International Journal of Design & Nature and Ecodynamics
Vol. 20, No. 9, September, 2025, pp. 2133-2146
Journal homepage: http://iieta.org/journals/ijdne

# Variations in Pesticide Practices Among Indonesian Farmers Across Different Commodities

Yovita Anggita Dewi[1], Astrina Yulianti[1], Vyta Wahyu Hanifah[2,3], Istriningsih[1*], Dadang[4], Maesti Mardiharini[2], Erizal Jamal[2], Anggita Tresliyana Suryana[1]

[1] Research Center for Behavioral and Circular Economics, National Research and Innovation Agency (BRIN), South Jakarta, 12710, Indonesia
[2] Research Center for Cooperative, Corporation, and People's Economy, National Research and Innovation Agency, South Jakarta, 12710, Indonesia
[3] Faculty of Arts, Business, Law, and Economics, Center for Global Food and Resources, School of Economics and Public Policy, University of Adelaide, Adelaide 5005, South Australia
[4] Department of Plant Protection, IPB University, Bogor 16680, Indonesia

Corresponding Author Email: istr001@brin.go.id



https://doi.org/10.18280/ijdne.200917

**Received:** 16 July 2024
**Revised:** 12 September 2024
**Accepted:** 17 September 2025
**Available online:** 30 September 2025

***Keywords:***
*farmers' behavior, Kruskal-Wallis test, post-hoc test, pesticide usage, determinant factors*

**ABSTRACT**

This study examines the differences in pesticide use among Indonesian farmers across various commodities, including food crops, horticulture, and estate crops. Conducted from June to October 2020 in five provinces (West Java, Banten, Central Java, North Sumatra, and Lampung), surveying 354 randomly selected farmers. Data were analyzed using non-parametric statistics, including the Kruskal-Wallis test and a post-hoc test using the Mann-Whitney U test. Findings reveal notable variations in the number of pesticide brands used, costs, types of pests and diseases, and seasonal purchasing patterns across commodity groups. Potato farmers use the most pesticide brands, red chili farmers incur the highest costs, and rice farmers experience the greatest pest and disease diversity and the highest seasonal purchasing frequency. In contrast, oil palm farmers use the fewest pesticide brands and face fewer pests and diseases, while maize farmers incur the lowest costs, and shallot farmers have the least seasonal purchase frequency. Farmers' motivation to engage in various pesticide-related behaviors is allegedly influenced by their level of knowledge and skills. Specifically, improper pesticide use is linked to a general lack of adequate training, suggesting that many farmers do not possess sufficient knowledge or skills for proper pesticide application. The study underscores the diverse pesticide-related behaviors among farmers and recommends tailored training programs to enhance their knowledge and skills.

## 1. INTRODUCTION

Pesticides are aimed at controlling pests, diseases, and weeds to minimize the risk of crop failure [1-3]. In some developing countries, including Southeast Asia, pesticide usage increases rapidly along with the intensification of agricultural activities [4-6]. As with Indonesian agricultural practices, the use of pesticides remains intensive and massive [7-9]. The lack of awareness and knowledge about pesticides leads farmers to use them improperly [1, 8, 10]. The massive import of pesticides from 2000 to 2012 also had an impact on increasing the use of pesticides by farmers [11]. According to study [12], Indonesia's average pesticide use was approximately 5.4 kg/ha, ranking among the highest in Southeast Asia (Table 1). The use has increased steadily since the 1990s and remained consistently high (Figure 1), surpassed only by Malaysia (5.5 kg/ha), indicating a relatively high intensity of pesticide application compared to neighboring countries.

Previous studies revealed changes in pesticide use behavior among farmer cohorts with different commodities [13-16]. Research [14] mentioned that in Bangladesh, excessive pesticide use was mainly found in vegetables such as beans and eggplant, but was less likely in rice. A study [17] of fruits and vegetables imported from Southeast Asia to four European countries found that 33% of samples from Vietnam, 11% of samples from Malaysia, and 9% of samples from Thailand contained pesticide residues exceeding the Maximum Residue Levels (MRLs). Clearly, horticultural commodities are heavily pesticide-sprayed. An intensive use of pesticides was also observed in some cases of Indonesian horticulture farming [2, 8].

