agriculture Science Journal*, vol. 1, no. 2, pp. 25-31.
- Ooi, PAC & Heong, KL 1988, 'Operation of a brown planthopper surveillance system in the Tanjung Karang Irrigation Scheme in Malaysia', *Crop Protection*, vol. 7, pp. 273-278.
- Pontius, J, Dilts, R & Bartlett, A 2002. *From farmer field school to community IPM: ten years of IPM training in Asia, Thailand*, Food and Agriculture Organization of the United Nations: Regional Office for Asia and the Pacific.
- Razali, R, Yaakop, S, Abdullah, M, Ghazali, SZ & Zuki, AA 2015, 'Insect species composition in an under SRI management in Tanjung Karang, Selangor, Malaysia', *Malaysian Applied Biology*, vol. 44, no. 4, pp. 59-66.
- Rothschild, GHL 1970, 'Parasites of rice stemborers in Sarawak (Malaysian Borneo)', *Entomophaga*, vol. 15, no. 1, pp. 21-51.
- Rothschild, GHL 1971, 'The biology and ecology of rice-stem borers in Sarawak (Malaysian Borneo)', *Journal of Applied Ecology*, vol. 8, no. 2, pp. 287-322.

- Rudzi, SK, Ho, YB, Tan, ESS, Jalaludin, J & Ismail, P 2022, 'Exposure of airborne pesticides and its residue in blood serum of paddy farmers in Malaysia', *International Journal of Environmental Research and Public Health*, vol. 19, no. 11.
- Salam, MA, Sarker, MNI & Sharmin, S 2021, 'Do organic fertilizer impact on yield and efficiency of rice farms? Empirical evidence from Bangladesh', *Heliyon*, vol. 7, no. 8.
- Saul-Gershenz, L 2009, 'Insect Zoos', eds VH Resh & RT Cardé, in *Encyclopedia of Insects*, Academic Press, Burlington, Massachusetts, pp. 516-523.
- Shanker, C, Mohan, M, Sampathkumar, M, Lydia, C & Katti, G 2013, 'Functional significance of *Micraspis discolor* (F.) (Coccinellidae: Coleoptera) in rice ecosystem', *Journal of Applied Entomology*, vol. 137, pp. 601-609.
- Shepard, BM, Hammig, MD, Carner, GR, Ooi, PAC, Smith, JP, Dilts, R & Rauf, A 2009, 'Implementing Integrated Pest Management in Developing and Developed Countries', eds R Peshin & AK Dhawan, in *Integrated Pest Management: Dissemination and Impact*, Springer, Dordrecht, Netherlands, pp. 275-302.
- Shrestha, S, Amgain, LP, Pandey, P, Bhandari, T & Khatiwada, S 2024, 'Adoption status of integrated pest management (IPM) practices among vegetable growers of Lamjung district of Nepal', *Heliyon*, vol. 10, no. 18.
- Sieglwart, M, Graillot, B, Lopez, CB, Besse, S, Bardin, M, Nicot, PC & Lopez-Ferber, M 2015, 'Resistance to bio-insecticides or how to enhance their sustainability: a review', *Frontier in Plant Science*, vol. 6.
- Sigsgaard, L 2000, 'Early season natural biological control of insect pests in rice by spiders - and some factors in the management of the cropping system that may affect this control ', In: S Toft & N Scharff, eds. in *Proceedings of the 19th European Colloquium of Arachnology*, 17-22 July, Aarhus University Press, Århus, Denmark.
- Sivapragasam, A 2022. *Biopesticides and their regulation in Malaysia*, Asia Pacific Biofertilizer and Biopesticide Information Platform, viewed 19.12 2022, <<https://apbb.fttc.org.tw/article/308>>.
- Sogawa, K & Cheng, CH 1979, 'Economic thresholds, nature of damage, and losses caused by the brown planthopper', in *Brown planthopper: Threat to rice production in Asia*, International Rice Research Institute, Manila, Philippines, pp. 125-142.
