Journal of Tropical Resources and Sustainable Science
Website : http://journal.umk.edu.my/index.php/jtrss/
eISSN : 2462-2389
Vol: 13 Issue 2, 2025, 319-325
DOI: https://doi.org/10.47253/jtrss.v13i2.1943

RESEARCH ARTICLE

Assessment of pesticide handling practices and the use of personal protective equipment among rice farmers in Pasir Mas, Kelantan

Hie Ling Wong[1,2*], Nur Azzulie Areff[2], Nur Syahirah Ismail[1], Sarifah Nadia Tamrin[1], Muhamad Azahar Abas[1] and Aweng Eh Rak[1]

[1]Faculty of Earth Science, Universiti Malaysia Kelantan, 17600 Jeli, Kelantan, Malaysia
[2]Environment & Sustainable Development Research Group, Universiti Malaysia Kelantan

ARTICLE HISTORY
Received : 14 July 2025
Accepted : 1 September 2025
Online : 15 December 2025

KEYWORDS
paddy,
farmers,
backpack/knapsack sprayer,
practices,
PPE

☒* **CORRESPONDING AUTHOR**
Dr. Wong Hie Ling
Faculty of Earth Science,
Universiti Malaysia Kelantan,
17600 Jeli, Kelantan,
Malaysia.
Email: hlwong@umk.edu.my

ABSTRACT

The extent to which rice farmers are exposed to pesticides is significantly influenced by their handling practices and use of personal protective equipment (PPE). This study collected contextual information from 20 rice farmers affiliated with the Kemubu Agricultural Development Authority (KADA) in Pasir Mas, Kelantan. The farmers were surveyed between July 2024 and April 2025. Data were collected through personal interviews and questionnaire surveys, and analysed using descriptive statistical methods. The farmers were aged 21 to 87 years, had 4 to 50 years of experience, and cultivated paddy fields ranging in size from 0.8 to 12.1 hectares. All of the farmers applied pesticides using manual and/or motorised backpack sprayers, with twelve of them having received KADA training between 2022 and 2024. However, none of them reported using alternative pest management methods. The most commonly used pesticides were liquid formulations (4-12 products per farmer), with insecticides being the most frequently used (2-7 products per farmer). All farmers reported using at least one product classified as WHO classes II or III, and some used unregistered and expired products. The most common method of disposing of empty pesticide containers was burying them in the ground (13 farmers). While all farmers wore basic protective clothing (long sleeves and long pants), only 14 wore non-absorbent gloves and boots. These findings suggest gaps in safe pesticide handling practices and PPE use, indicating the need for targeted training and behavioural change interventions, as well as improved access to appropriate protective equipment and waste disposal facilities for the rice farmers in the region.

1. INTRODUCTION

Rice is a staple crop that is widely cultivated in tropical and developing countries, including Malaysia. In these regions, knapsack/backpack sprayers are the predominant method of pesticide application; however, they can significantly contribute to the high levels of occupational pesticide exposure experienced by rice farmers (Wong & Brown, 2020). The widespread and often indiscriminate use of pesticides is commonly attributed to the perception that chemical control is essential for protecting yields, despite evidence showing that less than 1% of applied pesticides actually reach the intended target organisms (Bagheri et al., 2021). This inefficiency contributes to environmental contamination and significantly increases the risk of pesticide drift and direct exposure to rice farmers.

Occupational exposure to pesticides has been consistently linked to a range of adverse health symptoms in rice farmers. A cross-sectional study by Sapbamrer and Nata (2014) involving 182 rice farmers and 122 non-farmers found that exposed farmers had a significantly higher prevalence of respiratory symptoms, including breathing difficulties (odds ratio (OR): 2.8; $p<0.01$) and chest pains (OR: 2.5, $p<0.05$). Similarly, Ndayambaje et al. (2019) found that 90% of the 206 small-scale rice growers they surveyed experienced acute health effects during or shortly after applying pesticides, including headaches, breathing difficulties, nausea, stomach upset and skin itchiness. More recently, Kumar et al. (2025) reported that, of 139 rice farmers, 76.8% experienced skin irritation, 45.5% reported fatigue, and 44.5% suffered headaches due to insecticide exposure. These findings collectively highlight the significant health risks associated with pesticide use among rice farmers, emphasising the need for improved safety practices, protective equipment and training.

