



Research article

Farmers' knowledge and practice regarding good agricultural practices (GAP) on safe pesticide usage in Indonesia



Istriningsih^{a,*}, Yovita Anggita Dewi^b, Astrina Yulianti^b, Vyta W. Hanifah^b, Erizal Jamal^c, Dadang^g, Muhrizal Sarwani^d, Maesti Mardiharini^b, Iwan Setiajie Anugrah^e, Valeriana Darwis^e, Ewin Suib^c, Dwi Herteddy^c, Mas Teddy Sutriadi^f, Asep Kurnia^f, Elisabeth Srihayu Harsanti^f

^a Indonesian Institute for Agricultural Technology Transfer, Ministry of Agriculture, Indonesia

^b Indonesian Center for Agricultural Technology Assessment and Development, Ministry of Agriculture, Indonesia

^c Center for Plant Variety Protection and Agricultural Licensing, Ministry of Agriculture, Indonesia

^d Indonesian Center for Agricultural Land Resources Research and Development, Ministry of Agriculture, Indonesia

^e Indonesian Center for Agricultural Socio Economic and Policy Studies, Ministry of Agriculture, Indonesia

^f Indonesian Agricultural Environment Research Institute, Ministry of Agriculture, Indonesia

^g Department of Plant Protection, Faculty of Agriculture, IPB University, Indonesia

ARTICLE INFO

Keywords:
Agriculture
Pesticide
Good agricultural practices
Farmers' health
Indonesia

ABSTRACT

Synthetic pesticides are widely applied for pest and disease control in Indonesia. However, a lack of knowledge and use of Good Agricultural Practices (GAP) for safe pesticide usage among Indonesian farmers remains a problem. This study aims to investigate the gap between farmers' knowledge of GAP for safe pesticide usage and their application of it. This research was conducted in 2020 in five Indonesian provinces. Primary data collection was by means of a survey, in which 298 respondents answered structured questionnaires. The survey also identified the sources of the information recorded and the respondents' experience of pesticide exposure. The analysis tools used were the Wilcoxon Signed Ranked Test and Importance-Performance Analysis (IPA). There were significant differences in the results of the first analysis. These results appear to confirm the results of further analysis using IPA, which show that a high level of knowledge does not mean that farmers will apply this knowledge in practice: this is particularly relevant to wearing gloves and masks, using tools to remove blockages, never clearing blocked nozzles by blowing into them, and disposing of empty containers properly. Nevertheless, in some cases high levels of knowledge do result in high levels of application. Cases of pesticide exposure affecting human health by causing symptoms such as dizziness, nausea, and vomiting confirm that GAP for pesticide usage are not being implemented properly by some farmers. It is therefore recommended that their knowledge should be enhanced through the series of technical training programs using participatory approaches, so that farmers accumulate knowledge which will drive them to adopt GAP for safe pesticide usage.

1. Introduction

The agricultural sector plays an important role in the economic development and income of the majority of the Indonesian population; however, efforts to achieve optimal agricultural production are still challenged by various limiting factors, including water scarcity, climate change, and plant pests and diseases (Rozaki, 2020). Pesticide remains an essential production input for the control of pests and diseases (Skevas et al., 2013), although the ability of farmers to identify and recognize pests and diseases is also a major barrier to controlling them (Abang

et al., 2014). Synthetic pesticides are widely applied by farmers to control pests and diseases in Indonesia. The level of pesticide use in Indonesia has been increasing over the last few decades (Joko et al., 2020; Mariyono et al., 2018) and more than 4,000 pesticide brands are currently registered with the Ministry of Agriculture of Indonesia and permitted to be marketed in Indonesia (Darwis et al., 2020).

Pesticides are poisonous and dangerous materials (Bagheri et al., 2018; Polanco, 2012; Saeed et al., 2017). Studies conducted on the knowledge and usage of pesticides in several developing countries have shown that farmers' practices are often unsafe and can result in health

* Corresponding author.

E-mail address: istriningsih.iatt@gmail.com (Istriningsih).

problems (Atreya, Sitaula, et al., 2012; Bakhsh et al., 2017; Khan and Damalas, 2015; Kumela et al., 2018; Macharia et al., 2013) and environmental hazards (Abang et al., 2013; Karunamoorthi et al., 2012; Khan and Damalas, 2015; Macharia et al., 2013; Sharma et al., 2019). Improper use of pesticides is still prevalent in many areas, and this has a number of negative impacts. Systemic pesticides containing neonicotinoids and fipronil have a wide range of negative impacts on the ecosystem, such as poisoning freshwater, reducing biodiversity in freshwater, reducing numbers of natural predators, interfering with the pollination process, and threatening food production (Chagnon et al., 2015), as well as causing various health issues in humans and animals (Abang et al., 2013; Leong et al., 2020; Macharia et al., 2013; Rahaman et al., 2018). The effects of synthetic pesticide poisoning cases in humans worldwide are quite tremendous. Around 385 million cases of unintentional acute pesticide poisoning (UAPP) of farmers and agricultural workers are found every year, and in around 11,000 cases this poisoning is lethal (Boedeker et al., 2020). Several acute physiological health problems caused by pesticides are commonly discovered in humans, including reproductive inhibition, hormonal disorder, immune system disorder, and death (Hassaan and El Nemr, 2020). Health issues due to synthetic pesticide exposure are frequently found in farmers who apply synthetic pesticides, including Indonesian farmers (Irnayanti, 2019; Joko et al., 2020; Suhartono et al., 2018). Symptoms include skin irritation, sore eyes, dizziness, nausea, shortness of breath, thyroid function, and others.

Lack of knowledge about the harmful effects of pesticide exposure allegedly has an impact on low rates of adoption of preventive measures when using pesticides. Studies on the knowledge and application of safe pesticide usage have been performed by many researchers in recent years (Macharia et al., 2013; Mubushar et al., 2019; Yuantari et al., 2015). Interestingly, some scholars indicate that the relationship between knowledge and practice is not always linear. Many studies indicate that merely acquiring knowledge might not be enough to change farmers' behavior with regard to safe pesticide usage. The gap between knowledge and practice, particularly in pesticide usage, has been underlined by several scholars. Houbraken et al. (2016) state that the importance of using personal protection equipment (PPE) when handling pesticides is recognized by agricultural workers. Nevertheless, not all of them wear safety equipment. A similar finding is described by Lekei et al. (2014). Poor pesticide usage practices, such as lack of disposal management and the use of PPE, are common among farmers even when they have a good level of knowledge about the potential dangers of pesticides. Gesesew et al. (2016) found that although farmers are aware of the adverse effects of pesticides on human health, they continue to neglect the use of PPE when applying them.

The gap between Indonesian farmers' knowledge and practice of good agricultural practices (GAP) for safe pesticide usage has rarely been discussed in the scientific literature, and empirical evidence is lacking; the present study aims to address this. However, an analysis of the gap between knowledge and practice might not be sufficient to formulate recommendations for the improvement of GAP implementation at the farmers' level. This study therefore employs an Importance-Performance Analysis (IPA) approach to enrich the discussion. IPA is able to generate insights into critical aspects that require more attention, and identify potential resources that could be allocated effectively (Martilla and James, 1977). The IPA model can help to identify areas where resources should be allocated appropriately (McLeay et al., 2017).

This study aims to investigate the gap between farmers' knowledge and practice of GAP for safe pesticide usage in order to identify potential problems that should be considered and to formulate appropriate recommendations. The results of this study are expected to contribute to the development of regulations related to GAP for safe pesticide usage, which will help to increase awareness and application of GAP among farmers and reduce the potential environmental and health-related dangers of pesticide use.

2. Research hypothesis

Handling pesticides for farming purposes requires both adequate knowledge and appropriate practice in order to lessen the adverse effects of pesticides. Implementing GAP for pesticide use can help to reduce these harmful effects, and increasing farmers' knowledge of pesticides may increase the adoption of GAP among farmers. It has been found that North Carolina farmworkers are more likely to use personal protective equipment (PPE) when they know the names of the pesticides they are using, which demonstrates that knowledge significantly influences behavior (Levesque et al., 2012a). Safe behavior when managing leftover pesticides and disposing of pesticides is more prevalent among well-informed farmers (Mohanty et al., 2013). Fan et al. (2015) explain the causal effect of knowledge on farmers' behavior in terms of safe pesticide use in China. Their study found that the existing knowledge level of farmers significantly influenced their adoption of protective behaviors – such as wearing PPE, storing pesticides carefully, and reading the instructions prior to spraying. This implies that lack of knowledge potentially drives the improper use of pesticides. Likewise, farmers in Nepal have been found to handle pesticides more safely when they understand the color-coding that represents the relative dangers presented by different pesticides (Khanal and Singh, 2016).