**Table 1.** The average of pesticide use per area of cropland in Southeast Asian countries from 1990 to 2019

| No. | Country | Kg/ha |
|---|---|---|
| 1 | Malaysia | 5.5 |
| 2 | Indonesia | 5.4 |
| 3 | Vietnam | 5.3 |
| 4 | Philippines | 1.8 |
| 5 | Thailand | 1.7 |
| 6 | Myanmar | 0.3 |

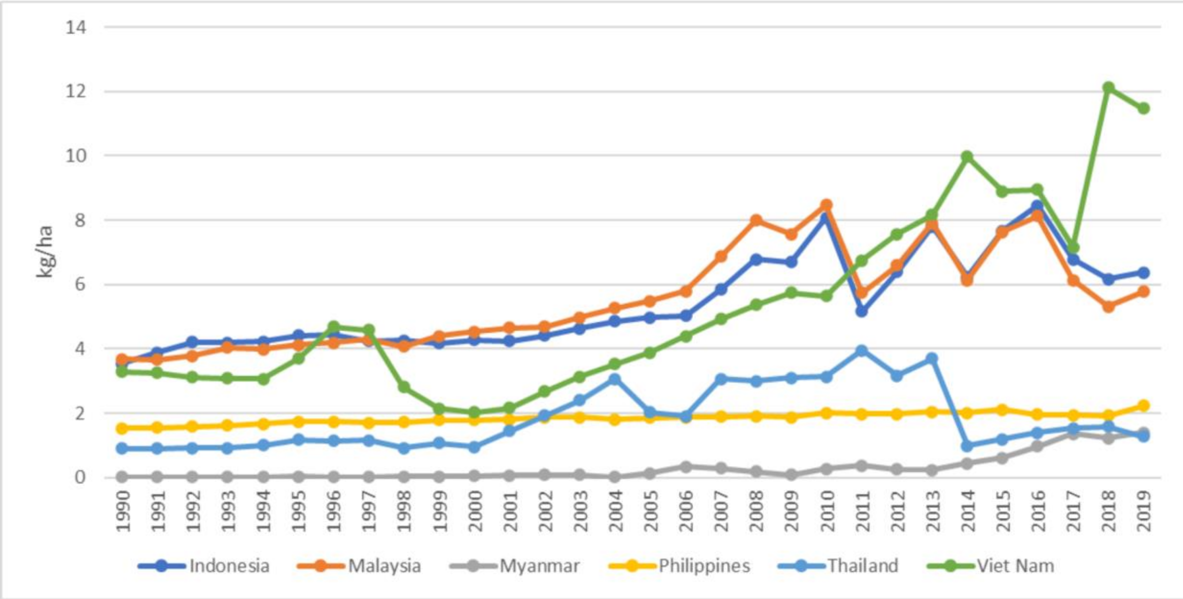


**Figure 1.** Pesticide use per area of cropland in Southeast Asian countries, 1990–2019

Additionally, some researchers found residue of pesticides in the soil, which indicates pesticides were used extensively and continuously at that time. For instance, chlorpyrifos, methidathion, and malathion residues were found in a shallot production centre in Brebes Regency, Indonesia [2]. The high pesticide use is compounded by the fact that vegetable farmers often use and mix multiple pesticides at the same time [2, 16, 18]. Mixing pesticides can be advantageous and disadvantageous. In terms of advantages, mixing is practised by many farmers to improve the effectiveness of pest and disease control, as well as to reduce labour costs regardless of the compatibility and active ingredients [15]. For instance, the practices of pesticide mixing in the case of Cambodian farmers continue due to the promotion and maintenance of dynamic communication and financial arrangements among farmers, sellers, and laborers [19]. Likewise, a trend of mixing practices of bio-pesticides and chemical pesticides increases among Chinese rice farmers for production diversification and an increase in pesticide varieties and costs [20]. Besides the benefits, mixing pesticides can also cause disadvantages. Therefore, farmers should use it with caution to avoid potential problems such as the emergence of resistance to pests and diseases and the effects of plant toxicity [21, 22].