Although farmers are often aware of the importance of using personal protective equipment (PPE), such as hats, masks, goggles, boots and gloves, this awareness does not always result in proper practice. Yuantari et al. (2015) found no significant correlation between farmers' knowledge and attitudes and their implementation of safe pesticide handling practices. A systematic review of 39 studies by Kangavari et al. (2024) identified various factors influencing farmers' protective measures against pesticide exposure, including socio-demographic characteristics (e.g., age, gender, level of education, income, farming experience, and experience of using pesticides), individual factors (e.g., knowledge, attitude, risk perception, and behavioural intention), and institutional support (e.g., government attention and agricultural extension services). Furthermore, environmental and structural factors such as the availability of training programmes, access to relevant information and media coverage and behaviour-change communication strategies, and integrated pest management (IPM) training were found to enhance farmers' safety behaviour and minimise pesticide use (Damalas & Koutroubas, 2017; Bondori et al., 2018; Kangavari et al., 2024).

Acknowledging the pivotal role of pesticide handling practices and PPE use in shaping exposure risks, this study examines how these factors influence pesticide exposure among rice farmers in the Pasir Mas district of Kelantan. It aims to provide contextual insights into the current status of pesticide use and practices among the selected farmers. These findings could inform future interventions aimed at improving occupational safety and reducing health risks in rice farming communities.

2. MATERIALS AND METHODS

This study involved 20 rice farmers affiliated with the Kemubu Agricultural Development Authority (KADA) in the Pasir Mas district of Kelantan. The farmers were recruited using a convenience sampling approach, in which participants were selected from those who were available and willing to take part in the survey during scheduled visits. Data collection took place in two phases: the first group of ten farmers was surveyed between July and October 2024, and the second group between January and April 2025. This covered two complete rice-growing seasons.

Data were obtained through face-to-face interviews, each lasting approximately 20 minutes. These were complemented by a structured questionnaire form, administered over a three- to four-month period to capture pesticide use behaviour across the two rice-growing seasons. Ethical approval for the surveys was granted by the Ethics Committee of the Faculty of Earth Science at Universiti Malaysia Kelantan (approval no.: UMK.A08.800-1/2/10(8)).

The interview comprised three main sections: (i) demographic and farm characteristics (e.g., age, level of education, pesticide-related training, farming experience and farm size); (ii) pesticide acquisition and application practices (e.g., subsidies for pesticides, type of sprayer used, hiring contractors and methods for disposing of empty containers); (iii) the use of PPE for different body parts. The questionnaire forms collected pesticide usage data for the whole season (e.g., application date, product name, amount applied and reasons for spraying).

Informed consent was obtained from all respondents prior to participation using a signed consent form. To ensure confidentiality, the farmers were anonymised and referred to as F01-F20 throughout this study. F01-F10 were from the first season, and F11-F20 were from the second. The data were entered into Microsoft Excel and cross-checked for accuracy and consistency. Pesticide-related information was cleaned and validated using the Malaysian Pesticide Information System (SISMARP, 2025), which was developed by the Pesticide Control Division of the Malaysian Department of Agriculture. Descriptive statistical analyses (mean, median and range) were then applied to summarise the findings.

3. RESULT AND DISCUSSION

3.1 Profile of the 20 Rice Farmers

Table 1 shows the demographic profile, land ownership and training background of the 20 rice farmers selected for the study. Their ages ranged from 21 to 87, with a median of 48. Of those for whom data were available, 15 of 17 farmers had completed a secondary school, while two had completed primary school. Their work experience varied from 4 to 50 years, with 12 of the farmers having worked in rice paddies for at least 10 years. A study by Kangkhetkron and Juntarawijit (2021) involving 680 farmers suggested that those who had completed secondary school and higher had better farming practices than those who had only completed primary school (OR: 1.77; 95% CI: 1.07-2.93). The study also found that farmers with more working experience had better practices.

The farmers in the present study cultivated rice on plots ranging in size from 0.8 to 12.1 hectares (median: 4.0 hectares), with 14 of them farming on rented land. However, only 12 farmers had participated in pesticide-related training provided by KADA between 2022 and 2024. Research has shown that farmers' associations are an effective channel for disseminating knowledge on pesticide legislation and raising awareness (Al Zadjali et al., 2013).

3.2 Pesticide Usage

Table 2 shows the total number of spraying days, the number of pesticide products used and the number of active substances applied by the 20 selected rice farmers throughout the entire rice-growing season. For most farmers, the number of active substances (range: 6-14 compounds; mean: 10 compounds) is either equal to or slightly higher than the number of pesticide products (range: 5-14 products; mean: 8

products). This indicates that some products contain more than one active substance in their formulations. The number of spraying days (range: 6-12 days; mean: 8 days) is often slightly lower than the number of products or substances used, suggesting that multiple products were applied on a single spraying day.