Perception of pesticide harmfulness and experience of pesticides' adverse effects on health have both been shown to be significant factors in driving farmers in Northern Greece to wear PPE (Damalas and Abdollahzadeh, 2016). Perception and experience indicate the accumulation of knowledge; thus, this finding may show that good knowledge about pesticides increases the likelihood that farmers will adopt protective behaviors. Meanwhile, failure to follow recommendations about the safe use and handling of pesticides among vegetable farmers in Ethiopia has been shown to be driven by the lack of farmers' knowledge about pesticides (Mengistie et al., 2017). Along with the pursuit of high profits, a low level of knowledge has been found to cause insufficient implementation of protective behavior among Bangladeshi farmers (Akter et al., 2018). Vegetable farmers in Nepal have failed to practice adequate safety behavior and the proper use of pesticides because of their lack of knowledge and awareness of the potential negative impacts of this behavior (Bhandari et al., 2018). Inappropriate knowledge of the risks associated with pesticides leads farmers in Iran to handle and apply pesticides improperly. Many farmers have been found to unnecessarily apply leftover pesticides, and disposal of pesticides is also managed incorrectly (Sharafi et al., 2018). Mequanint et al. (2019) state that Ethiopian farmworkers' handling and storage of pesticides significantly improved when the farmworkers had more accurate information about pesticides. In addition, Sapbamrer and Thammachai (2020) summarize the significant influence of positive attitudes and awareness on the increasing use of PPE. Furthermore, Kafle et al. (2021) describe how Nepali farmers who know more about the safe purchasing, mixing, spraying, and storing of pesticides tend to be more likely to adopt safe behaviors when handling and using them.

Conversely (Levesque et al., 2012b), state that not all forms of knowledge sway Hispanic farmworkers to wear PPE while handling pesticides. For instance, knowledge of the importance of wearing a hat, showering after direct contact, and laundering work clothes separately, does not significantly influence PPE use. Awareness of the potentially harmful impacts of pesticide contamination does not necessarily trigger vegetable farmers in Nepal to use safety tools adequately. Only 25% of farmers, for example, wear protectors when in direct contact with pesticides (Atreya, Sitaula, et al., 2012). This finding is in line with a study by Riccò et al. (2018), in which it was found that there is not always a linear correlation between knowledge of protective actions and the practice of them by pesticide applicators in Italy: the average percentage of workers who wear PPE is lower than the average percentage of workers who know why PPE should be worn. Furthermore, Sharifzadeh

et al. (2019) mention that perceived barriers at the farmers' level influence their non-adoption of protective behaviors such as using PPE, avoiding health risks, and using pesticides appropriately. A study by Taghdisi et al. (2019) found that, although knowledge significantly affects the practice of safe pesticide usage, the 'know-do' gap is still found among Iranian farmers; the study found that this gap is caused by the cost and difficulty of taking protective measures.

On the basis of the research described above, the present study hypothesizes that there is no difference between the mean of knowledge and practice scores with regard to GAP for safe pesticide usage. The hypotheses for this study are as follows:

H_0 : Knowledge of GAP for safe pesticide usage = practice of GAP for safe pesticide usage

H_1 : Knowledge of GAP for safe pesticide usage \neq practice of GAP for safe pesticide usage

3. Research methods

3.1. Study area

This study was undertaken from August to December 2020, and covers five provinces in Indonesia: West Java, Central Java, Banten, Lampung, and North Sumatra. These sites were purposively selected to represent the production centers of six commodities: (1) the food crop sub-sector was represented by rice paddies in West Java, Central Java, and North Sumatra, as well as by maize in Lampung and Banten; (2) the horticulture sub-sector was represented by shallots, red chilies, and potatoes in West Java and Central Java; (3) the estate crop sub-sector was represented by palm oil in North Sumatra and Lampung.

3.2. Sampling and data collection at farm level

Indonesia has 34 provinces, 514 districts/regencies/municipalities, 7,230 sub-districts, and 81,616 villages spread across the nation. Due to this huge number of administrative units, this study used purposive sampling of provinces, districts, sub-districts, and villages. The sampling method took six commodities (rice, maize, shallots, red chili, potato, and palm oil) into consideration, along with accessibility. The selection of these six commodities aligns with national priorities, as these commodities are the mainstay of the Ministry of Agriculture's program and contribute to local economic development. There were 298 respondents, who represented farmers managing the commodities in the wet season of 2020, were randomly sampled. The respondent sample consisted of: 77 rice paddy farmers (25.8%), 54 maize farmers (18.1%), 56 shallot farmers (18.8%), 43 red chili farmers (14.4%), 45 potato farmers (15.1%), and 23 palm oil farmers (7.7%).

3.3. Methods of data analysis

Data were collected by using structured questionnaires to interview the respondents. The variables relating to knowledge and practice of GAP for safe pesticide usage were modified from the study of Mubushar et al. (2019). To measure farmers' knowledge, sixteen questions were asked. Respondents could choose one from the following potential answers: (1) not at all, or have no knowledge; (2) slightly, or poor knowledge; (3) somewhat, or less knowledge; (4) moderately, or good knowledge; and (5) extremely, or excellent knowledge. Five options were available as answers to questions relating to farmers' practices: (1) never doing; (2) rarely doing; (3) sometimes doing; (4) often doing; and (5) always doing. The sixteen questions each represented different attributes of GAP for safe pesticide usage (see Table 5). An average score for each aspect of GAP knowledge and GAP practice was then calculated.

These scores were then further analysed using a Wilcoxon Signed Ranked Test and Importance-Performance Analysis (IPA) in the statistical analysis software IBM SPSS Statistics 28.0. Descriptive statistics

(primarily frequency distributions and percentages) were used to examine the demographic characteristics of the respondents. Firstly, a Wilcoxon Signed Ranked Test was conducted to analyze the differences between farmers' knowledge of GAP for safe pesticide usage and their practice of it. In other words, the Wilcoxon Signed Ranked Test was used to understand whether knowledge of GAP for safe pesticide usage is in line with its application; that is, whether a high level of knowledge of GAP leads to a high level of application of GAP.

An average score calculated for each of the 16 attributes was displayed in a Cartesian diagram to enable comparison; this was the result of IPA. In the diagram, the X-axis represents the level of practice, and the Y-axis represents the level of knowledge. There are four quadrants (Q): high knowledge-low practice (Q-1), high knowledge-high practice (Q-2), low knowledge-low practice (Q-3), and low knowledge-high practice (Q-4). Plotting each aspect in the diagram was intended to identify and explore which attributes still require more attention, owing either to low application in the field or to low knowledge at the farmers' level. This was used as the basis for providing policy recommendations to improve the implementation of GAP for safe pesticide usage.

The IPA model has been profoundly useful in research on the tourism sector (see Barbieri, 2010; Boley et al., 2017; Coghlan, 2012; Lai and Hitchcock, 2015; Sheng et al., 2014; Taplin, 2012). However, the application of this model in the agricultural sector, especially with regard to pesticide usage, has been limited (e.g. Gambelli et al., 2021; Habaora et al., 2020; Han et al., 2016; Lee et al., 2018). Hence, highlighting the usefulness of IPA in this field will help to address the application gap in the agricultural sector. To postulate the threshold in the IPA diagram, some studies use mean values of actual importance and performance, whilst other researchers choose to use median values if the assumptions of a true interval scale cannot be justified (Sever, 2015). In this study, the threshold specification was drawn using mean or average values.

As part of the IPA, a general view of all attributes was taken by measuring the compatibility rate using a weight factor for the scores of each attribute. The weight factor represents the value of the average score of each attribute in GAP knowledge against the total average score of all attributes, multiplied by the average score in GAP practice of each aspect accordingly. The compatibility rate could then be identified by calculating the total weight factor of all attributes divided by the maximum scale used (this study used five scales), and multiplying by 100%. The values ranged from 0 to 100. The formula is given below (adapted from Kasnadi and Indrayani (2019)):

Mean of Knowledge Score of the i^{th} attribute (MKS $_i$):

$$MKS_i = \frac{\sum K_i}{n} \quad (1)$$

Mean of Practice Score of the i^{th} attribute (MPS $_i$)

$$MPS_i = \frac{\sum P_i}{n} \quad (2)$$

Where:

K_i : Score of knowledge of the i^{th} attribute

P_i : Score of practice of the i^{th} attribute

n : Number of respondents

Weight Factor of the i^{th} attribute (WF $_i$)

Table 1. Output of the normality Kolmogorov-Smirnov test.

