Asian Development Policy Review
ISSN(e): 2313-8343
ISSN(p): 2518-2544
DOI: 10.55493/5008.v12i3.5114
Vol. 12, No. 3, 208-225.

URL: www.aessweb.com

Agricultural chemical input risk management practices in the paddy crop subsector: Evidence from Sungai Panjang, Sabak Bernam district, Malaysia

Rosmiza Mohd Zainol[1+]
Mohd Nor Mohd Rosmi[2]
Mohamad Syahrul Nizam Ibrahim[3]
Noor Azlina Masdor[4]

[1]*Center for Research in Development, Social and Environment, Faculty of Social Sciences and Humanities, Universiti Kebangsaan Malaysia, Selangor, Malaysia.*
[1]*Email: miza@ukm.edu.my*
[2,4]*Biotechnology and Nanotechnology Research Centre, Malaysian Agricultural Research and Development Institute, Selangor, Malaysia.*
[2]*Email: mnor.mrosmi@gmail.com*
[4]*Email: azlina@mardi.gov.my*
[3]*Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah, Malaysia.*
[3]*Email: mohamadsyahrulnizamibrahim@gmail.com*

(+ Corresponding author)

Article History
Received: 9 January 2024
Revised: 24 April 2024
Accepted: 13 May 2024
Published: 3 July 2024

Keywords
Chemical input
Farmers
Fertilizer
Paddy
Pesticide
Residues
Risk management
West Malaysia

ABSTRACT

This study aimed to assess Malaysian farmers' level of chemical input risk management practices and awareness, focusing on pesticide and fertilizer use. We disseminated a questionnaire to 141 farmers cultivating paddy fields in the Sungai Panjang parcel, Sabak Bernam, Selangor, Malaysia, using random sampling. The respondents' knowledge and practices on chemical input risk management for the use of pesticides were recorded based on the degree of agreement score. We used descriptive analysis to determine the level of interpretation of the mean score. The findings reveal a commendable level of agricultural chemical risk management practices among respondents, as evidenced by their adherence to safety guidelines and poison labels. The notable weaknesses in farmers' awareness were identified, such as the continued use of unregistered and illegal pesticides, and a lack of emphasis on the effective utilization of personal protective equipment. Embracing sustainable alternatives like green fertilizers and leveraging emerging technologies such as nanotechnology holds promise for enhancing productivity while mitigating environmental impact. Policy initiatives should prioritize incentivizing the adoption of such practices through supportive frameworks and targeted capacity-building efforts. These efforts align with broader sustainable development goals and contribute to the creation of a cleaner food chain and enhanced productivity. To fill these gaps, it is necessary to implement specific intervention programmes that focus on educating and empowering farmers regarding regulatory compliance and safety standards in order to guarantee the safety and quality of domestically produced rice.

Contribution/ Originality: This study illuminates knowledge gaps and improvement opportunities in Malaysian farmers' practices, enriching insights into chemical input management in agriculture. Its implications extend to policy formulation and tailored extension initiatives, emphasizing the necessity of focused awareness campaigns to foster safer, sustainable agricultural methods in the locale.

1. INTRODUCTION

The growing global population necessitates the production of food for an estimated 9.1 billion people, who are projected to inhabit the earth by 2050. To meet the demands of this growing population, there is a need to enhance

food production by 70% (Rahaman, Islam, & Jahan, 2018). Among the factors contributing to the increased demands are the population growth, income growth, changes in community lifestyles, and social economy. These factors have exacerbated the risk of a global food crisis in the past few decades (Liu, Pan, & Li, 2015). This can be achieved by effectively utilizing available plant genetic resources to develop high-yielding crop varieties and improving technologies for crop production and protection. However, insect pests and weeds pose a significant challenge in rice subsector and in particular agricultural systems, causing an annual loss of approximately 20-30% of agricultural produce due to pests, diseases, weeds, and rodents.

The Malaysian rice production system has encountered many obstacles in recent years, impeding its expansion. The issues encompassed in this context comprise unfavourable weather conditions, insufficient soil fertility and nutrient management, farmers' low awareness and expertise, hostility towards genetically modified planting materials, and inadequate utilisation of technology. The country's level of self-sufficiency in rice production and consumption has varied between 67% and 70% (Dorairaj & Govender, 2023). Risk to the quality and yield of rice are always there, like rice blast disease, bacterial leaf blight, tungro, and brown plant hopper (Dorairaj & Govender, 2023; Muhamad, Mahyoub, Intan, Abdul, & Amalia, 2019; Rosmiza, Muhammad, Milah, & Mohd, 2021). Baki (2004) found that a simple 5% infestation of weedy rice can lead to an estimated national loss of 64,880 metric tonnes in rice yield. In 2016, there was a significant outbreak of leaf blight disease in the paddy field of Sekinchan, Selangor. This outbreak resulted in a loss of 50-70% of the crop output, making it the most severe epidemic of its kind in the past 30 years (Toh, Loh, & Wong, 2019). This emphasises the substantial influence that the invasion of weedy rice can have on the overall efficiency of rice farming in the country. The conventional approach to disease management entails implementing cultural practices and chemical control methods by applying pesticides more frequently (Dorairaj & Govender, 2023).

Therefore, the utilization of chemical inputs like pesticides, fertilizers, weedicides, and herbicides has witnessed a surge in agricultural practices, primarily due to their positive impact on enhancing farm productivity, farmer income, and efficiency (Fuad et al., 2012; Kyire, Kuwornu, Bannor, Apiors, & Martey, 2023; Nabhan et al., 2018). In response to the escalating issues of pests and diseases such as nematodes, warheads, leaf caterpillars, rats, bacterial leaf blight, and declining soil fertility, farmers resort to the use of agrochemicals as a means to address these challenges (Rosmiza et al., 2021; Sabran, Abas, Mazlan, & Supramaniam, 2020). Pesticides offer notable advantages in pest management as they are highly efficient, act rapidly, are easy to apply, and provide a powerful and cost-effective solution (Rahaman et al., 2018). More surprising, global data show that toxic chemical waste, particularly expired pesticides, is a severe threat in several regions, such as Eastern Europe, Latin America, Africa, the Middle East, and Asia (Baharuddin, Sahid, Noor, Sulaiman, & Othman, 2011; Gaba et al., 2019). About 19,500 tonnes of chemical waste have expired in Ukraine, followed by Poland (15,000 tonnes), Macedonia (10,000 tonnes), and Asia (6,000 tonnes). China is an exception since it has already been hit by a serious ecological and food security crisis (Gaba et al., 2019; Zhang, He, Chen, & Cao, 2018).

In terms of pesticide use, Malaysia ranks the third highest in Southeast Asia after China and India, with a usage of 49,199 tons/per year (Sharma et al., 2019). The persistent usage of chemical input leads to gene flow, which is resistant to OnDuty and herbicide carryover effects. For example, the Clearfield rice variety, introduced in Louisiana and Arkansas, USA, in 2002 to address weedy rice issues, was reported to have exhibited resistance in the same year. In Louisiana, the average gene flow was recorded at 0.17%, while in Arkansas, resistance was observed in 2003, with gene flow percentages ranging from 0.11% to 0.76% (Sudianto et al., 2013). Even through this has exacerbated the situation, some populations of natural biological agents, such as birds, have become extinct due to the contaminated granary-stored rice. On the other hand, these species are beneficial for biologically controlling the rat population because they can eat up to five rice paddy rats per night (Ramlah et al., 2007).

In similar scenarios in Malaysia, illegal pesticide residues such as endosulfan and paraquat were detected at six water sampling sites at Bandar Brinchang, Sungai Bertam, and Sungai Terla in Cameron Highlands, which have

active and intensive agricultural activities. Furthermore, the frequent use of chemical inputs in field areas has led to the detection of anthropogenic pollutants, like the accumulation of heavy metals and pesticides (Khasanah, Mindari, & Suryaminarsih, 2021; Yin, 2016). Moreover, the illegal disposal of agricultural and industrial chemical waste, as well as improper disposal management practices harm the environment of terrestrial and aquatic life in the surrounding area. This may also threaten human health, especially for farmers who still use banned pesticides and consumers eating products contaminated with residues (Nor, Khalisanni, Azlina, Salmah, & Norshariani, 2020; Teen, Gires, & Pin, 2012). Roslina, Mazlin, Goh, and Ismail (2015) found that pesticide management was only moderate in the entire Permanent Food Production Park Program, which involved 350 farmers.

These factors have been a concern for decades and have prompted more researchers to investigate the risks of the inefficient management of agricultural chemical inputs in order to ensure the safety of environmental well-being and food quality in the commercial market (Armijn & Soegianto, 2020; Tahir & Talip, 2020). Thus, agroecology-based agriculture is an alternative farming system that can meet global food needs more efficiently and sustainably (Adnan, Nordin, Rahman, & Noor, 2017; Mishra et al., 2018). This approach is based on ecosystem services and reducing chemical inputs, including herbicides and pesticides used in agriculture (Bernasconi et al., 2021). Aware that pesticides and herbicides are still necessary to meet the needs of modern agriculture, it is believed that reducing these chemical inputs will play a significant part in mitigating the harmful impacts caused by poor agricultural chemical risk management practices.