A range of factors that can influence the intensity of pesticide use in rice fields, including pest control (for precautionary or treatment purposes), improving product appearance and increasing rice grain yields, saving labour, time and costs, and following neighbours' practices (Sapbamrer & Nata, 2014; Wong & Brown, 2020). According to Huang et al. (2022), agrotechnical stations and pesticide retailers can help reduce overuse of pesticides due to a lack of expertise by determining the timing, type and dosage of pesticide applications. The safe and optimal use of pesticides is crucial to protecting farmers' health (Afshari et al., 2021).

Figure 1 illustrates the classification of pesticide products used by the 20 selected rice farmers, categorised by type of pesticide, formulation, and toxicity class. Figure 1a shows that insecticides were the most frequently used type of pesticide, with individual farmers applying 2-7 products. This was followed by fungicides (1-5 products; mean: 3) and herbicides (1-3 products; mean: 2). Insecticides are generally not necessary in the early stages of rice cultivation (i.e., within the first 30 days after transplanting), since pest populations tend to be low at this time (Zhu et al., 2022). Conversely, high levels of insecticide use may suggest frequent pest and disease pressures in rice cultivation, potentially due to climatic factors such as temperature, rainfall, and relative humidity (Roy et al., 2024).

Figure 1b shows that all farmers predominantly used liquid formulations (4-11 products; mean: 7), with only 15 farmers using 1-2 wettable granule products and 11 farmers using 1-2 wettable powder products. This preference for liquid formulations is likely due to their ease of handling, pouring, measuring, transporting, and storing (Hipkins, 2025). However, the type of pesticide formulation can influence exposure risk. According to Groβkopf et al. (2013), wettable powders result in the highest level of operator exposure, followed by liquid formulations and wettable granules. Therefore, while liquid formulations offer operational ease, they still pose a substantial exposure risk if appropriate protective measures are not in place.

Table 1: Overview of 20 rice farmers' background, paddy field characteristics and pesticide-related training participation.

Farmer	Age (year)	Education level	Work experience (year)	Paddy grown area (ha)	Land ownership	Latest year of training	Training provided by
F01	38	Secondary school	4	0.8	Rental	n/a	n/a
F02	26	n/a	15	8.1	Own land	2023	KADA
F03	49	n/a	9	3.0	Rental	2024	KADA
F04	75	Primary school	15	2.8	Rental	2023	KADA
F05	35	Secondary school	5	8.1	Own land	2024	KADA
F06	37	Secondary school	10	2.0	Own land	2024	KADA
F07	45	Secondary school	10	12.1	Own land & rental	2024	KADA
F08	40	Secondary school	5	4.0	Own land	2023	KADA
F09	87	Secondary school	4	2.8	Own land	2024	KADA
F10	62	n/a	n/a	6.1	n/a	n/a	n/a
F11	79	Secondary school	50	4.0	Own & rental	n/a	n/a
F12	59	Secondary school	20	10.1	Rental	n/a	n/a
F13	70	Secondary school	30	1.6	Rental	n/a	n/a
F14	58	Secondary school	20	4.0	Rental	n/a	n/a
F15	57	Secondary school	25	4.0	Rental	n/a	n/a
F16	39	Secondary school	15	8.1	Rental	n/a	n/a
F17	46	Secondary school	7	4.5	Rental	2023	KADA
F88	30	Secondary school	10	1.6	Rental	2022	KADA
F19	21	Secondary school	5	5.3	Rental	2022	KADA
F20	58	Primary school	15	4.9	Rental	2023	KADA
Min	**21**	**-**	**4**	**0.8**	**-**	**-**	**-**
Median	**48**	**-**	**10**	**4.0**	**-**	**-**	**-**
Max	**87**	**-**	**50**	**12.1**	**-**	**-**	**-**

Table 2: Total number of spraying days, pesticide products and their active substances applied by the 20 selected farmers across the entire rice growing season.