Variables	Sig.*	Decision
Knowledge of GAP	0.22	Accept null hypothesis
Application of GAP	<0.001	Reject null hypothesis

* The significance level is .050.

Table 2. Related-samples Wilcoxon signed rank test summary.

Total N	298
Test Statistic	4160.500
Standard Error	1042.598
Standardized Test Statistic	-9.308
Asymptotic Sig. (2-sided test)	.000

$$WF_i = \frac{MKS_i}{\sum MKS_i} \times MPS_i \quad (3)$$

Compatibility Rate (CR)

$$CR = \frac{\sum WF_i}{HS} \times 100\% \quad (4)$$

Where:

HS: the highest scale, the maximum scale used (HS = 5)

4. Results

4.1. Demographic characteristics of the respondents

The age of the respondents ranged from 20 to 81 years old, with an average of 47.1. This indicated that respondents were in the working age group (OECD, 2021), with an average of 18.7 years of farming experience. Most respondents were male (95.6%), whilst 4.4% were female. The vast majority were literate, with an average period of formal education of 8.9 years. The percentages of respondents who had received primary, junior high, senior high, and higher education were 38.3%, 23.2%, 30.5%, and 6% respectively, and only 2% had never attended school. Farmer education can play a significant role in promoting safe pesticide use and in reducing pesticide overuse (Khan et al., 2015). In addition, according to Ríos-González et al. (2013), literate farmers have a relatively high level of knowledge of the consequences of pesticide use on human health and the environment.

There was high variation in the area of farmland managed by each respondent, from 0.02 to 20 hectares with an average of 1.1 hectares. Almost half (46.6%) of respondents managed farms of less than 0.5 hectare in size, 29.5% managed between 0.51 and 1 hectare, whilst the remainder (23.8%) cultivated more than a hectare of farmland. Most of the respondents were landowners (76.5%), while 23.5% were tenants. Nearly half of the respondents (45.3%) had never participated in pesticide training, whereas the other 54.7% had.

4.2. Knowledge and practice of GAP for safe pesticide usage

Data must meet normality requirements as a prerequisite for the Wilcoxon Signed Ranked Test. The Kolmogorov-Smirnov test was used to determine the normality of the data distribution in this study. The results of the normality test showed that only data for knowledge of GAP were normally distributed, while the data for application of GAP presented the opposite result (Table 1). Consequently, it was necessary to choose a correlation test which did not assume that the data were normally distributed, namely by using the non-parametric Wilcoxon test.

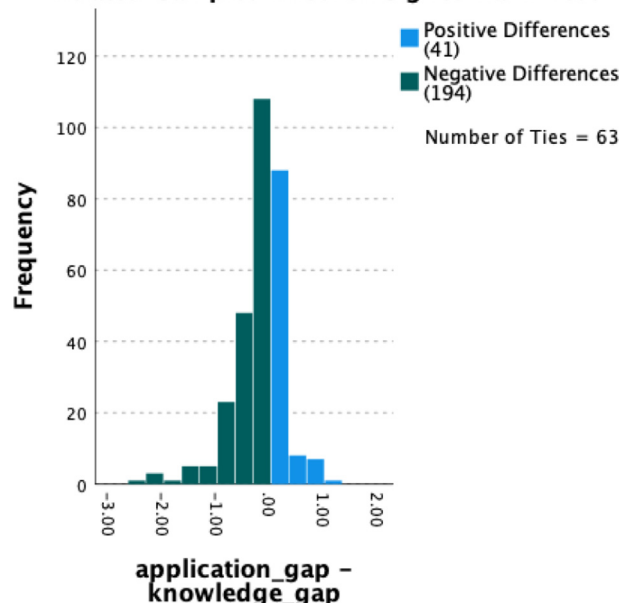
Table 3. Hypothesis test summary.

Null Hypothesis	Test	Sig. ^{a,b}	Decision
The median of differences between knowledge gap and application gap equals to 0	Related-Samples Wilcoxon Signed Rank Test	.000	Reject the null hypothesis

^a The significance level is .050.

^b Asymptotic significance is displayed.

Related-Samples Wilcoxon Signed Rank Test

**Figure 1.** Related-samples Wilcoxon signed rank test.

The Wilcoxon test results had a significance value of less than the alpha (α) value (0.05), which can be seen from the two-tail P value ($T < t$) (Table 2). This result supports the rejection of H_0 (Table 3), meaning that there is a difference between knowledge and application of GAP for safe pesticide usage. For instance, if farmers' knowledge of the importance of using personal protective equipment during spraying pesticides is high, there remains a possibility that farmers will not use personal protection in their application, even though they know that it is important to do so.

The results indicate that farmers with high knowledge do not necessarily apply it. It can be seen from Figure 1 that the negative differences (194) were higher than the positive differences (41), which illustrates that knowledge of GAP for safe pesticide usage does not necessarily correlate with application of GAP in the field. This analysis therefore contributed to the rejection of H_0 . Furthermore, this research also used IPA analysis to explore which attributes of GAP for safe pesticide usage can be used as leveraging points to improve practice.

The average score of farmers' knowledge was higher than that of farmers' practice in all provinces (Table 4). This indicates that, in general, farmers already have already obtained sufficient knowledge of GAP for safe pesticide usage from various sources, but implementation of this knowledge remains sub-optimal.

GAP for safe pesticide usage is explained by 16 attributes, as shown in Table 5. The three biggest gaps between knowledge and practice emerged in the attributes of wearing gloves and masks (0.62), applying pesticides only when pests and disease have occurred (0.41), and reading the instructions on the label (0.39). On average, the knowledge score was higher than the practice score (4.08 vs. 3.85). The compatibility rate was

Table 4. Characteristics of farmers' knowledge and practice regarding GAP for safe pesticide usage, by province.

No	Province	Average score of GAP knowledge	Average score of GAP Practice
1	Banten (n = 26)	4.11	3.96
2	Central Java (n = 112)	4.06	3.86
3	West Java (n = 76)	4.00	3.59
4	Lampung (n = 41)	4.21	4.11
5	North Sumatra (n = 43)	4.17	3.93

Table 5. Respondents' knowledge and practices regarding GAP for safe pesticide usage (n = 298).

No	Attributes	Average score of GAP knowledge	Average score of GAP Practice	Weight Factors	Practice-Knowledge Gaps
1	Purchasing sufficient pesticides for one season	4.21	4.19	0.27	(0.02)
2	Never reusing empty pesticide containers for other purposes in the house	4.42	4.33	0.29	(0.09)
3	Keeping pesticides in a separate room at home	4.45	4.49	0.31	0.04
4	Reading the instructions written on the label before use	4.12	3.73	0.24	(0.39)
5	Never mixing with bare hands	4.09	3.79	0.24	(0.30)
6	Wearing a long-sleeved shirt and long pants during application	4.34	4.16	0.28	(0.18)
7	Wearing gloves and mask during application	4.06	3.44	0.21	(0.62)
8	Using a tool to remove blockages	3.83	3.47	0.2	(0.36)
9	Never blowing with mouth to clear blocked nozzles out	3.96	3.61	0.22	(0.35)
10	Never smoking while mixing or applying pesticides	4.42	4.22	0.29	(0.20)
11	Taking a bath after completing the application	4.49	4.39	0.3	(0.10)
12	Washing hands with soap before eating and drinking	4.51	4.39	0.3	(0.12)
13	Disposing of empty containers according to directions on the label	3.95	3.69	0.22	(0.26)
14	Applying pesticides only after the occurrence of pest and disease attack	3.68	3.27	0.18	(0.41)
15	Recognizing the symptoms of pesticide poisoning in humans	3.55	3.26	0.18	(0.29)
16	Recognizing first aid treatments for pesticide poisoning	3.26	3.09	0.15	(0.17)
	Average	4.08	3.85	3.88	(0.23)
	Compatibility rate	77.60			

Note: The weight factor was calculated using Eq. (3).

77.60%, meaning that there was a gap of around 22% which must be closed in order to reach maximum compatibility between knowledge and practice (see equation 4).

On the basis of the IPA results, the average score of each attribute in Table 5 was then illustrated in a Cartesian diagram (Figure 2). There were three groups (represented by different colors) scattered mostly in Q-2 and Q-3, and only one attribute (red color) in Q-1; however, this attribute was close to Q-3 (attribute number 4: reading the instructions before using the product). The green color represents attributes that were as expected in this study, meaning that farmers had good knowledge and also applied it to their farming activity. These attributes were: 1 (purchasing sufficient pesticides for one season), 2 (never reusing empty pesticide containers for other purposes in the house), 3 (keeping pesticides in a separate room at home), 6 (wearing a long-sleeved shirt and long pants during application), 10 (never smoking while mixing or applying pesticides), 11 (taking a bath after completing the application), and 12 (washing hands with soap before eating and drinking).