Ecosystem stability and consumer safety in agricultural systems depend on farmers' management methods for agricultural chemicals (Roslina et al., 2015; Rosmiza et al., 2022; Sabran et al., 2020). The importance of practice and management, as well as the handling of pesticides, should be taken seriously by farmers. Taking into account the impact on the environment caused by the improper use of chemical inputs, including pesticides, we conducted a study that aimed to assess the current practices and farmer's awareness of the management of chemical risks, such as pesticides and fertilizers, notably among rice farmers in the Sungai Panjang parcel of Sabak Bernam, Selangor, Malaysia. The findings of this study can be useful for relevant agricultural stakeholders to highlight several inputs for an intervention plan toward effective agricultural chemical risk management practices among farmers, particularly in the paddy crop subsector, to secure their health and safety in addition to food security.

We structure this paper to provide a comprehensive analysis of agricultural chemical input management and its implications for sustainable agriculture. Following this introduction section, we delve into a thorough literature review, exploring the impact of inefficient management practices and elucidating existing methods and risk management practices in the agricultural sector. Subsequently, the methodology and study area are outlined, offering insights into the profiles of farmers engaged in rice cultivation and their practices concerning pesticides and fertilizers. The sections that follow show the results and discussions. They go into detail about how farmers handle and manage agricultural chemicals, as well as how well aware they are of risk management. They pay special attention to issues like understanding chemical properties, handling problems, and getting access to organic pesticides. Finally, the paper culminates in a conclusion that synthesizes key findings and proposes actionable awareness-raising and management strategies to foster sustainable agricultural practices.

2. LITERATURE REVIEW

2.1. Impact of Inefficient Management of Agricultural Chemical Inputs

The widespread usage of chemical inputs, such as pesticides and fertilizers in the global agricultural subsector leads to global security risks, including ecosystems, attributable to the negligence related to management, operations staff, and human health (Roslina et al., 2015; Rosmiza et al., 2021; Sabran et al., 2020) and also abundant yields at reasonable expenses (Dorairaj & Govender, 2023). However, this approach often proves ineffective in effectively eradicating the disease from its root. Pesticides, which consist of more than a thousand chemical compounds, are extensively utilized in agriculture to eliminate or control insects, weeds, and fungal diseases (De-

Assis, Barcella, Padilha, Pohl, & Beatriz Frantz Krug, 2020). However, it is important to note that these substances can also pose a threat to various organisms, such as birds, fish, beneficial insects, and non-target plants, as well as the overall environment including air, water, soil, and crops.

Pesticides in tropical climates can endure in soil and water for a period of 1 to 2 months, contingent upon variables such as temperature, sunlight, and the existence of microorganisms. Utilising these goods raises the risk of contamination for both workers and local residents (De-Assis et al., 2020). Environmental pollution occurs when pesticide contamination spreads beyond the intended target plants. Chemical residues can negatively impact human health by contaminating the environment and food supplies. Furthermore, climate change-related factors can impact the application of pesticides, leading to an escalation in usage and resultant contamination (Pretty & Hine, 2005; Tudi et al., 2021).

Farmers often apply excessive amounts of fertilizers and harmful pesticides without properly evaluating the specific needs of their fields, mainly due to a lack of sufficient knowledge. This indiscriminate use of inputs can contribute to the development of pests and disease resistance (Baharuddin et al., 2011; Parveen, 2010) a resurgence of pests, and outbreaks of secondary pests, ultimately resulting in environmental contamination, long-lasting residual toxicity, and the depletion of beneficial insect populations. In situations where natural enemies are absent, pest populations can multiply and significantly impact crop yields. Despite these disadvantages, chemical insecticides continue to be the predominant approach for managing rice insects (Rahaman et al., 2018). The continuous use of phenoxy herbicides in Malaysia's rice granaries in the late 1980s has historically led to a shift in weed species composition. This shift has favored the proliferation of graminaceous species such as barnyard grass (*Echinochloa crus-galli (L.) Beauv.*), jungle rice *(E. colona (L.) Link.*), red sprangletop (*Leptochloa chinensis (L.) Nees.*), saramollagrass (*Ischaemum rugosum*), knotgrass (*Paspalum distichum L.*), and more recently, weedy rice (Baki, 2004). This phenomenon highlights the impact of prolonged herbicide use on the weed community dynamics within Malaysian rice cultivation.

Researchers in agriculture, chemistry, environmental science, ecology, medicine, and economics have also expressed significant concern about the harmful effects of excessive use of agricultural pesticides on the environment and human health (Zhang, Yan, Guo, Zhang, & Ruiz-Menjivar, 2018). The US Geological Survey conducted a study that examined 51 significant river basins and aquifer systems, detecting pesticides in stream water samples from agricultural areas 97% of the time (Gilliom, 2007). Agricultural chemical pollution is far more severe in most developing nations (Elfvendahl, Mihale, Kishimba, & Kylin, 2004). Reports indicate that China has the highest utilisation of fertilisers and insecticides globally. Specifically, the amount of chemical fertilisers used has exceeded 59 million tonnes, and the amount of pesticides used has exceeded 1.8 million tonnes (National Bureau of Statistics of China, 2014). Farmers in developing nations are experiencing health issues, both immediate and long-lasting, due to their contact with agricultural pesticides. These health problems range from intense symptoms like headaches, skin rashes, and eye irritations to chronic conditions such as cancer, endocrine disruption, and birth defects (Zhang et al., 2018).

Given the widespread use of pesticides to enhance productivity, reduce labour requirements, and manage plant diseases, it is highly likely that all farmers will experience some level of pesticide exposure during their farm activities (De-Assis et al., 2020). Individuals exposed to pesticide contamination can experience both acute and chronic effects, ranging from mild toxicity to neurotoxicity and even fatality. Pesticides have been linked to various health issues, including neurological, endocrine, psychological, immunological, respiratory, hematological, skin, kidney, and liver problems, as well as fetal malformation. In other pertinent cases, the neglect of agricultural chemical input handling management has led to the annual death of nearly 600 farmers in Thailand. Meanwhile, 5,000 people were poisoned by paraquat, organophosphate and carbamate pesticides (Utomo, 2018).

Existing data show that 567 cases of paraquat poisoning occurred from 2009 to 2011 among farmers in Perak, Malaysia (Bernama, 2011). The risk of severe acute damage to the skin and eyes, nausea, vomiting, abdominal pain,

and even death has forced the government to ban this particular pesticide (Badrulhisam, Ismail, & Arumugam, 2019; Samadi, 2019). Moreover, according to Jaafar et al. (2009) and Nazar (2017) the impact of local agricultural activities on the water quality level in the Sungai Selangor Dam and Sungai Petani, Kedah, was significant, and the quality level was formerly classified as Class IV (contaminated). Therefore, if we continue to ignore the management aspects of agricultural chemical inputs, we risk similar adverse effects and potential disasters in the near future (Navitasari & Fangohoi, 2020). As a result, some of the world's poorest countries have had to enlist the help of the International Disease Prevention and Control Program to properly dispose of accumulated chemical waste through modern incinerator technology (Loha, Lamoree, Weiss, & de Boer, 2018).

Examining the situation in Southeast Asia, the widespread use of chemical inputs in agriculture is a significant problem that has significant consequences for both the environment and human health. Recent research in the regions highlights the significance of resolving these issues to prevent their deleterious impacts. Researchers and policymakers are concerned about the excessive use of pesticides and fertilisers in Southeast Asia, where agriculture plays a crucial role in the economy and people's lives. A study carried out by Nguyen, Nguyen, and Grote (2023) in Vietnam unveiled concerning concentrations of pesticide residues in water sources frequently employed for irrigation, suggesting possible hazards to both agricultural labourers and nearby inhabitants.

In Malaysia, Loi et al. (2022) conducted research that revealed the ongoing presence of pesticide contamination in both soil and rivers. This has significant consequences for the overall health of ecosystems and the well-being of humans. The study revealed heightened concentrations of pesticide residues in rice fields and adjacent water sources, which provide hazards to both farmers and residents downstream that depend on these resources. Furthermore, the excessive and unselective application of agricultural pesticides in Southeast Asia has been associated with negative health consequences among farming communities. A study conducted by Sampaothong and Punyawattoe (2024) in Thailand has revealed a worrisome increase in pesticide-induced illnesses, such as acute poisonings and chronic health issues, among agricultural labourers. These findings emphasise the necessity of implementing more stringent laws and enhancing safety protocols in order to safeguard vulnerable groups from the detrimental consequences of chemical exposure.

Moreover, the ecological ramifications of chemical-intensive farming in the area are becoming more evident. The study conducted by Romadhon et al. (2023) in Indonesia revealed substantial decline in biodiversity and deterioration of ecosystems due to the utilisation of pesticides. This poses a serious danger to the long-term viability of agricultural systems and the benefits they offer. Given these discoveries, there is an increasing acknowledgment of the necessity for sustainable farming methods and alternative approaches to controlling pests throughout Southeast Asia. Effective mitigation of chemical pollution in agriculture and promotion of sustainable farming systems for the future necessitate the cooperation of government agencies, research institutions, and local populations.

2.2. Methods and Agricultural Chemical Input Risk Management Practices

The improper handling of empty agricultural chemical containers presents significant environmental and health risks. In China, evidence of high pesticide concentrations was found in empty pesticide containers, soil, and water samples. Additionally, farmers have been observed using various improper disposal methods for waste pesticide packages, including discarding on-site, burying in landfills, burning on-site, storing for other purposes, discarding with regular garbage, recycling waste, and even selling them. However, these methods have significant drawbacks as they can lead to contamination of agricultural soil and underground water, as well as visual and air pollution. Moreover, they cause irreversible damage to the environment and human health (Xu et al., 2021).