Farmer	No. of spraying days	No. of pesticide products	No. of active substances
F01	6	9	11
F02	8	10	12
F03	7	12	12
F04	7	11	12
F05	9	10	12
F06	6	8	11
F07	7	9	13
F08	10	14	14
F09	9	7	10
F10	12	9	11
F11	11	10	11
F12	7	7	8
F13	7	6	7
F14	9	7	8
F15	7	5	7
F16	9	6	7
F17	7	5	6
F18	6	5	6
F19	11	8	9
F20	8	7	8
Mean	**8**	**8**	**10**

Figure 1c shows that all farmers applied 1-6 products (mean: 3), which were classified as both WHO class II (moderately hazardous) and class III (slightly hazardous). Additionally, 18 farmers reported using 1-7 products (mean: 2) classified as class IV, which pose a minimal acute hazard under normal use conditions (Tessema et al., 2022). Notably, two of the pesticide products had no assigned toxicity class as they were not registered with the SISMARP (2025). Further analysis also revealed the use of expired products, as defined by the SISMARP (2025). The presence of unregistered and expired products suggests gaps in regulatory oversight. This may contribute to the indiscriminate use of pesticides, particularly among low-income rice farmers who often lack access to reliable product information or safety training (Ndayambaje et al., 2019). These findings highlight the urgent need to strengthen pesticide registration and monitoring systems to reduce health risks among rice farmers in Malaysia.

According to Sapbamrer et al. (2023), the government can play a significant role in reducing pesticide use by establishing push and pull policies, introducing a pesticide tax, promoting alternative pesticide management, and developing a monitoring and certification system.

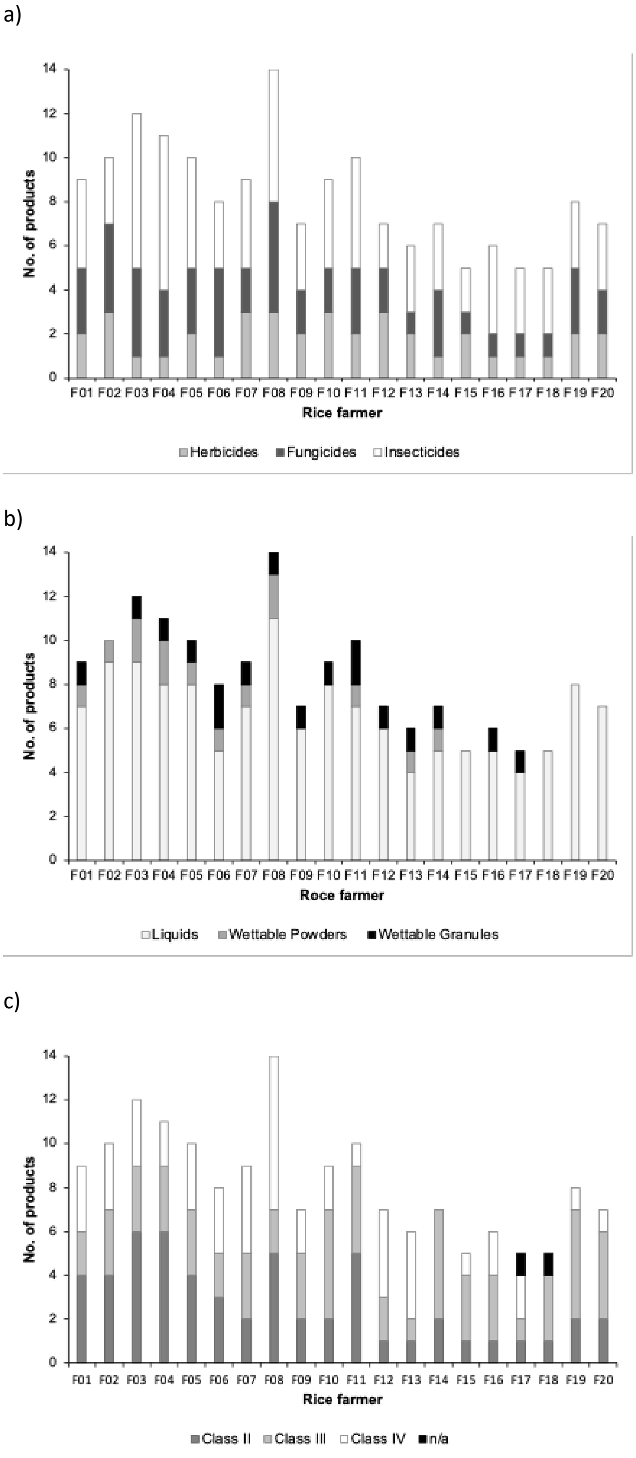

Figure 1: The classifications of pesticide products applied by the 20 selected rice farmers based on pesticide types (a), formulations (b) and toxicity classes (c).