Attributes marked in yellow required more encouragement or stimulation to improve the willingness of farmers to apply best practice. These attributes were: 7 (wearing gloves and a mask during application), 8 (using a tool to remove blockages), 9 (never blowing with the mouth to clear blocked nozzles), 13 (disposing of empty containers according to the directions on the label), 14 (applying pesticides only after the occurrence of pest and disease attack), 15 (recognizing the symptoms of pesticide poisoning in humans), and 16 (awareness of first aid treatments for pesticide poisoning).

Attributes marked in red were closer to Q-3, implying that they should receive the same attention as those in yellow color. These attributes were 4 (reading the instructions written on the label before use), and 5 (never mixing with bare hands).

4.3. Farmers' sources of information regarding pesticides

More than half of the respondents (54.7%) had attended training related to pesticides organized by the government or by private companies (see Table 6). These training programs aim to educate farmers in the proper use of pesticides, as pesticides are toxic materials that can potentially cause health and environmental issues if they are not used properly and wisely. Although training is a source of information about pesticides for farmers, they could also access information on pesticides

from many other sources. Fellow farmers were the source of information most often referred to (by 80% of respondents), followed by retailers (59%), agricultural extension officers (54%), field assistants from pesticide companies (51%), and farmer group leaders (50%) (see Figure 3). Previous studies have also found that most farmers consider fellow farmers as their main source of information on pesticide usage (Abang et al., 2013; Diemer et al., 2020; Mengistie et al., 2017).

Apart from the source of information, this study also identified the reasons why the respondents used pesticides on their farms. Figure 4 shows that most farmers believed that pesticides could prevent the occurrence of pest and disease attacks, while others assumed that using pesticides was a means of controlling these attacks. Similar findings were observed in studies by Rachmawaty (2016) and Zakiyatunnufus (2015). Farmers' anxiety about pest and disease attacks reducing their yields has driven them to take preventive action by spraying pesticides on a regular basis (Indiati and Marwoto, 2017). The results demonstrate that more farmers use pesticides as preventive rather than control measures, and that most farmers have participated in a pesticide training program (see Table 6), which indicates that farmers do not always apply the knowledge they have gained from these training programs. Pesticide training programs are generally aimed at control rather than preventive measures.

4.4. Health issues due to pesticide exposure

The use of pesticides often results in various health problems for farmers, and this has been well documented in previous studies (Atreya, Johnsen, et al., 2012; Bagheri et al., 2018; Bakhsh et al., 2017; Damalas and Koutroubas, 2017; Jambari et al., 2020; Joko et al., 2020; Kim et al., 2017; Macharia et al., 2013; Mengistie et al., 2017; Schreinemachers et al., 2017; Shammi et al., 2020; Sharafi et al., 2018). The results of the present study show that one in three (35%) of the sampled farmers had experienced health issues after pesticide application, and 65% of the sampled farmers had not. Unsafe behaviors during pesticide application – such as the poor use of personal protective equipment (PPE) – contribute to pesticide exposure, which is related to various health problems (Jallow et al., 2017). The impacts of pesticide exposure on human health can be categorized as: mild acute poisoning (dizziness, headache, mild skin irritation, body aches, diarrhea); severe acute poisoning (nausea, chills, stomach cramps, shortness of breath, salivation, shrinking of pupils,

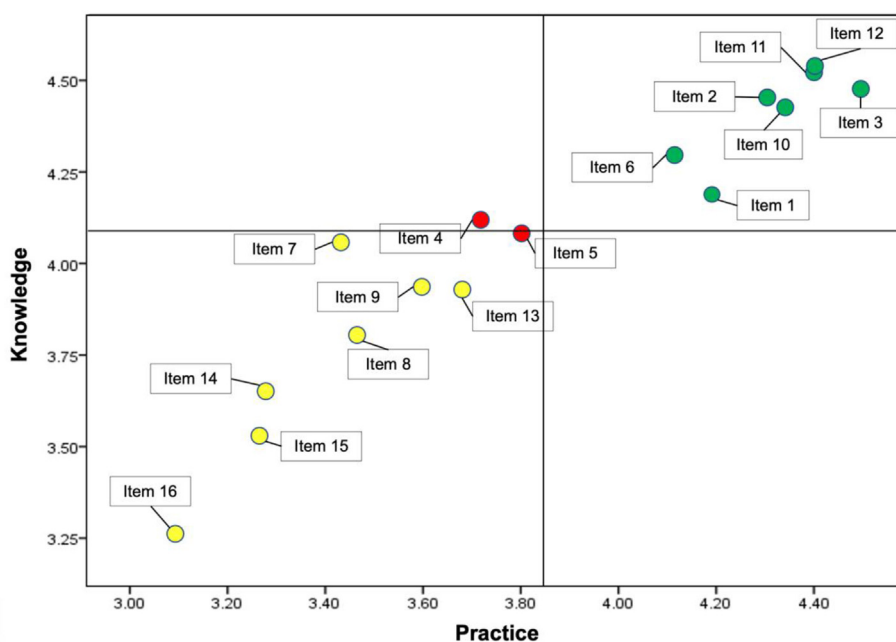


Figure 2. Cartesian diagram of knowledge and practice of GAP for pesticide usage.

increased pulse); and chronic poisoning (loss of consciousness, convulsions, death) (Yuantari et al., 2015). Figure 5 illustrates the health issues due to pesticide exposure found in the study sites. The most frequently reported symptom was dizziness (80%), which falls under the mild acute poisoning category. Similar findings have also been reported in other studies (Akter et al., 2018; Amilia et al., 2016; Kachaiyaphum et al., 2010). The second most common symptom reported by farmers after pesticide spraying was nausea (36%), which falls under the severe acute poisoning category. The other health issues reported also fell under these two categories, with the exception of loss of consciousness, which is included in chronic poisoning. This symptom, however, was reported by only a very small percentage of farmers (1%). The persistence of health issues experienced by farmers indicates the great importance of training on GAP for safe pesticide usage. Abdollahzadeh and Sharifzadeh (2021) suggest that an education program which increases farmers' awareness of the severity of pesticide impacts, as well as information on the benefits of PPE and its effectiveness in reducing health risks associated with pesticides, could encourage farmers to use PPE.

5. Discussion

Improper usage, handling, storage, and disposal of pesticides may result in unintended adverse impacts on the environment and on human health. This research has shown that pesticide usage causes health issues, as has been reported in previous studies (Amilia et al., 2016; Atreya, Johnsen, et al., 2012; Bagheri et al., 2018; Bakhsh et al., 2017; Damalas and Koutroubas, 2017; Jambari et al., 2020; Joko et al., 2020; Kim et al., 2017; Macharia et al., 2013; Mengistie et al., 2017; Schreinemachers et al., 2017; Sharafi et al., 2018). Analysis of farmers' knowledge and practice of GAP using a Wilcoxon Signed Ranked Test produced a significantly different result. This result appeared to confirm further analysis using IPA which showed that a high level of knowledge among farmers does not mean that they intend to apply this knowledge in practice. This finding is in line with those of other studies (e.g. Gesesew et al., 2016; Houbraken et al., 2016; Lekei et al., 2014). These cases can be clearly seen in the Cartesian diagram with reference to attributes 7 (wearing gloves and mask during application), 8 (using a tool to remove blockages), 9 (never blowing with the mouth to clear blocked nozzles), and 13 (disposing-off empty containers according to directions on the

label). These four aspects of GAP for safe pesticide usage are of major concern, because farmers have sufficient knowledge but still do not put this knowledge into practice.

During an interview in the survey, respondents clarified that they understood the importance of wearing gloves and mask when spraying pesticides on their farm, but still did not do so. The reason they gave was that, according to their experience, this practice was complicated; instead, some of them just used a scarf to cover their faces. This finding is consistent with prior studies which have found that farmers know and understand the importance of using masks and gloves during pesticide handling, nevertheless only a few farmers put this into practice (Jensen et al., 2011; Kumari and Reddy, 2013; Mengistie et al., 2017; Yuantari et al., 2015). On the other hand, a study by Mohanty et al. (2013) has found that farmers in South India with good knowledge used gloves (66.7%) and masks (78.6%) more often than farmers with poor knowledge (31% and 37.9%, respectively).