The Research Centre for Rural Economy, Ministry of Agriculture and Rural Affairs in China, performed a survey that revealed that 62% of Chinese farmers dispose of discarded pesticide packages by directly discarding them into fields or water bodies after use. As a consequence of this behaviour, more than 3.2 billion pesticide

packages are disposed of each year in a haphazard manner, with a total weight exceeding 100,000 tonnes. Due to the fact that 2% to 5% of pesticides stay in these packages and containers, there is a notable concern regarding the release of pesticide residues into the surrounding environment through precipitation or irrigation. This might result in irreversible degradation of water and soil ecosystems. Moreover, it is crucial to acknowledge that the majority of this pesticide packaging is made of non-biodegradable plastic, which worsens the harm to soil structure (Xu et al., 2021).

It is crucial to implement measures aimed at reducing the hazards associated with these containers and ensuring their safe disposal. These measures may include implementing a triple rinse procedure, establishing dedicated collection centers and facilitating the proper elimination of the containers. By adopting these actions, it can effectively mitigate the dangers posed by empty pesticide containers and safeguard both the environment and human health (Huici, Skovgaard, Condarco, Jørs, & Jensen, 2017). In Denmark, there is a legal requirement for empty pesticide containers to be returned to the retailers. Retailers must accept these containers and send them to the national chemical destruction plant for safe recycling of the plastic material. This practice ensures the proper handling and environmentally-friendly disposal of pesticide containers (Huici et al., 2017).

Implementing recommended practices from Occupational Health and Safety (OHS) and Public Health Organizations, which include the use of personal protective equipment (PPE), enables workers to effectively decrease their occupational exposure to a wide range of known or potentially harmful agrochemicals, such as pesticides. This, in turn, helps to mitigate the risks of health-related harm (Moreira & Da Silva, 2023). However, Van Den Berg et al. (2020) found that using PPE is not legally mandatory, causing it to be often neglected to reduce production costs in some poorer regions, such as Africa.

The presence of risk in agriculture is unavoidable, which emphasizes the importance of farmers adopting risk management practices to minimize the negative effects of risk on their farms and enhance their well-being. However, farmers have varying perceptions of these risks. It is argued that farmers' perception of risks plays a role in shaping their attitudes and the strategies they use to mitigate risks (Kyire et al., 2023). Hence, when seeking to implement risk management tools, it is crucial to take into account farmers' individual risk perceptions. Several behavioral and educational factors contribute to pesticide contamination and health concerns among farmers. These factors encompass the utilization of prohibited or restricted pesticides, lack of PPE usage, unsafe behaviors and practices during pesticide handling, excessive application, underestimation of label instructions, inadequate spraying techniques on farms, improper disposal of empty pesticide containers and residues, insufficient knowledge about hazards and health and environmental impacts, as well as inadequate education and training on the proper and safe use of pesticides (Moreira & Da Silva, 2023).

Work-related accidents among farmers occur due to their lack of knowledge, attitudes, and indifference towards self-protection (Bryan, Ratu, Oematan, & Roga, 2022). Baharuddin et al. (2011) and Hamsan et al. (2017) showed that wearing the appropriate PPE, which includes masks, glasses, hats, specialized clothing, shoes, and gloves, is a highly important factor since wind factors are the most significant in influencing the effects of the inhalation of toxins through respiration. This results in symptoms such as nausea, dizziness, and skin irritation (Bryan et al., 2022). According to Jallow, Awadh, Albaho, Devi, and Thomas (2017) and Sharma et al. (2019) neglecting PPE according to the complete specifications often leads to serious harm to the health of farmers if such chemical inputs come into contact with the skin or are inhaled. If exposed to excessive organophosphate pesticides, the respiratory system narrows, causing respiratory muscle paralysis in the human lungs (Badrulhisam et al., 2019).

According to Bryan et al. (2022) based on data provided by the National Poisoning Information Center (NPIC), there were 771 reported cases of pesticide poisoning in Indonesia in 2016. The main cause of these poisonings is attributed to the behavior of farmers who neglect the use of PPE while spraying pesticides. This was primarily due to the belief among farmers that using PPE significantly hampers their movement during work. Additionally,

farmers perceive that the cost of acquiring quality PPE is economically burdensome, making it challenging for them to obtain the necessary equipment.

Likewise, the knowledge of farmers in Malaysia on the risks of agricultural chemical inputs to the environment and human health remains low, leading to the misuse of unregistered illegal pesticides (Baharuddin et al., 2011; Hafidzi, 2019; Sabran et al., 2020). Farmers continue to use unregistered chemical pesticides due to factors like low prices and illegal sales (Hafidzi, 2019; Roslina et al., 2015). Despite the availability of a range of organic pesticides on the market, it remains possible for unregistered pesticides to be obtained commercially, particularly through online purchases or illegal smuggling from neighboring countries (Fuad et al., 2012; Nabhan et al., 2018).

3. METHODOLOGY AND STUDY AREA

We conducted a study using a questionnaire instrument with 141 respondents to capture the actual quantitative data in the field. Farmers cultivating paddy fields in Sungai Panjang, Sabak Bernam District, Selangor, Malaysia, randomly selected the sample. We recorded the respondents' knowledge and practices on chemical input risk management for the use of pesticides based on the degree of agreement score. We used descriptive analysis based on frequency, mean, and standard deviation to determine the level of interpretation of the mean square. The interpretation levels are based on mean score, where the low is between 1.00 and 2.49, the medium is between 2.50 and 3.79, and the high is between 3.80 and 5.00 (Wahab & Idris, 2016).

The study area was chosen because the paddy planting parcel in Sungai Panjang is under the administration of the Integrated Agriculture Development Area (IADA), Northwest Selangor, and is among the largest paddy production granaries in the world. The Sungai Panjang Parcel is located within the Mukim of Sungai Panjang, which covers an area of 28,179 hectares. Meanwhile, the paddy land-use area is 262 hectares (Figure 1) and is located at latitude 3°43'45" U and longitude 101°5'9" T.

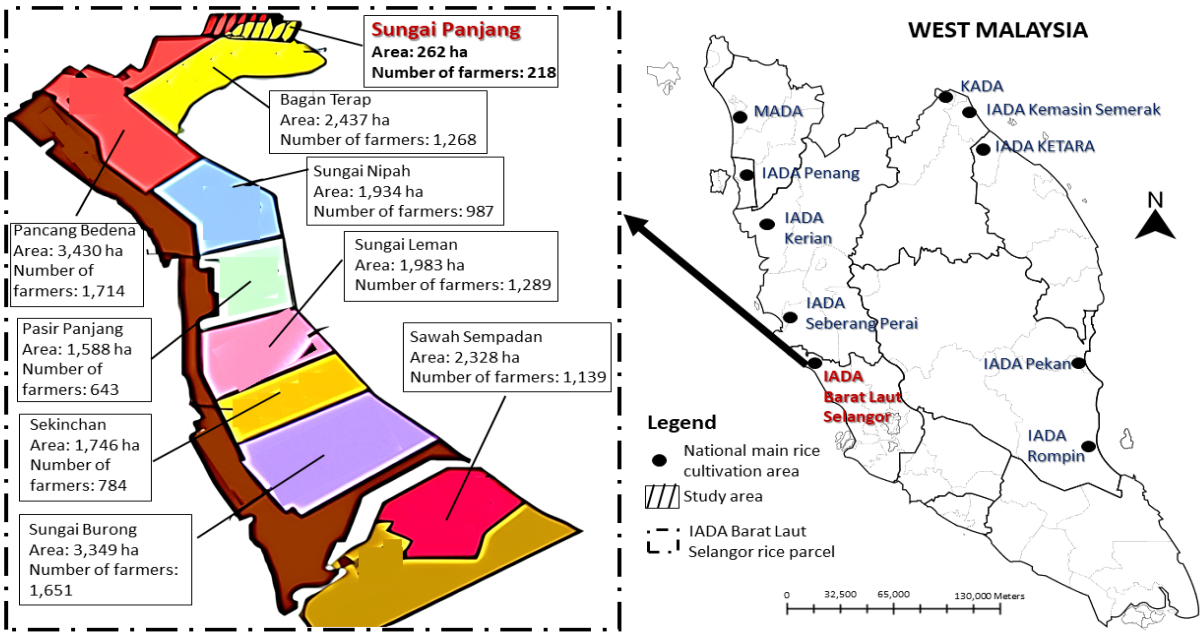

Figure 1. The area of the paddy cultivation plant in Sungai Panjang that located in the integrated agricultural development area (IADA) of Barat Laut Selangor.

4. RESULTS AND DISCUSSION

4.1. Profile of Farmers and Rice Cultivation

According to the respondent profiles, all of the respondents were males. Over half of the respondents (54.6%) were between 30 and 40 years old, followed by 41 to 50 years old (34.8%). About 8.5% of them were under 30 years old, while the remaining 2.1% of the respondents were over 50 years old. Most respondents are educated at the

secondary level (84.4%), followed by the lower level (15.6%). Meanwhile, the paddy cultivation profile showed that most respondents (96.5%) worked in the fields full-time, while the minority group of 3.5% were part-time farmers for ancillary income.