3.3 Pesticide Handling Practices

Table 3 shows the pesticide-related activities carried out by the 20 selected rice farmers. All of the farmers relied on backpack/knapsack sprayers as the primary method of applying pesticides. Of these, 11 used motorised/power sprayers, four used manual sprayers and four alternated between the two types. In terms of application purpose, 14 farmers reported applying pesticides for both precautionary and treatment purposes, while six applied pesticides solely to treat existing pest or disease problems. These findings suggest a tendency towards prophylactic pesticide use, which could lead to over-application and increased exposure risks. Li et al. (2022) conducted a large-scale study involving 3410 rice farmers in China, which found that those who purchased crop insurance used 33.3% fewer pesticides than those without insurance, supporting this concern. This suggests that external risk management mechanisms, such as insurance, can reduce farmers' reliance on preventive chemical applications.

Table 3: Pesticide handling practices of the 20 selected rice farmers.

Farmer	Sprayer type (backpack/ knapsack)	Reason for spraying	Hiring contractor	Pesticide mixing/ loading location	Adhere to the recommended application rate	Sprayer tank cleaning method	Method of pesticide container disposal	Alternative pest management strategies
F01	Manual	Precaution & treatment	No	Home	Yes	Water	Burning	No
F02	Manual & motorised/ power	Precaution & treatment	Yes	Home	Yes	Soap & water	n/a	No
F03	Motorised/ power	Precaution & treatment	No	Home	Yes	Soap & water	Burying in the ground	No
F04	Manual	Precaution & treatment	No	Home	Yes	Soap & water	Burying in the ground	No
F05	Motorised/ power	Precaution	Yes	Home	Yes	Soap & water	Burying in the ground	No
F06	Manual & motorised/ power	Precaution & treatment	No	Home	Yes	Soap & water	Throwing into a municipal waste bin	No
F07	Manual & motorised/ power	Precaution & treatment	Yes	Home	Yes	Water	Throwing into a municipal waste bin	No
F08	Manual & motorised/ power	Precaution & treatment	Yes	Home	Yes	Water	Burying in the ground	No
F09	Motorised/ power	Precaution & treatment	No	Home	Yes	Water	Burying in the ground	No
F10	n/a	Precaution & treatment	n/a	n/a	n/a	n/a	n/a	No
F11	Manual	Treatment	Yes	Paddy field	Yes	Soap & water	Burning	No
F12	Motorised/ power	Treatment	No	Paddy field	Yes	Soap & water	Burying in the ground/ throwing into a municipal waste bin	No
F13	Motorised/ power	Treatment	Yes	Paddy field	Yes	Soap & water	Burying in the ground	No
F14	Motorised/ power	Treatment	No	Paddy field	Yes	Water	Throwing in the field/ burning	No
F15	Motorised/ power	Treatment	No	Paddy field	Yes	Water	Burying in the ground	No
F16	Motorised/ power	Precaution & treatment	Yes	Paddy field & store	Yes	Water	Burying in the ground/ burning	No
F17	Motorised/ power	Precaution & treatment	Yes	Paddy field & home	Yes	Water	Burying in the ground/ burning	No
F18	Manual	Precaution & treatment	No	Paddy field	Yes	Soap & water	Burying in the ground	No
F19	Motorised/ power	Precaution & treatment	Yes	Paddy field	Yes	Soap & water	Burying in the ground	No
F20	Motorised/ power	Precaution & treatment	Yes	Home	Yes	Water	Burying in the ground	No

Half of the farmers reported hiring pesticide applicators to carry out spraying, which may result in lower direct exposure than self-application. Some of these farmers used drone technology for application, a method known to enhance operational efficiency, reduce labour intensity, and potentially lower pesticide use (Wang et al., 2022). A study of 1185 rice growers in Hubei Province, China, by Yan et al. (2024) found that farmers who used socialised pest control services by outsourcing pest management to professional service providers (e.g., plant-protection companies) used 9.30%

less pesticide than those who did not. The study also found that farmers using drone sprayers used 12.4% less pesticide than those using ground backpack sprayers. These findings suggest that outsourcing pest control to professionals and adopting advanced spraying technologies can lead to more efficient and sustainable pesticide use.