- Tan, JL, Ang, KY, Chow, MH, Lee, ETY, Lee, KH, Lee, LY, Ooi, SW, Soh, WC & Sithambaram, R 2020, 'A preliminary study on reducing the dosage of chemical fertiliser by using empty fruit bunch as soil amendment on the growth of choy sum', *ASM Science Journal*, vol. 13.
- Taylor, P 2018. *PestSmart Diagnostic Field Guide*, Wallingford, United Kingdom, Centre for Agriculture and Bioscience (CAB) International.
- Thorburn, C 2015, 'The rise and demise of integrated pest management in rice in Indonesia', *Insects*, vol. 6, no. 2, pp. 381-408.
- van den Berg, H, Ketelaar, JW, Dicke, M & Fredrix, M 2020, 'Is the farmer field school still relevant? Case studies from Malawi and Indonesia', *NJAS - Wageningen Journal of Life Sciences*, vol. 92.
- Waddington, H, Snilstveit, B, Hombrados, J, Vojtkova, M, Phillips, D, Davies, P & White, H 2014, 'Farmer field schools for improving farming practices and farmer outcomes: A systematic review', *Campbell Systematic Reviews*, vol. 6.
- Wang, LH 1988, 'New villages growing old in Malaysia', *Habitat International*, vol. 12, no. 2, pp. 35-42.
- Wang, X-Q, Guo, J-s, Li, D-T, Yu, Y, Hagoort, J, Moussian, B & Zhang, C-X 2021, 'Three-dimensional reconstruction of a whole insect reveals its phloem sap-sucking mechanism at nona-resolution', *eLife*, vol. 10.
- Wongsiri, T, Wongsiri, N, Tirawat, C, Navavichit, S, Lewvanich, A & Yasumatsu, K 1980, 'Abundance of natural enemies of rice insect pests in Thailand', in *Problems of insect pest management in developing countries: Proceedings of a Symposium on Tropical Agriculture Research*, 6 - 7 August, Japan International Research Center for Agricultural Sciences, Kyoto, Japan.
- Wu, D-H, Chen, C-T, Yang, M-D, Wu, Y-C, Lin, C-Y, Lai, M-H & Yang, C-Y 2022, 'Controlling the lodging risk of rice based on a plant height dynamic model', *Botanical Studies*, vol. 63.
- Xin, J, Buss, LJ, Harmon, CL, Vergot, P, Frank, MS & Lester, WJ 2018, 'Plant and pest diagnosis and identification through DDIS: AE225, rev. 3/2018', *Extension Data Information Source (EDIS)* 2018, vol. 2.

- Yaakop, S, David-Dass, A, Shaharuddin, US, Sabri, S, Badrulisham, AS & Che-Radziah, CMZ 2020, 'Species richness of leaf roller and stem borers (Lepidoptera) associated with different paddy growth and first documentation of its DNA barcode', *Pertanika Journal of Tropical Agricultural Science*, vol. 43, no. 4, pp. 523-535.
- Yuan, S, Stuart, AM, Laborte, AG, Edreira, JIR, Dobermann, A, Kien, LVN, Thúy, LT, Paothong, K, Traesang, P, Tint, KM, San, SS, Villafuerte II, MQ, Quicho, ED, Pame, ARP, Then, R, Flor, RJ, Thon, N, Agus, F, Agustiani, N, Deng, N, Li, T & Grassini, P 2022, 'Southeast Asia must narrow down the yield gap to continue to be a major rice bowl', *Nature Food*, vol. 3, pp. 217-226.
- Zainab, S, Ram, B & Singh, RN 2017, 'Environmental effect on yellow stem borer, *Scirpophaga incertulas* (Walker) and rice leaf folder, *Cnaphalocrocis medinalis* (Guenee) on rice crop', *Journal of Environmental Biology*, vol. 38, no. 2, pp. 291-295.
- Zhong, W, Tan, Z, Wang, B & Yan, H 2019, 'Next-generation sequencing analysis of *Pardosa pseudoannulata*'s diet composition in different habitats', *Saudi Journal of Biological Sciences*, vol. 26, no. 1, pp. 165-172.