Most of the respondents (91.5%) cultivate paddy fields on a small scale, with an area of fewer than five hectares. The findings showed that only a handful (5.7%) of the respondents work in medium-scale paddy fields between 5 to 10 hectares, while the remaining 2.8% work in paddy fields over 10 hectares. Most respondents (64.5%) cultivate rice within 5 to 10 years. Only 24.8% of the respondents have experience of ten years and above. However, some respondents (10.6%) ventured into the paddy sector less than five years ago.

In the main season, the yield obtained by most respondents ranged from 3.0 to 5.0 tons/ha (51.8%), followed by a range of 5.1 to 7.0 tons/ha (29.1%). The lowest yield below 3.0 tons/ha was recorded at 16.3%. However, some still farmers still achieve an average yield of over 7.1 tons/ha (2.8%) this season. Compared to the off-season, most respondents only obtained yields in the range of 3.1 to 5.0 tons/ha (67.4%). Some also obtained a modest yield of just under 3.0 tons/ha (26.9%). During the off-season, only a minority obtained yields in the range of 5.1 to 7.0 tons/ha (5.7%). Since 2016, the average main season yield has declined to an average of 4.5 tons/ha due to diseases and pests such as nematodes, BLB disease, and warfare attacks affecting nearly 2,000 hectares in the Barat Daya Selangor Integrated Agricultural Development Area (IADA) (Izuan, 2020).

The recommendation of crop rotation by Malaysian Agricultural Research and Development Institute (MARDI) (2023) led to the finding that 98 respondents implemented the method of crop variety rotation every crop season (69.5%). However, only 43 respondents (30.5%) used the same variety each season. The rotation of crop varieties in each cropping season aims to reduce the risk of similar diseases and pests attacking in the subsequent season (Rofiqoh, 2019). This coincides with the development of each variation because it has its own capabilities in terms of high yield, resistance to disease, and environmental resistance to the production of good yields (Malaysian Agricultural Research and Development Institute (MARDI), 2023).

4.2. Practices of Handling and Management of Agricultural Pesticides and Fertilizers by Farmers

We assessed the management and handling of agricultural waste by farmers in Sungai Panjang based on their knowledge of the chemical pesticides they use and the disposal of empty pesticide bins. The findings confirmed a high interpretation with a mean value of 4.03 (s.d=0.167). It was found that 97.2% of the respondents agreed, and 2.8% disagreed, that safety guidelines and poison labels should be scrutinised before their usage. Their response demonstrates that they are concerned about the impacts of specific chemical inputs on human health and the environment. This result is consistent with Sharifzadeh, Abdollahzadeh, Damalas, and Rezaei (2018) findings, which stated that farmers with a good understanding of agricultural pesticides and fertilizers risk management are aware of dose, danger, and toxicity levels.

Meanwhile, a high interpretation was also obtained with a mean value of 4.65 (s.d=0.480) in terms of the method of disposal of pesticide bins or empty fertiliser containers into domestic landfills. A large percentage (64.5%) of the respondents "strongly agreed," and 35.5% "agreed." This observation shows that respondents have better practices for disposing of pesticide containers compared to farmers in Penang, as reported by Sabran and Abas (2021). Their good attitude, subjective norms, and concerns for the environment align with their intentions and practices when disposing of pesticide bins or containers (Raza et al., 2022). Baharuddin et al. (2011) also highlighted the handling of agricultural pesticide containers as a critical cause for intervention strategies related to the safety of their use in order to prevent worse risks from occurring. However, direct disposal into ordinary domestic areas is not the optimal method, according to the Environmental Quality Act of 1974. The Department of Environment licenses a special disposal center to dispose of empty chemical containers after rinsing and punching (Department of Agriculture, 2018). The findings show that burning or planting pesticide barrels or empty fertiliser containers after rinsing was agreed upon by 75.2%, strongly agreed upon by 7.1%, and disagreed upon by 17.7%. The Department

of Agriculture (2018) recommends against the burning method except for cardboard-type containers, after considering the environmental conditions and obtaining permission from the local authorities.

The method of collecting empty pesticides or fertilizer bins for the Empty Pesticides Bin Recycling Program was strongly agreed upon by 71.6% and 28.4% of the respondents, who gave a high interpretation with a mean value=4.72 (s.d=0.452) (Figure 2). This method is also recommended by the Department of Agriculture (2017) but if the pesticide container is composed of High-Density Polyethylene (HDPE), it needs to be rinsed three times and punched before being sent to a nearby Recycling Program facility. Nevertheless, the overall results align with those of Yang et al. (2014) and Roslina et al. (2015) whereby nearly 90% of farmers are knowledgeable regarding the risks of pesticide use on human health in the event of neglecting safety procedures for use.

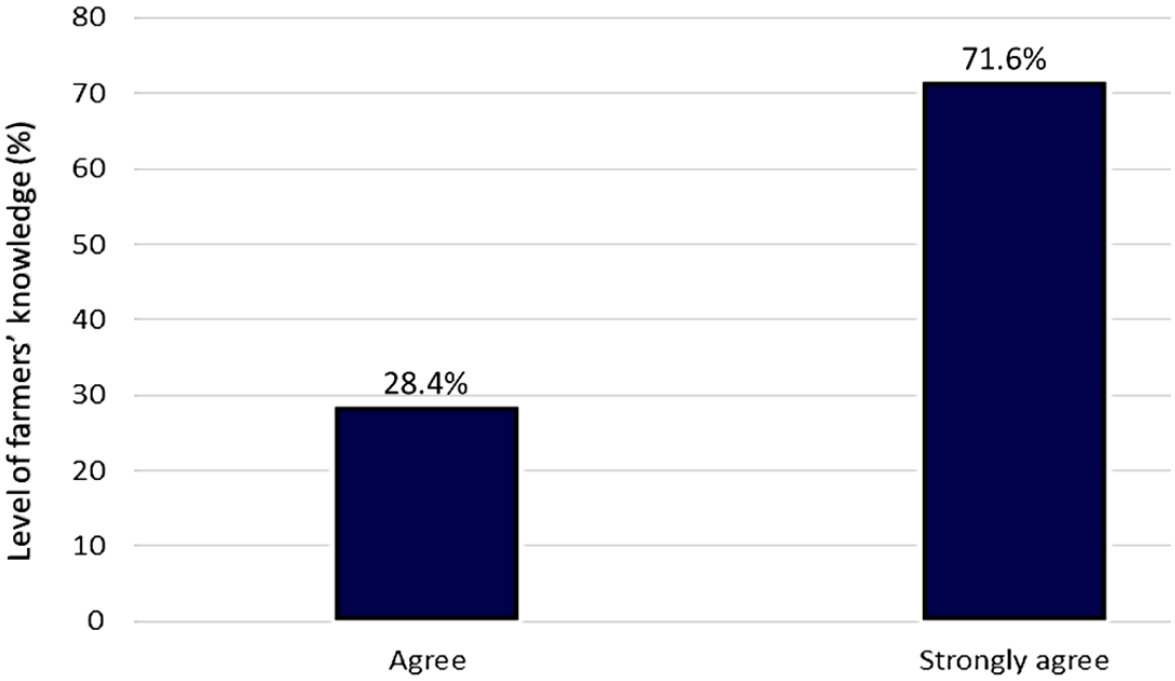

Figure 2. Respondents' consent to the empty pesticides bin recycling program.

4.3. The Level of Awareness of Farmers Related to Risk Management of Agricultural Pesticides and Fertilizers

4.3.1. Lack of Understanding of the Properties and Types of Chemicals used in Pesticides

Based on Table 1, a high interpretation with a mean value of 4.62 (s.d=0.488) shows that the majority of respondents (61.7%) strongly agreed, and the remainder agreed (38.3%) that they too often experience symptoms such as headache, diarrhoea, vomiting, and nausea, after handling pesticides. Fuad et al. (2012) attribute this to the negative externalities of pesticide handling on farmers' health. A lack of pesticide training was significantly more associated with health symptoms (Sharafi et al., 2018). Undoubtedly, a lack of knowledge of the types of active ingredients found in pesticides leads to misuse and serious problems in the agricultural environment, as well as the pollution of chemical residues in harvested produce (Fuad et al., 2012; Rosmiza et al., 2022). The findings also confirmed (67.4% and 14.9%) that harmful pesticides (e.g., paraquat and endosulfan) were used by farmers, respectively. These findings are in line with those by Baharuddin et al. (2011); Roslina et al. (2015), and Hafidzi (2019), who found that farmers still practise the use of certain unregistered and illegal pesticides. Farmers lack information, specifically related to the chemical properties contained in the pesticides, which allow the use of doses in cocktails (multi-residue) to obtain immediate effects (Nabhan et al., 2018). They might still have aspects of neglect in managing and handling agricultural chemicals, especially in terms of pesticides. According to Hamsan et al. (2017) 92.8% of farmers harvested earlier after spraying, and there were symptoms of poisoning such as coughing, difficulty breathing, and chest tightness after poisoning activities. Sharma and Singhvi (2017) also

conducted an evaluation study on farmers, who found that greater poisoning symptoms were associated with organophosphate and organochlorine type pesticides in India. Moreover, the primary factor contributing to farmers' increased vulnerability to environmental and health hazards is their limited technical expertise, which leads to improper pesticide usage (Ahmad et al., 2019).