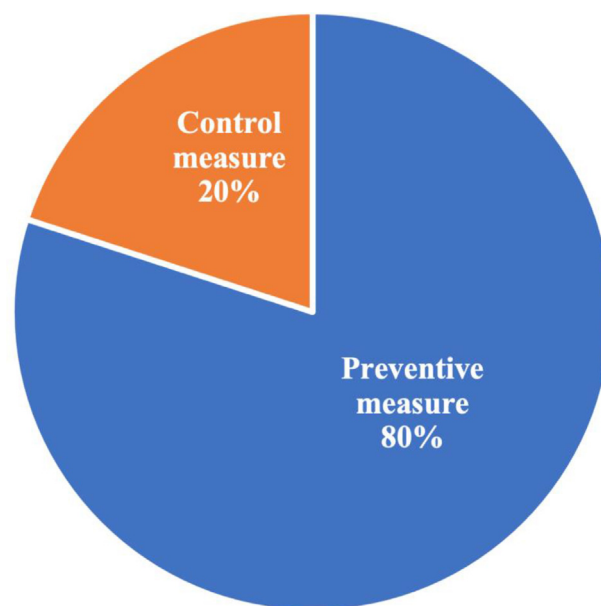
Another case covered using a tool to remove blockages and never blowing with the mouth to clear blocked nozzles out. Many farmers understood that it was dangerous to be in direct contact with chemical pesticides, and therefore used tools (of any kind) to clear blockages. However, when they faced such a problem and did not have any tools to hand, they then used part of their body, such their mouth, to clear the blockage. According to Matthews (2008), farmers in Asian countries commonly use sticks to clear blockages, while a few farmers in Morocco used their fingers. In addition, a study by Mubushar et al. (2019) in Pakistan found that 29.2% of farmers used wires to remove nozzle blockages. This study also revealed that 21.5% of farmers always blew into nozzles with their mouths to remove blockages, and another 49.7% sometimes did so. The remainder (28.7%) claimed that they never used their mouths to clear nozzle blockages. This unsafe practice could put farmers at higher risk due to the potential for pesticide exposure through oral routes.

The last case covered disposing of empty containers according to the directions on the label. Most respondents mentioned that they read the instructions on how to dispose of the containers. This showed they are knowledgeable about this issue, nevertheless failed to follow the instructions given. They believed that as long as they kept the empty pesticide containers away from other family members, the containers were being stored safely. Some of them threw empty pesticide containers

Table 6. Demographic characteristics of the respondents (n = 298).

Variable	Frequency (n)	Percentage (%)	Min	Max	Mean
Age (years old)			20	81	47.1
1. < 30	19	6.4			
2. 30–50	173	58.0			
3. > 50	106	35.6			
Farming experience (years)			1	56	18.7
1. < 10	68	22.8			
2. 10–30	190	63.8			
3. > 30	40	13.4			
Education (years of period of formal education)			0	17	8.9
1. 0	6	2.0			
2. < 6	114	38.3			
3. 7–9	69	23.2			
4. 10–12	91	30.5			
5. > 12	18	6.0			
Size of farm land (hectare)			0.02	20	1.1
1. < 0.5	139	46.6			
2. 0.51–1	88	29.5			
3. 1.01–2	39	13.1			
4. 2.01–4	20	6.7			
5. > 4	12	4.0			
Family size (persons)			1	11	3.9
1. 1–2	120	40.3			
2. 3–4	69	23.2			
3. 5–6	91	30.5			
4. > 6	18	6.0			
Gender					
1. Male	258	95.6			
2. Female	13	4.4			
Farmer status					
1. Landowner	228	76.5			
2. Tenant	70	23.5			
Participation in pesticide training					
1. Yes	163	54.7			
2. No	135	45.3			

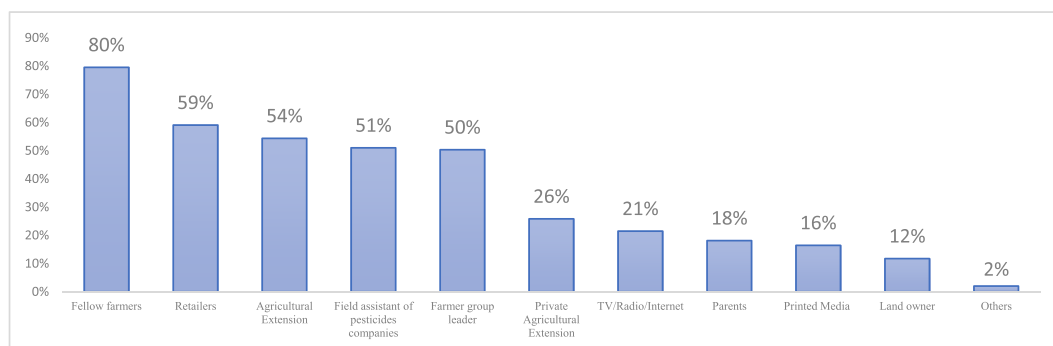
into the field, then burned them along with other by-products of the farm. Previous studies have recorded the use of several improper disposal methods for empty pesticide containers, such as throwing them away on the farm's field, throwing them away into irrigation canals or rivers, burying them on the farm, burning them on the farm, reusing them for various household purposes, collecting and selling them, and reusing them for the storage of other pesticides (Bagheri et al., 2018; Gaber and Abdel-Latif, 2012; Jallow et al., 2017; Karunamoorthi et al., 2012;

**Figure 4.** The purpose of pesticide use (n = 298).

Macharia et al., 2013; Mengistie et al., 2017; Mohanty et al., 2013; Mubushar et al., 2019). These unsafe disposal practices can be an important source of pesticide exposure (Jallow et al., 2017) and may have harmful effects on humans, animals, and the environment.

Therefore, the gap between knowledge and practice does not graph *per se* on to either knowledge level or application level. Among other measures, there should be attempts to raise the awareness of farmers about the consequences of improper and unwise usage of pesticides. It is inevitable that awareness also relates to the health risks of pesticide exposure. Some issues with symptoms have been identified in the survey. It seems that a lack of experience of the issues increases ignorance of the risk of using pesticides improperly and unwisely. This finding is similar to the results of the study by Sharafi et al. (2018).

Most farmers mentioned that the application of pesticides was intended to prevent the occurrence of pest and disease attacks. This shows that they are aware of the risks of doing nothing to prevent these attacks. However, the salient issue is their knowledge of how to use pesticides properly and wisely; and in particular, awareness of the procedure of spraying pesticides only when there is an attack, and considering both the Integrated Pest Management (IPM) concept and the impact of pesticides on humans and the environment. As these farmers have been practicing their farming activity for their whole lives, their knowledge is greatly influenced by their peers. The analysis above has listed sources of information from experienced farmers, and fellow farmers were a dominant information source which farmers trusted. This could provide an opportunity to assign fellow farmers to persuade others

**Figure 3.** Source of information regarding pesticides (n = 298).

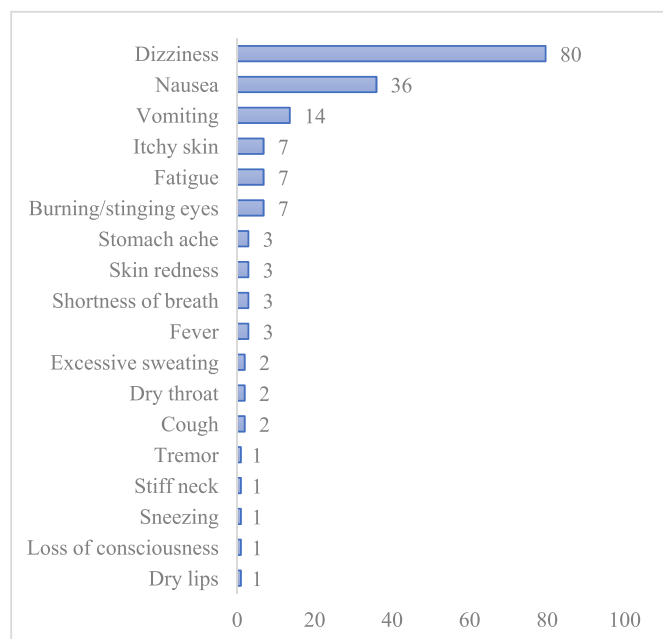


Figure 5. Health issues after pesticide application (n = 103).

to apply GAP for pesticide usage. According to Bagheri et al. (2019), farmers' reference groups are able to play a role in disseminating comprehensive information regarding the safe use of pesticides to other farmers.