Eleven farmers surveyed reported preparing (mixing/loading) pesticide solutions in close proximity to their homes. This raises concerns about potential environmental exposure and health risks for household members and nearby residents. Although all of the farmers stated that they adhered to the recommended application rates and cleaned the sprayer tank with water and/or soap, their disposal practices for empty pesticide containers varied. The most common method was burying the containers in the ground (reported by 13 farmers), followed by burning them (reported by 5 farmers), and disposing of them in a municipal waste bin (reported by 3 farmers). Such practices reflect inconsistent waste management and pose potential environmental hazards. Previous studies have shown that farmers' behaviour when disposing of pesticide waste is influenced by several factors, including spraying experience, awareness of pesticide risks, proximity to an agriculture service centre or urban areas, and their membership of farmers' associations (Al Zadjali et al., 2013; Bondori et al., 2018).

All farmers reported not using alternative pest management practices in their paddy fields. This highlights the importance of promoting alternative pest management strategies and supportive measures that encourage changes in on-farm practices (Sapbamrer et al., 2024). One example is ecological engineering, which involves growing nectar-producing flowering plants on the rice bunds to promote biocontrol and planting trap plants around paddy fields to minimise the initial pest populations (Zhu et al., 2022).

3.4 PPE Use

Figure 2 shows the number of rice farmers reported using different types of PPE to protect their hands, bodies, and respiratory systems during three key pesticide handling activities: mixing/loading, spraying, and cleaning the sprayer. All farmers consistently wore long sleeves and long pants for all of these tasks, providing a basic layer of protection. Non-absorbent gloves made of plastic or rubber (mean: 13 farmers) were used more frequently than absorbent fabric gloves (mean: 7 farmers) during all activities. Similarly, boots (mean: 13 farmers) were used more commonly than rubber shoes (mean: 5 farmers) during all activities.

In terms of respiratory protection, cotton or disposable masks were used by most farmers, particularly during mixing/loading (17 farmers) and spraying (19 farmers). However, the widespread use of absorbent work materials, including fabric gloves, cotton masks, and regular work clothes, may increase the risk of dermal and inhalation exposure as these materials can retain pesticide residues rather than repel them. Naksata et al. (2020) emphasised that the effectiveness of PPE depends on material properties, as it can affect the level of protection against pesticides (2020). The continued reliance on inappropriate PPE materials among farmers highlights the need for targeted education and training programmes to improve awareness of the safe handling of pesticides and the appropriate protective measures.

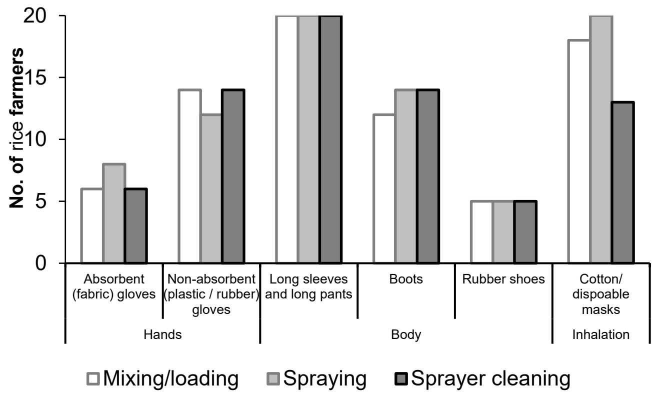

Figure 2: Types of PPE used by 20 selected farmers during pesticide mixing /loading, spraying and sprayer cleaning activities.

Numerous studies proposed a variety of factors influencing farmers' use of PPE and engagement in safe pesticide handling practices, including the level of education, knowledge of and attitudes towards safety, and participation in training related to the health risks of pesticide exposure (Tessema et al., 2022; Kangavari et al., 2024). A systematic review of 31 studies published between 2000 and 2019 by Afshari et al. (2021) found that, although educational and behavioural interventions improved participants' knowledge and attitude, they were less effective in translating these improvements into actual behavioural change, leaving the risk of pesticide exposure often remained high.

Similarly, Ndayambaje et al. (2019) reported in a cross-sectional study of 206 small-scale rice growers that there was no significant association between education and literacy levels and the use of PPE. Notably, even trained pesticide applicators exhibited poor preventive practices, highlighting the need for more comprehensive, practical training that goes beyond basic awareness, focusing on the correct use of PPE and adherence to safety protocols, and on adequate facilities for pesticide waste disposal (Tessema et al., 2022). These findings suggest that factors beyond education and training may influence PPE use, including demographic, behavioural, psychosocial, and environmental factors (Sapbamrer & Thammachai, 2020). A holistic approach that addresses these multiple dimensions is therefore essential to improving pesticide safety practices among rice farmers.