Differential behavior in pesticide use among farmer cohorts and commodities may be influenced by various determinants. Given this complexity, it is critical to understand how pesticide use practices differ among farmers across various commodity groups—food crops, horticulture, and estate crops—and to identify the factors driving these differences. Specifically, this study seeks to address the following research question: What are the differences in pesticide use practices among Indonesian farmers across various commodities, and what determinants influence these differences? To explore this, the study investigates (i) the variation in the number of pesticide brands used by farmers for controlling pests and diseases across different types of crops, (ii) the differences in the costs incurred by farmers for purchasing pesticides for each crop type, (iii) the types of pests and diseases that affect crops in each category (food crops, horticulture, estate crops) and how these influence pesticide practices, and (iv) farmers' purchasing habits for pesticides, including whether they buy enough for a single planting season or stock up for multiple seasons, and how these habits vary by crop type. These questions are fundamental in exploring not only the extent of variation in pesticide use but also the underlying motivations and decision-making processes that lead to such diversity. In Indonesia, variations in farmers' pesticide use across commodities have not been thoroughly documented. This paper provides empirical evidence on the difference in farmers' behavior regarding pesticide usage and the determinants of pesticide use based on different commodities in Indonesia, namely food crops, horticulture, and estate crops. By offering a comprehensive analysis of these indicators, the study will provide valuable insights to inform the development of targeted policy interventions designed to enhance pesticide management strategies for different commodities.

## 2. METHODOLOGY

### 2.1 Survey design and data collection

The study was conducted from June to December 2020 across five provinces in Indonesia: West Java, Banten, Central Java, North Sumatra, and Lampung (Figure 2), collectively accounting for 14.7% of all provinces in the country. These provinces were selected due to their significance as major agricultural production centres representing a diverse range of commodities, including food crops (rice, maize), horticultural crops (shallot, red chili, potato), and estate crops (oil palm). The selection was based on their unique agroecological conditions and the variety of cultivated commodities, which are critical to understanding the diverse pesticide use practices among Indonesian farmers. This purposive selection helps capture a broad spectrum of farming practices and socio-economic contexts that influence pesticide use.

A quantitative approach was employed, using a survey method and individual interviews with a structured questionnaire to gather data from 354 randomly selected respondents across 33 sub-districts and 73 villages within these five provinces. Before commencing the study, the farmers were informed about the purpose of the survey by the local extension agents and sought their consent to be interviewees. The survey was designed to gather comprehensive information on various aspects of pesticide use practices. To ensure validity and reliability, the survey questions were constructed based on an extensive review of existing literature on pesticide use, farmer behavior, and agricultural practices, as well as consultations with experts in the field. The structured questionnaire included both closed and open-ended questions covering the following key themes:

1. Demographic information: Age, education level, farming experience, land ownership status, and land size.
2. Pest and disease management: Types of pests and diseases encountered, estimated level of crop damage from pests and diseases if pesticides are not applied, perceived effectiveness of pesticides used, pesticide purchasing patterns, types and number of pesticide brands used, frequency and methods of pesticide application, mixing practices, and the rotation of pesticide brands used.
3. Economic factors: Costs associated with pesticide purchases and financial considerations influencing pesticide use decisions.
4. Knowledge and skills: Participation in pesticide training.
5. Information sources: Access to and use of information sources, such as extension services, fellow farmers, pesticide retailers, and mass media, to obtain pesticide information.

The questionnaire was designed to gather both quantitative data (e.g., the number of pesticide brands used and the cost of pesticides) and qualitative data (e.g., farmers' motivations, perceptions, and decision-making processes regarding pesticide use). To enhance reliability, the survey was pre-tested with a small group of farmers to refine question clarity and relevance.

A total of 354 respondents, classified based on six commodity cohorts, participated in this study, as detailed by regency and commodity in Table 2. They were rice (83 farmers), maize (60 farmers), shallot (63 farmers), red chili (60 farmers), potato (58 farmers), and oil palm (30 farmers).