4.3.2. Concerns in Handling Pesticides

The proper management and handling of chemical substances in the agricultural sector, particularly in food crop production, play a vital role in ensuring the safety of users and the well-being of the environment (Department of Agriculture, 2018). A significant majority of respondents (97.2%) agreed, with 2.8% strongly agreeing, on the importance of reading labels to understand the hazards and risks associated with chemical substances before their use. This finding resulted in a high interpretation score, with a mean value of 4.03 (s.d = 0.167).

Regarding the disposal of empty pesticide or fertilizer containers, the method of utilizing nearby domestic waste disposal areas received a high interpretation score, with a minimum value of 4.65 (s.d = 0.480), due to strongly agreed (64.5%) and agreed (35.5%) among respondents. The practice of handling disposal through methods such as burying or burning empty pesticide or fertilizer containers after rinsing was also supported by a majority of respondents (75.2%) who agreed and 7.1% strongly agreed, and the remaining 17.7% expressed somewhat less agreed. Furthermore, a significant majority of respondents (71.6%) strongly agreed and 28.4% agreed endorsed the practice of collecting empty chemical pesticide and fertilizer containers for recycling programs or incineration. This resulted in a high interpretation score, with a mean value of 4.72 (s.d = 0.452).

The practice of self-cleaning after using chemical input (pesticides and fertilizers) in the field was strongly agreed upon by most of the respondents 63.8% and agreed upon by 18.4% of the respondents. However, some respondents somewhat disagreed (16.3%) and disagreed (1.4%) on this matter. This finding led to a high interpretation score, with a mean value=4.45 (s.d=0.814; Table 1). A survey analysis by Gesesew, Woldemichael, Massa, and Mwanri (2016) also showed similar findings: only 50% of the respondents acted to clean themselves after performing the poisoning process on their farms. The method of self-cleaning using soap and water is an early emergency action to reduce irritation and toxins in the event of contact with human skin (Badrulhisam et al., 2019). This practice is highly important to implement, as the risk of spills and splashes is high, especially when farmers implement pesticide dosages and mixtures.

The practice of using PPE was strongly agreed upon by 60.3% of the respondents and agreed upon by 21.3% when handling chemical inputs such as fertilisers and pesticides. Meanwhile, the remainder (17.7%) somewhat disagreed, and only 0.7% disagreed, giving a high interpretation with a mean value of 4.41 (s.d=0.802). However, most respondents disagreed (74.5%), 16.3% disagreed, and 7.8% strongly disagreed with using appropriate PPE when handling pesticides. This observation leads to a low interpretation, with a mean value of 2.11 (s.d=0.536) (Table 1). The data demonstrates that although farmers frequently use PPE when handling pesticides, their safety is questionable due to inadequate PPE equipment. This finding is concerning appropriate use of PPE can allow farmers to protect from the toxicity of certain pesticides (Baharuddin et al., 2011; Sharma et al., 2019). Jallow et al. (2017) also support the idea that the active and inert materials found in pesticides are the most important factor in minimising exposure to pesticide toxicity. Based on the physiological aspect, this phenomenon could indicate that it is likely that the respondents have low levels of perceived severity of pesticide adverse effects, cues, action and/or perceived PPE benefits, as noted by Sharifzadeh, Abdollahzadeh, and Damalas (2023). However, it is a proven fact that adherence to PPE usage among farmers can significantly reduce work-related accidents and illnesses. This indicates that attitudes alone do not automatically translate into action. For views to manifest into tangible actions, they require supportive factors or enabling conditions (Bryan et al., 2022).

4.3.3. Cost-Cutting Measures and the Difficulties of Acquiring Organic Pesticides in the Market

Despite the availability of good management practices for managing chemical inputs by farmers, the appropriate use of PPE when handling pesticides remains to be neglected.

Table 1. Level of awareness related to the risks of the use of chemical inputs risk management of paddy cultivation.

Level of awareness	Scale					n=141		
	1	2	3	4	5	Mean	Standard deviation (S.D)	Interpretation
Symptoms of health disorders after handling pesticides	-	-	-	54 (38.3%)	87 (61.7%)	4.62	0.488	High
Farmers still use paraquat/ Endosulfan pesticides	-	-	25 (17.7%)	21 (14.9%)	95 (67.4%)	4.50	0.780	High
Reading the label for the type of hazards and risks associated with chemical substances before use	-	-	-	137 (97.2%)	4 (2.8%)	4.03	0.167	High
Disposing of empty pesticide/Fertilizer containers in nearby domestic waste disposal areas	-	-	-	50 (35.5%)	91 (64.5%)	4.65	0.480	High
Burying or burning empty pesticide/ Fertilizer containers after rinsing	-	-	25 (17.7%)	106 (75.2%)	10 (7.1%)	3.89	0.488	High
Collecting empty pesticide/Fertilizer containers for recycling programs or disposing of them using an incinerator	-	-	-	40 (28.4%)	101 (71.6%)	4.72	0.452	High
Practice self-cleaning after using chemical input (Pesticides or fertilizers)	-	2 (1.4%)	23 (16.3%)	26 (18.4%)	90 (63.8%)	4.45	0.814	High
Practice the use of PPE when handling chemical pesticides and fertilizers	-	1 (0.7%)	25 (17.7%)	30 (21.3%)	85 (60.3%)	4.41	0.802	High
Use of appropriate PPE equipment	11 (7.8%)	105 (74.5%)	23 (16.3%)	2 (1.4%)	-	2.11	0.536	Low
Bio-organic or nano-organic pesticide products are difficult to obtain in the market	-	1 (0.7%)	25 (17.7%)	41 (29.1%)	74 (52.5%)	4.33	0.790	High
Knowledge related to rapid kits for screening of pesticide residues and heavy metals in agriculture	-	2 (1.4%)	22 (15.6%)	21 (14.9%)	96 (68.1%)	4.50	0.807	High
Mean average = 4.13								

Note: Scale 1 = Strongly disagree; 2 = Disagree; 3 = Somewhat disagree; 4 = Agree; 5= Strongly agree.

This finding coincides with prior work and case studies by Van Den Berg et al. (2020); Samadi (2019), and Hafidzi (2019), leading to a possible lack of knowledge on the nature of the pesticides used and the cost of PPE to be borne by farmers. Regarding the alternative of organic pesticides and fertilisers with nanotechnology, the majority of respondents strongly agree (52.5%), agree (29.1%), somewhat disagree (17.7%) and disagree (0.7%) that it is difficult to obtain in the market (Table 1). However, Merdu et al. (2020) and Rosmiza et al. (2022) noted a growing market awareness and acceptance of organic farming among modern farmers. This is because its active content is readily biodegradable and requires minimal safety management, making it a sustainable alternative in the agricultural sector. Therefore, it is highly desirable to pest management through research and development, aiming

to explore safer organic alternative sources in future. Due to the scarcity of bioorganic and nanoorganic pesticides, respondents should adopt the ecocentric approach of Norwegian apple farmers, who reduce the use of pesticides to protect beneficial insects, such as bees, that play an essential role in the ecosystem (Milford, Hatteland, & Ursin, 2022). Farmers' ecocentric values can be motivated by their level of knowledge, attitudes, and practices, as noted by Ibrahim et al. (2023); Kyire et al. (2023), and Moreira and Da Silva (2023).

In summary, this study found that, on average, farmers' level of chemical inputs (e.g. pesticides and fertilizers) risk management practices were reasonably well developed, with an average mean score of 4.13. Farmers' awareness of pesticide management and handling is critical, as they are at the forefront of ensuring the safety and quality of agricultural products for consumers. The attitude of pesticide operators can be assessed through their awareness of the use of pesticides by taking into account the standards set by manufacturers to reduce potential hazards and pollution to agricultural systems. However, this study found that farmers still use unregistered and illegal pesticides to date due to low prices and illegal sales commercially through online purchases or illegal smuggling from other countries. Despite the availability of a range of organic pesticides on the market, it remains possible for unregistered pesticides to be obtained, particularly through online purchases or illegal smuggling from neighboring countries, as stated by Fuad et al. (2012) and Nabhan et al. (2018).

Therefore, it is not uncommon for poisoning symptoms to be detected in most farmers, even if personal hygiene is practised after applying pesticides in the field. This is often repeated when some farmers do not use the appropriate PPE, such as N95-type PPE, when dealing with pesticides, as noted by Bryan et al. (2022); Jallow et al. (2017), and Sharma et al. (2019). They may lack knowledge that toxic contamination can still occur due to poison vapours (aerosols) inhaled through the respiratory tract, even if wearing medical-type half-face masks or fabrics.

5. AWARENESS RAISING AND MANAGEMENT STRATEGIES TOWARD SUSTAINABLE AGRICULTURE

To reduce the harmful effects of chemical input contamination, particularly pesticides, on the ecosystem and non-target organisms, it is crucial to implement innovative scientific approaches, technologies, and effective procedures. These efforts encompass the adoption of integrated pest management (IPM), the enforcement of legislation banning hazardous pesticides, and the creation of a National Implementation Plan (NIP). The purpose of these efforts is to mitigate the adverse effects linked to the utilisation of chemicals in agriculture. Furthermore, it is critical to effectively communicate the scientific discoveries obtained from exposure assessments and evaluations of occupational and environmental health risks. This will enhance scientific education on the application of chemical inputs, reduce negative health consequences arising from chemical usage, and promote safety for both those applying the chemicals and the surrounding community, thereby contributing to sustainable development. Additionally, it is crucial to prioritise the advancement of biopesticides and biofertilizers in conjunction with chemical inputs in order to minimise contamination.