4.0 CONCLUSION

This study reveals that rice farmers employ a variety of methods to manage pesticides. This highlights the need for improved training, stricter regulation, and the promotion of safer, alternative pest management strategies to mitigate health and environmental risks. Improving farmers' understanding of and ability to implement alternative pest management strategies, as well as providing them with appropriate protective equipment and waste disposal infrastructure, is essential for promoting safer agricultural practices. Furthermore, understanding farmers' current behaviours and decision-making processes can inform the development of context-specific best practice guidelines that minimise chemical inputs while sustaining crop productivity.

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to the Malaysian Ministry of Education (Kementerian Pendidikan Malaysia) for the financial support provided through the Fundamental Research Grant Scheme for Exploratory Research (FRGS-EC) (grant no. FRGS-EC/1/2024/WAS04/UMK/02/8). They would also like to thank the Kemubu Agricultural Development Authority (KADA) for their valuable assistance and cooperation in conducting the farmer surveys.

REFERENCES

Afshari, M., Karimi-Shahanjarini, A., Khoshravesh, S., & Besharati, F. (2021). Effectiveness of interventions to promote pesticide safety and reduce pesticide exposure in agricultural health studies: a systematic review. PloS One, 16(1), e0245766. https://doi.org/10.1371/journal.pone.0245766

Al Zadjali, S., Morse, S., Chenoweth, J., & Deadman, M. (2013). Disposal of pesticide waste from agricultural production in the Al-Batinah region of Northern Oman. *Science of The Total Environment,* 463-464, 237-242. https://doi.org/10.1016/j.scitotenv.2013.06.014

Bagheri, A., Emami, N., & Damalas, C. A. (2021). Farmers' behavior towards safe pesticide handling: an analysis with the theory of planned behavior. *Science of the Total Environment*, 751, 141709. https://doi.org/10.1016/j.scitotenv.2020.141709

Bondori, A., Bagheri, A., Allahyari, M. S., & Damalas, C. A. (2018). Pesticide waste disposal among farmers of Moghan region of Iran: current trends and determinants of behaviour. *Environ. Monit. Assess*, 191(1):30. https://doi.org/10.1007/s10661-018-7150-0

Damalas, C. A. and Koutroubas, S. D. (2017). Farmers' training on pesticide use is associated with elevated safety behaviour. *Toxics*, 5(3), 19. https://doi.org/10.3390/toxics5030019

Groβkopf, C., Mielke, H., Westphal, D., Erdtmann-Vourliotis, M., Hamey, P., Bouneb, F., Rautmann, D., Stauber, F., Wicke, H., Maasfeld, W., Salazar, J. D., Chester, G., & Martin, S. (2013). A new model for the prediction of agricultural operator exposure during professional application of plant protection products in outdoor crops. *J. Verbr. Lebensm*., 8, 143-153. https://doi.org/10.1007/s00003-013-0836-x

Hipkins, P. A. (2025). Pesticide formulation demonstration. PennState Extension. College of Agricultural Sciences, The Pennsylvania State University. https://extension.psu.edu/pesticide-formulation-demonstration

Huang, Y., Luo, X., Liu, D., Du, S., Yan, A., & Tang, L. (2021). Pest control ability, technical guidance, and pesticide overuse: evidence from rice farmers in rural China. *Environ. Sci. Pollut. Res.*, 28, 39587-39597. https://doi.org/10.1007/s11356-021-13607-0

Kangavari, M., Sarvi, M., Afshari, M., & Maleki, S. (2024). Understanding determinants related to farmers' protective measures towards pesticide exposure: a systematic review. PloS One, 19(2), 20298450. https://doi.org/10.1371/journal.pone.0298450

Kangkhetkron, T. and Juntarawijit, C. (2021). Factors influencing practice of pesticide use and acute health symptoms among farmers in Nakhon Sawan, Thailand. *International Journal of Environmental Research and Public Health*, 18, 8803. https://doi.org/10.3390/ijerph18168803

Kumar, N., Nie, V., Palaniappan, K., & Bohatko-Naismith, J. (2025). Insecticide exposure and associated acute health effects in farmers in a rice growing district of India. *International Journal of Environmental Health Research*, 35(5), 1143-1155. https://doi.org/10.1080/09603123.2024.2382305