**Table 2.** Total samples and commodities from the research site

| Province & District | Number of Samples (Farmer) | Commodity |
|---|---|---|
| 1. North Sumatra | | |
| Serdang Bedagai | 36 | Rice |
| Serdang Bedagai | 15 | Oil palm |
| 2. Lampung | | |
| Lampung Selatan | 30 | Maize |
| Lampung Selatan | 15 | Oil palm |
| 3. Banten | | |
| Lebak | 30 | Maize |
| 4. West Java | | |
| Karawang | 16 | Rice |
| Garut | 19 | Red chili |
| Garut | 22 | Potato |
| Cirebon | 28 | Shallot |
| 5. Central Java | | |
| Brebes | 35 | Shallot |
| Wonosobo | 41 | Red chili |
| Wonosobo | 36 | Potato |
| Sragen | 31 | Rice |
| Total | 354 | |

### 2.2 Data analysis

Descriptive and inferential statistics were used to analyze the survey results, providing a comprehensive understanding of the variations in pesticide use and the factors driving these differences. The study's variables are summarized in Table 3.

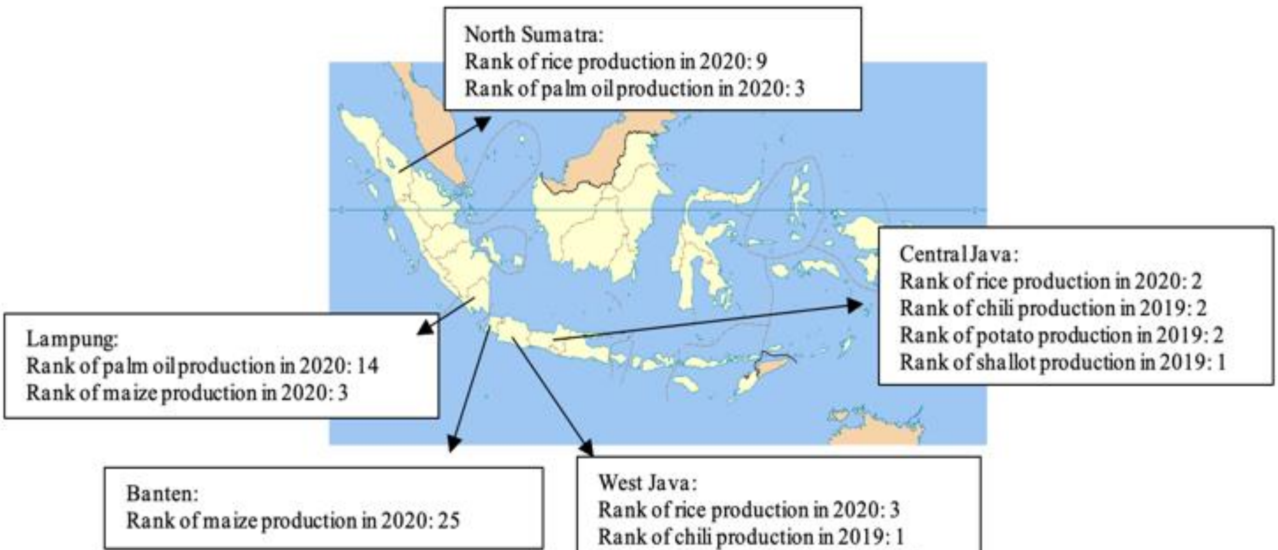


**Figure 2.** Research sites and production ranking in the country

**Table 3.** The classification of variables used in the study is based on the methods of analysis

| Variable | Definition | Value | Data Type |
|---|---|---|---|
| *Descriptive Analysis:* | | | |
| 1. Age | The farmer's age | Years | Ratio |
| 2. Education | The farmer's education level | Years | Ratio |
| 3. Farming experience | The duration of farming experience | Years | Ratio |
| 4. Land area | The cultivated land managed by the farmer | Hectare | Ratio |
| 5. Number of sources of pesticide information | The number of persons/institutions (formal/informal)/business units that are accessed by farmers to obtain pesticide information | Units | Ratio |
| 6. Pesticide's efficacy | The efficacy of pesticides that have been generally used in controlling pests and diseases, according to farmers' opinions | Percentage | Ratio |
| 7. Pests damage | The amount of damage caused by pests if the crops did not get any pesticide treatment, according to the farmer's estimation | Percentage | Ratio |
| 8. Diseases damage | The amount of damage caused by diseases if the crops did not get any pesticide treatment, according to the farmers' estimation | Percentage | Ratio |
| 9. Farmer's status | The ownership status of the lands that were managed by farmers | Owner / Cultivator | Nominal |
| 10. Pesticide training | Farmer participation in pesticide training | Yes / No | Nominal |
| 11. Purchasing purpose | The purpose that motivated farmers to purchase pesticides | Control / Preventive | Nominal |
| 12. Pesticide mixing | Mixing more than one brand of the same or different types of pesticides in a tank before spraying on the planting area | Yes / No | Nominal |
| 13. Pesticide rotation | The rotation of used brands (from the same or different pesticide companies) of the same type of pesticides for the different seasons | Yes / No | Nominal |
| *Statistical Analysis:* | | | |
| 1. Pesticide brands | The number of pesticides brands which were used by farmers in one season at the same time for all types of pesticides | Number | Ratio |