The results of this study show that farmers have a good level of knowledge (Table 5) that comes from various sources of information related to the use of pesticides which are associated with various stakeholders: agricultural extension officers, the private sector, farmer groups, and kiosks or pesticide practitioners (see Figure 3). However, this knowledge *per se* is not sufficient to motivate farmers to change their behavior when practicing GAP for safe pesticide usage. Therefore, appropriately designed training programs focusing on GAP for safe pesticide usage are still needed. This aligns with the result given in Table 6 which shows that just over half of the respondents attended training on pesticide use, meaning that the other farmers did not have a chance to attend this training. This research therefore has further implications for training providers (government, pesticide companies, and non-governmental organizations) and inclusive access to the training.

In practice, the training could be provided through a combination of various methods with hands-on experience, such as lectures, group discussions, farmer field schools, field visits, and other extension techniques using information and communication technologies (e.g. videos, smartphones, tablets, social media, and podcasts). In addition, participatory methods are believed to increase the effectiveness of technical training (Kansanga et al., 2021; Wiedemann et al., 2022), and thus participatory approaches should also be considered by the service providers and applied during the technical training to achieve the goal of capacity building for actors involved in the chain of pesticide usage.

6. Conclusion and recommendations

Pesticides can have negative impacts on human health when applied improperly and unwisely. The use of pesticides according to GAP aims to minimize the undesirable effects of pesticides. It can be concluded from the results of this study that levels of knowledge about pesticides do not correspond with the implementation of GAP for pesticide use; for example,; (i) reading the instructions written on the label before use, (ii)

never mixing with bare hands, (iii) wearing gloves and a mask during application, (iv) using a tool to remove blockages, (v) never blowing with mouth to clear blocked nozzles, and (vi) disposing of empty containers according to the directions on the label. These attributes require further intervention, but two attributes in particular (4 and 5) are of paramount concern due to the high level of knowledge about them among farmers which is combined with a lack of practice of them. Nonetheless, in some other cases it can be found that high levels of knowledge do correlate with high levels of practice: (i) keeping pesticides in a separate room at home, (ii) taking a bath after completing the application, and (iii) washing hands with soap before eating and drinking.

Training is recommended as a form of intervention which can narrow the 'know-do' gap and increase the practice of safe behaviors. Increasing the frequency and intensity of training is crucial to reducing human health problems related to pesticide exposure. Findings from this study show that cases of human health problems resulting from poor pesticide practices are still emerging; this confirms that GAP for pesticide use is still not being well implemented.

Therefore, it is recommended that a series of training programs, with easy-to-understand formats and meeting farmers' needs, be carried out to enhance farmers' knowledge of GAP for safe pesticide usage. The training should be provided as a series, rather than a one-off event, so that knowledge accumulates at the farmer's level. Series of training events with participatory approaches are necessary to enhance and enrich farmers' knowledge and skills, to change their attitudes, and to encourage them to put their knowledge into practice. After several training events, farmers would accumulate knowledge that could increase their awareness of the importance of GAP principles.

As the main source of information, the program could be designed not only for extension officers but also for innovative farmers, in order to reach a wider audience of targeted farmers. An effort could be made to improve personal capacity building, in particular for selected farmers or peers (as well as pesticide practitioners and extension officers) through technical training or training of trainers (TOT). Generally, technical training or TOT could contribute to the process of delivering a set of knowledge and skills relating to the active ingredients of pesticides, the importance of reading labels, the positive and negative impacts of using pesticides, the proper and wise application of pesticides in terms of dosage and time of application, types of pest and disease attacks, procedures, and the quality of pesticides. The resulting accumulation of knowledge could then drive farmers to adopt GAP for using pesticides safely and wisely. Concerned authorities could provide innovative farmers with incentive schemes to encourage them to serve as role models for other farmers by convincing them to follow the practices of innovative farmers in using pesticides safely and according to GAP.

7. Strengths and limitations of the study

The main strength of this study, which differentiates it from similar research in the literature, is that it involves respondents who represent farmers of the six main agricultural commodities across Indonesia. Furthermore, this study also explains 16 attributes of GAP for safe pesticide usage that are not widely practiced, so that further intervention to enhance the implementation of GAP can be planned effectively.

However, due to the sample size and the purposive sampling strategy used, the results of this study cannot be generalized to describe the pesticide-related behavior of all Indonesian farmers. Other farmers not sampled in this study may have different behaviors, depending on their intention to apply GAP. In addition, memory-related side-holding is a constraint in this study, because respondents needed to use their memories to recall the practices they employ when using pesticides in the last planting season.

Declarations

Author contribution statement

Istriningsih; Astrina Yulianti; Yovita Anggita Dewi; Vyta W. Hanifah: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Erizal Jamal; Muhrizal Sarwani; Mas Teddy Sutriadi; Ewin Suib; Dwi Herteddy: Conceived and designed the experiments; Wrote the paper.

Dadang; Maesti Mardiharini; Iwan Setiajie Anugrah; Valeriana Darwis: Conceived and designed the experiments; Performed the experiments; Wrote the paper.

Asep Kurnia; Elisabeth Srihayu Harsanti: Performed the experiments; Wrote the paper.

Funding statement

This work was supported by the Center for Plant Variety Protection and Agricultural Licensing, Ministry of Agriculture, Indonesia.

Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

Supplementary content related to this article has been published online at <https://doi.org/10.1016/j.heliyon.2021.e08708>.

Acknowledgements

The authors wish to thank the Center for Plant Variety Protection and Agricultural Licensing, Ministry of Agriculture, Indonesia, for the financial support in conducting this research. Much appreciation also goes to the agricultural extension workers and farmers who have been involved in this research as respondents for this study.

References

- Abang, A.F., Kouamé, C.M., Abang, M., Hanna, R., Fotso, A.K., 2014. Assessing vegetable farmer knowledge of diseases and insect pests of vegetable and management practices under tropical conditions. *Int. J. Veg. Sci.* 20 (3), 240–253.
- Abang, A.F., Kouame, C.M., Abang, M., Hannah, R., Fotso, A.K., 2013. Vegetable growers perception of pesticide use practices, cost, and health effects in the tropical region of Cameroon. *Int. J. Agron. Plant Prod.* 4 (5), 873–883.
- Abdollahzadeh, G., Sharifzadeh, M.S., 2021. Predicting farmers' intention to use PPE for prevent pesticide adverse effects: an examination of the Health Belief Model (HBM). *J. Saudi Soc. Agri. Sci.* 20 (1), 40–47.
- Akter, M., Fan, L., Rahman, M.M., Geissen, V., Ritsema, C.J., 2018. Vegetable farmers' behaviour and knowledge related to pesticide use and related health problems: a case study from Bangladesh. *J. Clean. Prod.* 200, 122–133.
- Amilia, E., Joy, B., Sunardi, S., 2016. Residu Pestisida pada Tanaman Hortikultura (Studi Kasus di Desa Cihanjuang Rahayu Kecamatan Parongpong Kabupaten Bandung Barat). "Pesticide residues on horticultural crops in Cihanjuang Rahayu village, Parongpong district, Bandung Barat regency. *Jurnal Agrikultura* 27 (1), 23–29.
- Atreya, K., Johnsen, F.H., Sitaula, B.K., 2012a. Health and environmental costs of pesticide use in vegetable farming in Nepal. *Environ. Dev. Sustain.* 14 (4), 477–493.
- Atreya, K., Sitaula, B.K., Overgaard, H., Bajracharya, R.M., Sharma, S., 2012b. Knowledge, attitude and practices of pesticide use and acetylcholinesterase depression among farm workers in Nepal. *Int. J. Environ. Health Res.* 22 (5), 401–415.
- Bagheri, A., Bondori, A., Allahyari, M.S., Damalas, C.A., 2019. Modeling farmers' intention to use pesticides: an expanded version of the theory of planned behavior. *J. Environ. Manag.* 248, 1–9.
- Bagheri, A., Emami, N., Allahyari, M.S., Damalas, C.A., 2018. Pesticide handling practices, health risks, and determinants of safety behavior among Iranian apple farmers. *Human Ecol. Risk Assess.* 24 (8), 2209–2223.