Li, H., Yuan, K., Cao, A., Zhao, X., & Guo, L. (2022). The role of crop insurance in reducing pesticide use: evidence from rice farmers in China. *Journal of Environmental Management*, 306, 114456. https://doi.org/10.1016/j.jenvman.2022.114456

Naksata, M., Watcharapasorn, A., Hongsibsong, S., & Sapbamrer, R. (2020). Development of personal protective clothing for reducing exposure to insecticides in pesticide applicators. *Int. J. Environ. Res. Public Health*, 17(9), 3303. https://doi.org/10.3390/ijerph17093303

Ndayambaje, B., Amuguni, H., Coffin-Schmitt, J., Sibo, N., Ntawubizi, M., & VanWormer, E. (2019). Pesticide application practices and knowledge among small-scale local rice growers and communities in Rwanda: a cross-sectional study. *Int J. Environ. Res. Public Health*, 16(23), 4770. https://doi.org/10.3390/ijerph16234770

Roy, T. K., Kabir, M. M. M., Akter, S., Nayeem, A., Alam, Z., Hasan, M. R., Bari, M. N., & Sannal, A. (2024). Seasonal variations of insect abundance: correlating growth stage-specific metrics with weather patterns in Rangpur Region, Bangladesh. *Heliyon*, 10(18), e38121. https://doi.org/10.1016/j.heliyon.2024.e38121

Sapbamrer, R. and Nata, S. (2014). Health symptoms related to pesticide exposure and agricultural tasks among rice farmers from northern Thailand. *Environ. Health Prev. Med*, 19(1), 12-20. https://doi.org/10.1007/s12199-013-0349-3

Sapbamrer, R., Kitro, A., Panumasvivat, J., & Assavanopakun, P. (2023). Important role of the government in reducing pesticide use and risk sustainably in Thailand: current situation and recommendations. *Frontiers in Public Health*, 11, 1141142. https://doi.org/10.3389/fpubh.2023.1141142

Sapbamrer, R., Sittitoon, N., Thongtip, S., Chaipin E., Sutalangka, C., La-up, A., Thirarattanasunthon, P., Thammachai, A., Suwannakul, B., Sangkarit, N., Kitro, A., Panumasvivat, J., & Srisookkum, T. (2024). Socio-demographic, agricultural, and personal protective factors in relation to health literacy among farmers from all regions of Thailand. *Frontiers in Public Health*, 12, 1364296. https://doi.org/10.3389/fpubh.2024.1364296

SISMARP. (2025). *Malaysian Pesticide Information System* developed by the Pesticide Control Division, Malaysian Department of Agriculture. http://www.portal.doa.gov.my/sismarp/

Tessema, R. A., Nagy, K., & Adam, B. (2022). Occupational and environmental pesticide exposure and associated health risks among pesticide applicators and non-applicator residents in rural Ethiopia. *Frontiers in Public Health*, 10, 1017189. https://doi.org/10.3389/fpubh.2022.1017189

Wang, L., Huang, X., Li, W., Yan, K., Han, Y., Zhang, Y., Pawlowski, L., & Lan, Y. (2022). Progress in agricultural unmanned aerial vehicles (UAV) applied in China and prospects for Poland. *Agriculture*, 12, 397. https://doi.org/10.3390/agriculture12030397

Wong, H. L. and Brown, C. D. (2020). Assessment of occupational exposure to pesticides applied in rice fields in developing countries: a critical review. *International Journal of Environmental Science and Technology*, 18, 499-520. https://doi.org/10.1007/s13762-020-02834-6

Yan, A., Luo, X., Tang, L., Huang, Y., & Du, S. (2024). Can socialized pest control service reduce the intensity of pesticide use? Evidence from rice farmers in China. *Pest Manag. Sci*, 80(2), 317-332. https://doi.org/10.1002/ps.7764

Yuantari, M. G. C., Van Gestel, C. A. M., Van Straalen, N. M., Widianarko, B., Sunoko, H. R., & Shobib, M. N. (2015). Knowledge, attitude, and practice of Indonesian farmers regarding the use of personal protective equipment against pesticide exposure. *Environ. Monit. Assess*, 187, 142. https://doi.org/10.1007/s10661-015-4371-3

Zhu, P., Zheng, X., Johnson, A. C., Chen, G., Xu, H., Zhang, F., Yao, X., Heong, K., Lu, Z., & Gurr, G. M. (2022). Ecological engineering for rice pest suppression in China. A review. *Agronomy for Sustainable Development*, 42, 69. https://doi.org/10.1007/s13593-022-00800-9