Regarding the intervention program, it is recommended that relevant stakeholders consider the farmers' current level of awareness and knowledge regarding the use of chemical inputs in agriculture. This will guarantee the safe management and handling of these inputs. It is important to provide training to farmers on the proper use of PPE and the use of registered chemical inputs. Encouraging the adoption of integrated pest management practices will help minimize the use of chemical inputs in the field, ensuring they are only used when necessary and at the recommended dosage. Farmers should be educated about the different types of pests, weeds, and diseases, so they can apply suitable chemical inputs in the field according to the recommended doses.

To promote sustainable agricultural production, farmers should practice good agronomic practices, such as selecting disease-resistant rice varieties to reduce reliance on chemical pesticides. The use of modern machinery and technology should also be encouraged to minimize post-harvest losses. Additionally, promoting the use of agricultural by-products, such as rice straws as crop media and fertilizer inputs, can contribute to sustainable

practices. We should encourage small and medium-scale farmers to participate in organic input assistance schemes for pest control. Research and development efforts should focus on achieving high rice yields, particularly in developing high-tech organic products for pest and disease control. Legal support, such as ensuring the quality of seeds, availability of registered pesticides, and establishing agricultural chemical input disposal centers, should be prioritized by relevant ministries. This support should particularly target small and medium farmers, aiming to enhance the competitiveness, quality, and safety of the local rice production value chain for consumers.

Special attention should be given to farmers with limited knowledge of chemical control and safe handling. It is recommended that the government offer incentives to farmers who adopt appropriate agricultural practices, including the use of organic inputs as an alternative for crop pest, weed, and disease management. These incentives are crucial in promoting the continued adoption of environmentally friendly and safer technologies by farmers. To support agroecological agriculture, the application of modern, environmentally-friendly technologies needs to be intensified, besides the introduction of the concept of Good Agricultural Practices (GAP) through the myGAP certification scheme in Malaysia (Ali, Ibrahim, Aiyub, & Kasavan, 2020; Department of Agriculture, 2017; Loh, Lee, Ahmad, Aziz, & Ishak, 2008; Rosmiza et al., 2022). Thus, the continuous support and training provided by agencies play a crucial role in assisting farmers who lack the necessary knowledge to obtain myGAP certification, thereby facilitating its expansion.

Farmers should use innovative technologies is agriculture to detect farm management issues. This would enable farmers to instantly detect contaminant chemical residues in crop samples during initial inspections, ensuring suitability for harvest. Consequently, farmers can effectively plan the timing of crop harvesting before safely marketing their produce. Moreover, products labeled as pesticide-free become more valuable as they demonstrate improved food safety standards. These applications indirectly contribute to increasing farmers' income and, subsequently, the national income by enhancing the safety and quality of agricultural exports.

Results show that farmers still employ unregistered and illegal pesticides even though their chemical risk management practises are good in this study. This demonstrates that several agricultural extension strategies by stakeholders, such as implementing an intervention program on agricultural chemical risk management practices among farmers, are crucial in the study area. This research, while limited to the study area, suggests a need for intensified enforcement and monitoring of the sale and use of illegal chemical inputs in the agricultural sector across the country. Environmental ethics must be instilled among farmers to recognise that managing agricultural fertilizers and pesticides is crucial for human health (Verharen et al., 2021). Mobile awareness campaigns are ideal for rural agricultural areas since they use interactive techniques and awareness speeches to help farmers understand the significance of better agricultural chemical input management and handling.

In addition, it is crucial to enhance education and awareness regarding management and handling of chemical inputs in agriculture to reach small and medium-scale farmers. Strengthening technical support and outreach educational activities for local farmers is essential for effective control and management of pests, weeds, and disease infestations. We should conduct regular awareness campaigns, lectures, final days, and training sessions to promote good agricultural practices among rice growers. Collaboration between the government agencies, academic institutions and other local or international organizations is necessary to provide comprehensive information and support to rice growers regarding chemical inputs management.

6. CONCLUSIONS

The preliminary data highlights the importance of enhancing farmers' awareness of the usage and handling of pesticides within the rice industry sub-sector, particularly in Sungai Panjang parcel, Sabak Bernam, Selangor, Malaysia. The findings reveal a commendable level of agricultural chemical risk management practices among respondents, as evidenced by their adherence to safety guidelines and poison labels. Leveraging these existing good practices presents an opportunity for broader adoption within the community. However, the study also uncovers

notable weaknesses in awareness, such as the continued use of unregistered and illegal pesticides, and a lack of emphasis on the effective utilization of personal protective equipment (PPE). Addressing these gaps necessitates targeted intervention programs aimed at educating and empowering farmers on regulatory compliance and safety protocols.

Moreover, the imperative for a paradigm shift towards greener agricultural practices emerges as a central theme. Embracing sustainable alternatives like green fertilizers and leveraging emerging technologies such as nanotechnology holds promise for enhancing productivity while mitigating environmental impact. Policy initiatives should prioritize incentivizing the adoption of such practices through supportive frameworks and targeted capacity-building efforts. These efforts align with broader sustainable development goals and contribute to the creation of a cleaner food chain and enhanced productivity.

Despite its insights, the study has several limitations that warrant consideration. First, the focus on a specific geographical area may limit the generalizability of findings to broader agricultural contexts. Future research should aim for more diverse sampling to ensure representative insights. Secondly, reliance on self-reported data may introduce response bias, necessitating the incorporation of objective measures or observational data to enhance validity. Thirdly, temporal constraints inherent to preliminary studies may limit the capture of long-term trends or dynamics within the agricultural sector. Continued monitoring and longitudinal studies are essential for assessing the sustainability and efficacy of implemented interventions over time. Finally, external factors beyond the study's scope, such as economic fluctuations or policy changes, could influence farmers' practices and perceptions regarding agricultural chemical usage. Acknowledging these limitations is crucial for refining future research endeavors and informing evidence-based policy interventions aimed at promoting sustainable agricultural practices and mitigating chemical risks effectively.

Funding: This study received no specific financial support.
Institutional Review Board Statement: The Ethical Committee of the Malaysian Agricultural Research and Development Institute has granted approval for this study on 27 August 2021 (Ref. No. 20210827/R/MAEC00104).
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Data Availability Statement: Upon a reasonable request, the supporting data of this study can be provided by the corresponding author.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

REFERENCES

Adnan, N., Nordin, S. M., Rahman, I., & Noor, A. (2017). Adoption of green fertilizer technology among paddy farmers: A possible solution for Malaysian food security. *Land use Policy, 63*, 38-52. https://doi.org/10.1016/j.landusepol.2017.01.022

Ahmad, A., Shahid, M., Khalid, S., Zaffar, H., Naqvi, T., Pervez, A., . . . Nasim, W. (2019). Residues of endosulfan in cotton growing area of Vehari, Pakistan: An assessment of knowledge and awareness of pesticide use and health risks. *Environmental Science and Pollution Research, 26*, 20079-20091. https://doi.org/10.1007/s11356-018-3169-6

Ali, N. I. M., Ibrahim, N. I., Aiyub, K., & Kasavan, S. (2020). Implementation of good agricultural practices (GAP) among rice farmers in Sekinchan, Sabak Bernam, Selangor. *Geografia-Malaysian Journal of Society and Space, 16*(3), 247-262.

Armijn, A., & Soegianto, A. (2020). *Comparison of bioaccumulation of heavy metals through environmental contact in mangroves, Crustacea (P. monodon), and Bivalvia (Anadara sp.). case study: Exposure to Lapindo Mud Pollutants.* Ecotoxicology Paper, No. 1-9.

Badrulhisam, Z., Ismail, S. A., & Arumugam, U. (2019). A cross-sectional study on pesticide exposure with lung capacity and skin disease symptoms among rice farmers in Seberang Perai Tengah, Penang: Pesticide exposure and lung capacity. *MAEH Journal of Environmental Health*, *1*(1), 1-9.

Baharuddin, M. R. B., Sahid, I. B., Noor, M. A. B. M., Sulaiman, N., & Othman, F. (2011). Pesticide risk assessment: A study on inhalation and dermal exposure to 2, 4-D and paraquat among Malaysian paddy farmers. *Journal of Environmental Science and Health, Part B*, *46*(7), 600-607. https://doi.org/10.1080/03601234.2011.589309

Baki, B. (2004). Invasive weed species in Malaysian agro-ecosystems: Species, impacts and management. *Malaysian Journal of Science*, *23*(1), 1-42.