- Bakhsh, K., Ahmad, N., Tabasum, S., Hassan, S., Hassan, I., 2017. Health hazards and adoption of personal protective equipment during cotton harvesting in Pakistan. *Sci. Total Environ.* 598, 1058–1064.
- Barbieri, C., 2010. An importance-performance analysis of the motivations behind agritourism and other farm enterprise developments in Canada. *J. Rural Commun. Dev.* 1–16. February. <http://www.jrcd.ca/include/getdoc.php?id=831&article=396&mod>.
- Bhandari, G., Atreya, K., Yang, X., Fan, L., Geissen, V., 2018. Factors affecting pesticide safety behaviour: the perceptions of Nepalese farmers and retailers. *Sci. Total Environ.* 631–632, 1560–1571.
- Boedeker, W., Watts, M., Clausing, P., Marquez, E., 2020. The global distribution of acute unintentional pesticide poisoning: estimations based on a systematic review. *BMC Publ. Health* 20 (1875).
- Boley, B.B., McGehee, N.G., Tom Hammett, A.L., 2017. Importance-performance analysis (IPA) of sustainable tourism initiatives: the resident perspective. *Tourism Manag.* 58, 66–77.
- Chagnon, M., Kreutzweiser, D., Mitchell, E.A.D., Morrissey, C.A., Noome, D.A., Van Der Sluijs, J.P., 2015. Risks of large-scale use of systemic insecticides to ecosystem functioning and services. *Environ. Sci. Pollut. Control Ser.* 22, 119–134.
- Coghlan, A., 2012. Facilitating reef tourism management through an innovative importance-performance analysis method. *Tourism Manag.* 33 (4), 767–775.
- Damalas, C.A., Abdollahzadeh, G., 2016. Farmers' use of personal protective equipment during handling of plant protection products: determinants of implementation. *Sci. Total Environ.* 571, 730–736.
- Damalas, C.A., Koutroubas, S.D., 2017. Farmers' training on pesticide use is associated with elevated safety behavior. *Toxics* 5 (3).
- Darwis, V., Mardiharini, M., Anugrah, I.S., Istriningsih, Dadang, 2020. Industri Pestisida di Indonesia. "Pesticides Industry in Indonesia. In: Jamal, E., Dadang, Sarwani, M. (Eds.), *Pestisida di Indonesia: Industri, Rantai Pasok, dan Penggunaan*. "Pesticides in Indonesia: Industry, Supply Chain and Use. IPB Press.
- Diemer, N., Staudacher, P., Atuhaire, A., Fuhrmann, S., Inauen, J., 2020. Smallholder farmers' information behavior differs for organic versus conventional pest management strategies: a qualitative study in Uganda. *J. Clean. Prod.* 257, 120465.
- Fan, L., Niu, H., Yang, X., Qin, W., Bento, C.P.M., Ritsema, C.J., Geissen, V., 2015. Factors affecting farmers' behaviour in pesticide use: insights from a field study in Northern China. *Sci. Total Environ.* 537, 360–368.
- Gaber, S., Abdel-Latif, S., 2012. Effect of education and health locus of control on safe use of pesticides: a cross sectional random study. *J. Occup. Med. Toxicol.* 7 (1), 1–7.
- Gambelli, D., Solfanelli, F., Orsini, S., Zanoli, R., 2021. Measuring the economic performance of small ruminant farms using balanced scorecard and importance-performance analysis: a european case study. *Sustainability* 13 (6).
- 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).
- Habaora, F., Maria Fuah, A., Abdullah, L., Priyanto, R., Yani, A., Priyo Purwanto, B., 2020. Importance-performance analysis toward productivity of Bali cattle based on agroecosystem in timor island. *J. Anim. Vet. Adv.* 19 (5), 57–66.
- Han, S.-D., Yun, S.-H., Jang, D.-H., 2016. An importance-performance analysis of using farmers in a rice co-nursery : focus on the East Gunsan Agricultural Cooperative. *Kor. J. Anim. Sci.* 43 (1), 144–151.
- Hassaan, M.A., El Nembr, A., 2020. Pesticides pollution: classifications, human health impact, extraction and treatment techniques. *Egypt. J. Aquat. Res.* 46 (3), 207–220.
- Houbraken, M., Bauweraerts, I., Fevery, D., Van Labeke, M.C., Spanoghe, P., 2016. Pesticide knowledge and practice among horticultural workers in the Lâm Đông region, Vietnam: a case study of chrysanthemum and strawberries. *Sci. Total Environ.* 550, 1001–1009.
- Indiati, S.W., Marwoto, 2017. Penerapan Pengendalian Hama Terpadu (PHT) pada Tanaman Kedelai. "Application of integrated pest control (IPM) on soybean plants. *Buletin Palawija* 15 (2), 87–100.
- Imayanti, W., 2019. Pola dan Perilaku Penyemprotan Pestisida Serta Keluhan Kesehatan Petani di Desa Pariksubungan Kabupaten Simalungun. "Pesticide Spraying Patterns and Behaviors and Farmers Health Complaints in Pariksubungan Village, Simalungun Regency". Sumatera Utara University.
- Jallow, M.F.A., Awadh, D.G., Albaho, M.S., Devi, V.Y., Thomas, B.M., 2017. Pesticide knowledge and safety practices among farm workers in Kuwait: results of a survey. *Int. J. Environ. Res. Publ. Health* 14 (4).
- Jambari, N.S.A., Samad, N.I.A., Anua, S.M., Ruslan, R., Hamzah, N.A., 2020. Knowledge and practice (KAP) on pesticide exposure among farmers in Kota Bharu, Kelantan. *Malays. J. Med. Health Sci.* 16 (November), 56–62.
- Jensen, H.K., Konradsen, F., Jørs, E., Petersen, J.H., Dalsgaard, A., 2011. Pesticide use and self-reported symptoms of acute pesticide poisoning among aquatic farmers in phnom penh, Cambodia. *J. Toxicol.* 2011.
- Joko, T., Dewanti, N.A.Y., Dangiran, H.L., 2020. Pesticide poisoning and the use of personal protective equipment (PPE) in Indonesian farmers. *J. Environ. Publ. Health* 2020, 1–7.
- Kachaiyaphum, P., Howteerakul, N., Sujirarat, D., Siri, S., Suwannapong, N., 2010. Serum cholinesterase levels of Thai chilli-farm workers exposed to chemical pesticides: prevalence estimates and associated factors. *J. Occup. Health* 52 (1), 89–98.
- Kafle, S., Vaidya, A., Pradhan, B., Jørs, E., Onta, S., 2021. Factors associated with practice of chemical pesticide use and acute poisoning experienced by farmers in Chitwan district, Nepal. *Int. J. Environ. Res. Publ. Health* 18 (4194).
- Kansanga, M.M., Kerr, R.B., Lupafya, E., Dakishoni, L., Luginaah, I., 2021. Does participatory farmer-to-farmer training improve the adoption of sustainable land management practices? *Land Use Pol.* 108 (105477).