Bernama. (2011). *Farmers are asked to be careful when using paraquat herbicides. Mstar*. Retrieved from https://www.mstar.com.my

Bernasconi, C., Demetrio, P. M., Alonso, L. L., Loughlin, M. T. M., Cerdá, E., Sarandón, S. J., & Marino, D. J. (2021). Evidence for soil pesticide contamination of an agroecological farm from a neighboring chemical-based production system. *Agriculture, Ecosystems & Environment*, *313*, 107341. https://doi.org/10.1016/j.agee.2021.107341

Bryan, J., Ratu, J., Oematan, G., & Roga, A. U. (2022). Relationship between behavior and work accident in rice farmers using pesticides in Oebobo Village, Batu Putih District. *Asian Journal of Logistics Management*, *1*(2), 74-83. https://doi.org/10.14710/ajlm.2022.16715

De-Assis, M. P., Barcella, R. C., Padilha, J. C., Pohl, H. H., & Beatriz Frantz Krug, S. (2020). Health problems identified in rural workers occupationally exposed to pesticides. *Revista Brasileira De Medicina do Trabalho*, *18*(3), 352-363.

Department of Agriculture. (2017). *Malaysia's good agricultural practices certification scheme (myGAP). Department of Agriculture Malaysia*. Retrieved from https://www.doa.gov.my/index.php/pages/view/373

Department of Agriculture. (2018). *Development of pesticides*. Retrieved from http://www.portal.doa.gov.my/sismarp/background

Dorairaj, D., & Govender, N. T. (2023). Rice and paddy industry in Malaysia: Governance and policies, research trends, technology adoption and resilience. *Frontiers in Sustainable Food Systems*, *7*, 1093605. https://doi.org/10.3389/fsufs.2023.1093605

Elfvendahl, S., Mihale, M., Kishimba, M. A., & Kylin, H. (2004). Pesticide pollution remains severe after cleanup of a stockpile of obsolete pesticides at Vikuge, Tanzania. *AMBIO: A Journal of the Human Environment*, *33*(8), 503-508. https://doi.org/10.1639/0044-7447(2004)033[0503:pprsac]2.0.co;2

Fuad, M. M., Junaidi, A., Habibah, A., Hamzah, J., Toriman, M., Lyndon, N., . . . Azima, A. (2012). The impact of pesticides on paddy farmers and ecosystem. *Advances in Natural and Applied Sciences*, *6*(1), 65-70.

Gaba, V., Hrushevska, T., Strelko, O., Kyrychenko, A., Rudyuk, M., & Gusar, I. (2019). *Improvement of international rail transportation of Benzene between Ukraine and the European Union countries*. Paper presented at the Second International Scientific and Practical Conference: Energy-Optimal Technologies, Logistic and Safety on Transport (EOT-2019). EDP Sciences.

Gesesew, H. A., Woldemichael, K., Massa, D., & Mwanri, L. (2016). Farmers knowledge, attitudes, practices and health problems associated with pesticide use in rural irrigation villages, Southwest Ethiopia. *PloS One*, *11*(9), e0162527. https://doi.org/10.1371/journal.pone.0162527

Gilliom, R. J. (2007). Pesticides in U.S. Streams and groundwater. *Environmental Science & Technology*, *41*(10), 3408-3414. https://doi.org/10.1021/es072531u

Hafidzi, M. N. (2019). *Illegal pesticides on rice plants threaten the health of consumers. Utusan Malaysia*. Retrieved from https://spel.upm.edu.my

Hamsan, H., Ho, Y. B., Zaidon, S. Z., Hashim, Z., Saari, N., & Karami, A. (2017). Occurrence of commonly used pesticides in personal air samples and their associated health risk among paddy farmers. *Science of the Total Environment*, *603*, 381-389. https://doi.org/10.1016/j.scitotenv.2017.06.096

Huici, O., Skovgaard, M., Condarco, G., Jørs, E., & Jensen, O. C. (2017). Management of empty pesticide containers—A study of practices in Santa Cruz, Bolivia. *Environmental Health Insights*, *11*, 1-7. https://doi.org/10.1177/1178630217716917

Ibrahim, M. S. N., Assim, M. I. S. A., Johari, S., Mohammad, S. K. W., Afandi, S. H. M., & Hassan, S. (2023). Public awareness on biodiversity conservation and well-being: Case of Gunung Mulu National Park, Sarawak. *GeoJournal*, *88*(3), 3471-3496. https://doi.org/10.1007/s10708-022-10818-x

Izuan, M. I. T. (2020). *Rice is affected by diseases. Daily news*. Retrieved from https://www.sinarharian.com.my

Jaafar, M., Ahmad, A., Sakawi, Z., Abdullah, M., Sulaiman, N., & Mokhtar, N. (2009). Water quality index (IKA) Sg. Selangor after the construction of the Sg Dam. Selangor. *Geografia-Malaysian Journal of Society and Space*, *5*(3), 68–75.

Jallow, M., Awadh, D., Albaho, M., Devi, V., & Thomas, B. (2017). Pesticides knowledge and safety practices among farm workers in Kuwait: Results of a survey. *International Journal of Environmental Research and Public Health*, *14*(4), E340-E340. https://doi.org/10.3390/ijerph14040340

Khasanah, U., Mindari, W., & Suryaminarsih, P. (2021). Study of heavy metal pollution in rice fields in the industrial area of Sidoarjo Regency. *Jurnal Teknik Kimia*, *15*(2), 73-81. https://doi.org/10.33005/jurnal_tekkim.v15i2.2545

Kyire, S. K. C., Kuwornu, J. K., Bannor, R. K., Apiors, E. K., & Martey, E. (2023). Perceived risk and risk management strategies under irrigated rice farming: Evidence from Tono and Vea irrigation schemes-Northern Ghana. *Journal of Agriculture and Food Research*, *12*, 100593. https://doi.org/10.1016/j.jafr.2023.100593

Liu, Y., Pan, X., & Li, J. (2015). Current agricultural practices threaten future global food production. *Journal of Agricultural and Environmental Ethics*, *28*, 203-216. https://doi.org/10.1007/s10806-014-9527-6

Loh, K. S., Lee, Y. H., Ahmad, M., Aziz, S. A., & Ishak, Z. (2008). Electrochemical biosensor based on immobilized alkaline phosphatase enzyme for detection of 2, 4-dichlorophenoxyacetic acid toxicity. *Malaysian Journal of Analytical Sciences*, *12*(2), 473-479.

Loha, K. M., Lamoree, M., Weiss, J. M., & de Boer, J. (2018). Import, disposal, and health impacts of pesticides in the East Africa Rift (EAR) zone: A review on management and policy analysis. *Crop Protection*, *112*, 322-331. https://doi.org/10.1016/j.cropro.2018.06.014

Loi, J. X., Chua, A. S. M., Rabuni, M. F., Tan, C. K., Lai, S. H., Takemura, Y., & Syutsubo, K. (2022). Water quality assessment and pollution threat to safe water supply for three river basins in Malaysia. *Science of The Total Environment*, *832*, 155067. https://doi.org/10.1016/j.scitotenv.2022.155067

Malaysian Agricultural Research and Development Institute (MARDI). (2023). *Scope of paddy & rice research. The Official Portal of the Malaysian Institute of Agricultural Research and Development*. Retrieved from https://www.mardi.gov.my

Merdu, J. A., Er, A. C., Samsudin, S., Maizan, N., Sazali, M. S. N., Ahmad, H., & Nawi, N. F. M. (2020). A comparative study of organic and conventional cultivation in Cameron Highlands, Pahang. *Journal of Social Science Advanced Research*, *1*(2), 43–60.

Milford, A. B., Hatteland, B. A., & Ursin, L. Ø. (2022). The responsibility of farmers, public authorities and consumers for safeguarding bees against harmful pesticides. *Journal of Agricultural and Environmental Ethics*, *35*(3), 1–22. https://doi.org/10.1007/s10806-022-09889-0

Mishra, B., Gyawali, B. R., Paudel, K. P., Poudyal, N. C., Simon, M. F., Dasgupta, S., & Antonious, G. (2018). Adoption of sustainable agriculture practices among farmers in Kentucky, USA. *Environmental Management*, *62*, 1060-1072. https://doi.org/10.1007/s00267-018-1109-3

Moreira, A., & Da Silva, M. V. (2023). Pesticide application as a risk factor/behaviour for workers' health: A systematic review. *Environments*, *10*(9), 160. https://doi.org/10.3390/environments10090160

Muhamad, S. M., Mahyoub, B., Intan, M., Abdul, H. M.-A., & Amalia, Z. (2019). Managing weedy rice (Oryza sativa L.) in Malaysia: Challenges and ways forward. *Journal of Research in Weed Science*, *2*(2), 149-167. https://doi.org/10.26655/JRWEEDSCI.2019.3.6

Nabhan, K. J., Khalik, W. M. A. W. M., Abdullah, M. P., Othman, M. R., Isahak, A., & Zulkepli, S. A. (2018). Assessment of multiresidue pesticides in agricultural soils from Ledang, Malaysia and related potential health risks. *Nature Environment and Pollution Technology*, *17*(1), 99-106.

National Bureau of Statistics of China. (2014). *China statistical yearbook 2013*. Beijing: China Statistics Press.

Navitasari, L. M. P., & Fangohoi, L. S. P. (2020). *Agricultural systems*. Jakarta: Media Sains Indonesia.

Nazar, M. N. (2017). *Deterioration of river water quality due to weather and human activities: A case study in Sungai Petani, Kedah*. Master's Thesis. Universiti Sains Malaysia.

Nguyen, T.-T., Nguyen, T. T., & Grote, U. (2023). Credit, shocks and production efficiency of rice farmers in Vietnam. *Economic Analysis and Policy*, *77*, 780-791. https://doi.org/10.1016/j.eap.2022.12.018

Nor, M. M. R., Khalisanni, K., Azlina, N. M., Salmah, A. A., & Norshariani, A. R. (2020). Residual toxins in vegetables. *Agromedia*, *54*, 34–35.

Parveen, S. (2010). Rice farmers' knowledge about the effects of pesticides on environmental pollution in Bangladesh. *Bangladesh Research Publication Journal*, *3*(4), 1214-1227.

Pretty, J., & Hine, R. (2005). Pesticide use and the environment. In J. Pretty (Ed.), The Pesticide Detox: Towards a More Sustainable Agriculture. In (pp. 1-18). London: Earthscan.

Rahaman, M. M., Islam, K. S., & Jahan, M. (2018). Rice farmers' knowledge of the risks of pesticide use in Bangladesh. *Journal of Health and Pollution*, *8*(20), 181203. https://doi.org/10.5696/2156-9614-8.20.181203

Ramlah, S. A. A., Norman, K., Basri, M. W., Najib, M. A., Mazmira, M. M. M., & Kushairi, A. D. (2007). Ecology and biology of pests. in integrated pest management system for wrapper caterpillar control in oil palm farms. In (1st ed., pp. 1-28). Kuala Lumpur: Malaysian Palm Oil Board.

Raza, A., Naqvi, S. A. A., Mehdi, M. A., Usman, M., Ali, S., Shah, A. A., & Hussain, B. (2022). An analysis of the circular economy practices of pesticide container waste in Pakistan. *Recycling*, *8*(1), 1-18. https://doi.org/10.3390/recycling8010004

Rofiqoh, N. A. (2019). *Study of the intensity of bacterial grain rot disease (Burkholderia glumae) and control techniques in rice plantings in Mayang District, Jember Regency*. Doctoral Thesis. Universitas Jember.

Romadhon, M., Mujiyo, M., Cahyono, O., Maro'ah, S., Istiqomah, N., & Irmawati, V. (2023). *Potential soil degradation of paddy fields through observation approaches from various sources of environmental diversity*. Paper presented at the IOP Conference Series: Earth and Environmental Science.

Roslina, M. S., Mazlin, M., Goh, C. T., & Ismail, S. A. (2015). Pesticide use behavior among farmers in Selangor. *Jurnal Pengguna Malaysia*, *25*, 11-25.

Rosmiza, M. Z., Mohd, N., Che, N. S., Zainal, M., Mapjabil, J., Mr, M. N., & Marzuki, M. (2022). The role of agricultural institutions in promoting community involvement in fertigation in community gardens. *Journal of Asian Scientific Research*, *12*(2), 70-79. https://doi.org/10.55493/5003.v12i2.4496

Rosmiza, M. Z., Muhammad, Z. S., Milah, Z., & Mohd, N. M. R. (2021). Nematode attacks and their influence on farming economics. *Asian Journal of Agriculture and Rural Development*, *11*(1), 105-112. https://doi.org/10.18488/journal.ajard.2021.111.105.112

Sabran, S. H., & Abas, A. (2021). Knowledge and awareness on the risks of pesticide use among farmers at Pulau Pinang, Malaysia. *SAGE Open*, *11*(4), 21582440211064894. https://doi.org/10.1177/21582440211064894

Sabran, S. H., Abas, A., Mazlan, S. M., & Supramaniam, S. D. (2020). Pesticide use practices among rice farmers in Penang. *Akademika*, *90*(1), 5-19.

Samadi, A. (2019). *Ban the poison paraquat. Daily Metro*. Retrieved from https://www.hmetro.com.my

Sampaothong, S., & Punyawattoe, P. (2024). Comparison of carbon footprint, environment impact, efficacy and benefit – cost ratio of insecticide resistance management with conventional abstract. *The Open Agriculture Journa*, *18*(1), 1–9. https://doi.org/10.2174/0118743315286838240116042733

Sharafi, K., Pirsaheb, M., Maleki, S., Arfaeinia, H., Karimyan, K., Moradi, M., & Safari, Y. (2018). Knowledge, attitude and practices of farmers about pesticide use, risks, and wastes; a cross-sectional study (Kermanshah, Iran). *Science of the Total Environment*, *645*, 509-517. https://doi.org/10.1016/j.scitotenv.2018.07.132

Sharifzadeh, M. S., Abdollahzadeh, G., & Damalas, C. A. (2023). Farmers' behaviour in the use of integrated pest management (IPM) practices: Perspectives through the social practice theory. *International Journal of Pest Management*, 1-14. https://doi.org/10.1080/09670874.2023.2227607

Sharifzadeh, M. S., Abdollahzadeh, G., Damalas, C. A., & Rezaei, R. (2018). Farmers' criteria for pesticide selection and use in the pest control process. *Agriculture*, *8*(2), 1-16. https://doi.org/10.3390/agriculture8020024

Sharma, A., Kumar, V., Shahzad, B., Tanveer, M., Sidhu, G. P. S., Handa, N., . . . Parihar, R. D. (2019). Worldwide pesticide usage and its impacts on ecosystem. *SN Applied Sciences*, *1*(11), 1-16. https://doi.org/10.1007/s42452-019-1485-1

Sharma, N., & Singhvi, R. (2017). Effects of chemical fertilizers and pesticides on human health and environment: A review. *International Journal of Agriculture, Environment and Biotechnology*, *10*(6), 675-680. https://doi.org/10.5958/2230-732x.2017.00083.3

Sudianto, E., Song, B. K., Neik, T. X., Scott, R. C., Saldain, N. E., & Burgos, N. R. (2013). Clearfield rice: Its development, success, and key challenges on a global perspective. *Crop Protection*, *49*, 40–51.

Tahir, S. H., & Talip, A. M. (2020). Food safety policy in Sabah, Malaysia: A case study of rice granaries in Kota Belud district. *Jurnal Kinabalu*, *26*(1), 23-39.

Teen, L. P., Gires, U., & Pin, L. C. (2012). Harmful algal blooms in Malaysian waters. *Sains Malaysiana*, *41*(12), 1509-1515.

Toh, W., Loh, P., & Wong, H. (2019). First report of leaf blight of rice caused by Pantoea ananatis and Pantoea dispersa in Malaysia. *Plant Disease*, *103*(7), 1764-1764. https://doi.org/10.1094/pdis-12-18-2299-pdn

Tudi, M., Daniel Ruan, H., Wang, L., Lyu, J., Sadler, R., Connell, D., . . . Phung, D. T. (2021). Agriculture development, pesticide application and its impact on the environment. *International Journal of Environmental Research and Public Health*, *18*(3), 1112. https://doi.org/10.3390/ijerph18031112

Utomo, H. F. S. (2018). *Toxic agricultural chemicals kill people in Thailand every year. Coverage 6.* Retrieved from https://www.liputan6.com

Van Den Berg, H., Gu, B., Grenier, B., Kohlschmid, E., Al-Eryani, S., Da Silva Bezerra, H. S., . . . Velayudhan, R. (2020). Pesticide lifecycle management in agriculture and public health: Where are the gaps? *Science of the Total Environment*, *742*, 140598. https://doi.org/10.1016/j.scitotenv.2020.140598

Verharen, C., Bugarin, F., Tharakan, J., Wensing, E., Gutema, B., Fortunak, J., & Middendorf, G. (2021). African environmental ethics: Keys to sustainable development through agroecological villages. *Journal of Agricultural and Environmental Ethics*, *34*(3), 1-18. https://doi.org/10.1007/s10806-021-09853-4

Wahab, M. K. A., & Idris, M. R. M. (2016). Malay language teachers' interpretation of the absorption of language philosophy elements for national integration: A needs analysis study. *Jurnal Pendidikan Bahasa Melayu*, *6*(1), 1-15.

Xu, X., Zhang, Z., Kuang, Y., Li, C., Sun, M., Zhang, L., & Chang, D. (2021). Waste pesticide bottles disposal in rural China: Policy constraints and smallholder farmers' behavior. *Journal of Cleaner Production*, *316*, 128385. https://doi.org/10.1016/j.jclepro.2021.128385

Yang, X., Wang, F., Meng, L., Zhang, W., Fan, L., Geissen, V., & Ritsema, C. J. (2014). Farmer and retailer knowledge and awareness of the risks from pesticide use: A case study in the Wei River catchment, China. *Science of the Total Environment*, *497*, 172-179. https://doi.org/10.1016/j.scitotenv.2014.07.118

Yin, S. A. (2016). *Bioaccumulation of heavy metals and metallothionein effects on reproductive biology of Asian swamp Eel (Monopterus Albus Zuiew, 1793) in Paddy Fields in Tumpat, Kelantan, Malaysia.* Doctoral Dissertation, PhD Thesis, Universiti Putra Malaysia.

Zhang, J., He, C., Chen, L., & Cao, S. (2018). Improving food security in China by taking advantage of marginal and degraded lands. *Journal of Cleaner Production*, *171*, 1020-1030. https://doi.org/10.1016/j.jclepro.2017.10.110

Zhang, L., Yan, C., Guo, Q., Zhang, J., & Ruiz-Menjivar, J. (2018). The impact of agricultural chemical inputs on environment: Global evidence from informetrics analysis and visualization. *International Journal of Low-Carbon Technologies*, *13*(4), 338-352. https://doi.org/10.1093/ijlct/cty039