- Karunamoorthi, K., Mohammed, M., Wassie, F., 2012. Knowledge and practices of farmers with reference to pesticide management: implications on human health. *Arch. Environ. Occup. Health* 67 (2), 109–116.
- Kasnadi, Indrayani, R., 2019. Importance of the performance analysis (IPA) and customer satisfaction for determining the service strategies through the servqual model approach. *J. Manag. Bus.* 18 (1), 25–31.
- Khan, M., Damalas, C.A., 2015. Farmers' willingness to pay for less health risks by pesticide use: a case study from the cotton belt of Punjab, Pakistan. *Sci. Total Environ.* 530–531, 297–303.
- Khan, M., Mahmood, H.Z., Damalas, C.A., 2015. Pesticide use and risk perceptions among farmers in the cotton belt of Punjab, Pakistan. *Crop Protect.* 67 (1), 184–190.
- Khanal, G., Singh, A., 2016. Patterns of pesticide use and associated factors among the commercial farmers of Chitwan, Nepal. *Environ. Health Insights* 10, 1–7.
- Kim, K.H., Kabir, E., Jahan, S.A., 2017. Exposure to pesticides and the associated human health effects. *Sci. Total Environ.* 575, 525–535.
- Kumari, P.L., Reddy, K.G., 2013. Knowledge and Practices of safety use of Pesticides among Farm workers. *IOSR J. Agric. Vet. Sci.* 6 (2), 1–8. www.iosrjournals.org.
- Kumela, T., Simiyu, J., Sisay, B., Likhayo, P., Mendesil, E., Gohole, L., Tefera, T., 2018. Farmers' knowledge, perceptions, and management practices of the new invasive pest, fall armyworm (*Spodoptera frugiperda*) in Ethiopia and Kenya. *Int. J. Pest Manag.* 65 (1), 1–9.
- Lai, I.K.W., Hitchcock, M., 2015. Importance-performance analysis in tourism: a framework for researchers. *Tourism Manag.* 48, 242–267.
- Lee, K.H., Bonn, M.A., Cho, M., 2018. Green tea quality attributes: a cross-cultural study of consumer perceptions using importance–performance analysis (IPA). *J. Foodserv. Bus. Res.* 21 (2), 218–237.
- Lekei, E.E., Ngowi, A.V., London, L., 2014. Farmers' knowledge, practices and injuries associated with pesticide exposure in rural farming villages in Tanzania. *BMC Publ. Health* 14 (389).
- Leong, W.H., Teh, S.Y., Hossain, M.M., Nadarajaw, T., Zabidi-Hussin, Z., Chin, S.Y., Lai, K.S., Lim, S.H.E., 2020. Application, monitoring and adverse effects in pesticide use: the importance of reinforcement of Good Agricultural Practices (GAPs). *J. Environ. Manag.* 260, 109987.
- Levesque, D.L., Arif, A.A., Shen, J., 2012a. Association between workplace and housing conditions and use of pesticide safety practices and personal protective equipment among North Carolina farmworkers in 2010. *Int. J. Occup. Environ. Med.* 3 (2), 53–67.
- Levesque, D.L., Arif, A.A., Shen, J., 2012b. Effectiveness of pesticide safety training and knowledge about pesticide exposure among hispanic farmworkers. *J. Occup. Environ. Med.* 54 (12), 1550–1556.
- Macharia, I., Mithöfer, D., Waibel, H., 2013. Pesticide handling practices by vegetable farmer in Kenya. *Environ. Dev. Sustain.* 15, 887–902.
- Mariyono, J., Kuntariningsih, A., Kompas, T., 2018. Pesticide use in Indonesian vegetable farming and its determinants. *Manag. Environ. Qual. Int. J.* 29 (2), 305–323.
- Martilla, J.A., James, J.C., 1977. Importance-performance analysis. *J. Market.* 41 (1), 77–79.
- Matthews, G.A., 2008. Attitudes and behaviours regarding use of crop protection products - a survey of more than 8500 smallholders in 26 countries. *Crop Protect.* 27, 834–846.
- McLeay, F., Robson, A., Yusoff, M., 2017. New applications for importance-performance analysis (IPA) in higher education: understanding student satisfaction. *J. Manag. Dev.* 36 (6), 780–800.
- Mengistie, B.T., Mol, A.P.J., Oosterveer, P., 2017. Pesticide use practices among smallholder vegetable farmers in Ethiopian Central Rift Valley. *Environ. Dev. Sustain.* 19 (1), 301–324.
- Mequanint, C., Getachew, B., Mindaye, Y., Amare, D.E., Guadu, T., Dagne, H., 2019. Practice towards pesticide handling, storage and its associated factors among farmers working in irrigations in Gondar town, Ethiopia, 2019. *BMC Res. Notes* 12 (1), 1–6.
- Mohanty, M.K., Behera, B.K., Jena, S.K., Srikanth, S., Mogane, C., Samal, S., Behera, A.A., 2013. Knowledge attitude and practice of pesticide use among agricultural workers in Pudukcherry, South India. *J. Forensic Legal Med.* 20 (8), 1028–1031.
- Mubushar, M., Aldosari, F.O., Baig, M.B., Alotaibi, B.M., Khan, A.Q., 2019. Assessment of farmers on their knowledge regarding pesticide usage and biosafety. *Saudi J. Biol. Sci.* 26 (7), 1903–1910.
- OECD, 2021. Working Age Population. <https://data.oecd.org/pop/working-age-population.htm>.
- Polanco, Y., 2012. Factors Related to the Use of Synthetic Pesticides Among Agricultural Rural Communities in Colombia: Implications for Human Health, Rural Development and Conservation. University of Florida.
- Rachmawaty, V., 2016. Pengetahuan, Sikap dan Tindakan Petani dalam Pengendalian Hama dan Penyakit Kentang di Kecamatan Cikajang dan Cisarupan Kabupaten Garut. "Farmer's Knowledge, Attitude and Behavior in Potato Pests and Diseases Control in Cikajang and Cisarupan Districts.". IPB University.
- Rahaman, M.M., Islam, K.S., Jahan, M., 2018. Rice Farmers' knowledge of the risks of pesticide use in Bangladesh. *J. Health Pollut.* 8 (20).
- Riccò, M., Vezzosi, L., Gualerzi, G., 2018. Health and safety of pesticide applicators in a high income agricultural setting: a knowledge, attitude, practice, and toxicity study from North-Eastern Italy. *J. Prevent. Med. Hygiene* 59 (3), E200–E211.
- Ríos-González, A., Jansen, K., Javier Sánchez-Pérez, H., 2013. Pesticide risk perceptions and the differences between farmers and extensionists: towards a knowledge-in-context model. *Environ. Res.* 124, 43–53.
- Rozaki, Z., 2020. COVID-19, agriculture, and food security in Indonesia. *Rev. Agri. Sci.* 8, 243–260.
- Saeed, M.F., Shaheen, M., Ahmad, I., Zakir, A., Nadeem, M., Chishti, A.A., Shahid, M., Bakhsh, K., Damalas, C.A., 2017. Pesticide exposure in the local community of Vehari District in Pakistan: an assessment of knowledge and residues in human blood. *Sci. Total Environ.* 587–588, 137–144.
- Sapbamrer, R., Thammachai, A., 2020. Factors affecting use of personal protective equipment and pesticide safety practices: a systematic review. *Environ. Res.* 185 (March).
- Schreinemachers, P., Chen, H., Nguyen, T.T.L., Buntong, B., Bouapao, L., Gautam, S., Le, N.T., Pinn, T., Vilaysone, P., Srinivasan, R., 2017. Too much to handle? Pesticide dependence of smallholder vegetable farmers in Southeast Asia. *Sci. Total Environ.* 593–594, 470–477.
- Sever, I., 2015. Importance-performance analysis: a valid management tool? *Tourism Manag.* 48, 43–53.
- Shammi, M., Sultana, A., Hasan, N., Mostafizur Rahman, M., Saiful Islam, M., Bodrud-Doza, M., Khahir Uddin, M., 2020. Pesticide exposures towards health and environmental hazard in Bangladesh: a case study on farmers' perception. *J. Saudi Soc. Agri. Sci.* 19 (2), 161–173.
- Sharafi, K., Pirsaeed, 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). *Sci. Total Environ.* 645, 509–517.
- Sharifzadeh, M.S., Abdollahzadeh, G., Damalas, C.A., Rezaei, R., Ahmadyousefi, M., 2019. Determinants of pesticide safety behavior among Iranian rice farmers. *Sci. Total Environ.* 651, 2953–2960.
- Sharma, A., Kumar, V., Shahzad, B., Tanveer, M., Sidhu, G.P.S., Handa, N., Kohli, S.K., Yadav, P., Bali, A.S., Parihar, R.D., Dar, O.I., Singh, K., Jasrotia, S., Bakshi, P., Ramakrishnan, M., Kumar, S., Bhardwaj, R., Thukral, A.K., 2019. Worldwide pesticide usage and its impacts on ecosystem. *SN Appl. Sci.* 1 (1446).
- Sheng, X., Simpson, P.M., Siguaw, J.A., 2014. U. S. winter migrants' park community attributes: an importance-performance analysis. *Tourism Manag.* 43, 55–67.
- Skevas, T., Stefanou, S.E., Lansink, A.O., 2013. Do farmers internalise environmental spillovers of pesticides in production? *J. Agric. Econ.* 64 (3), 624–640.
- Suhartono, S., Kartini, A., Subagio, H.W., Budiyo Utari, A., Suratman, S., Sakundarno, M., 2018. Pesticide exposure and thyroid function in elementary school children living in an agricultural area, Brebes District, Indonesia. *Int. J. Occup. Environ. Med.* 9 (3), 137–144.
- Taghdisi, M.H., Besheli, B.A., Dehdari, T., Khalili, F., 2019. Knowledge and practices of safe use of pesticides among a group of farmers in Northern Iran. *Int. J. Occup. Environ. Med.* 10 (2), 66–72.
- Taplin, R.H., 2012. Competitive importance-performance analysis of an Australian wildlife park. *Tourism Manag.* 33 (1), 29–37.
- Wiedemann, R., Stamm, C., Staudacher, P., 2022. Participatory knowledge integration to promote safe pesticide use in Uganda. *Environ. Sci. Pol.* 128, 154–164.
- 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 (3), 1–7.
- Zakiyattunufus, L., 2015. Pengetahuan, Sikap dan Tindakan Petani Sayuran dalam Penggunaan Pesticida di Kabupaten Pandeglang. "Knowledge, Attitudes and Behavior of Vegetable Farmers in the Use of Pesticides in Pandeglang Regency." IPB University.