| 2. Cost of pesticides | The contribution of pesticide costs to the total farming costs incurred in one season | Percentages | Ratio |
| 3. Types of pests and diseases | The number of pests and disease types attacking in one season | Number | Ratio |
| 4. Seasonal purchasing | The level of purchasing habits was only for one season's needs | 1 To 5 (Never To Very Often) | Interval |

The non-parametric methods employed in this study are specifically the Kruskal-Wallis test and Post-Hoc analysis. Using the Kruskal-Wallis test and subsequent Mann-Whitney U tests allowed for a robust analysis of differences in pesticide use practices across multiple commodity groups, aligning with the study's aim to explore the variations in farmers' behavior. These methods were chosen due to their suitability for comparing multiple groups with non-normally distributed data. The Kruskal-Wallis test, a non-parametric method, was selected to determine whether there are statistically significant differences in pesticide use practices among different commodity groups (food crops, horticulture, and estate crops). This test is appropriate for comparing three or more independent groups when the data do not meet the assumptions required for parametric tests, such as normality and homogeneity of variance. In this study, key variables like the number of pesticide brands used, pesticide costs, types of pests and diseases, and seasonal purchasing patterns were measured on an ordinal or non-normally distributed scale, making the Kruskal-Wallis test suitable for analysing these differences across multiple groups. Following the Kruskal-Wallis test, post-hoc tests using the Mann-Whitney U test were conducted to identify specific group differences. The Mann-Whitney U test, also a non-parametric test, was used to perform pairwise comparisons between groups to determine which specific commodity groups differ in pesticide use practices. This test is appropriate when comparing two independent samples that do not follow a normal distribution, aligning with the nature of the data in this study.

Before applying the Kruskal-Wallis and Mann-Whitney U tests, key assumptions were checked:

- Normality: The Kolmogorov-Smirnov test was applied to test the normality of the data for key variables. The results indicated that the data were not normally distributed ($p < 0.05$), justifying the use of non-parametric methods.
- Independence of Observations: Each respondent's data were treated as independent, fulfilling the assumption of independence required for both the Kruskal-Wallis and Mann-Whitney U tests.
- Homogeneity of Variances: While the Kruskal-Wallis test does not require the assumption of equal variances, the assumption was still checked to better understand the data's characteristics.

**Table 4.** Output of the test of normality, Kolmogorov-Smirnov

| Variables | Sig.* | Decision |
|---|---|---|
| Pesticide's brands | <0.001 | Rejected null hypothesis |
| Cost of pesticides | <0.001 | |
| Types of pests and diseases | <0.001 | |
| Seasonal purchasing | <0.001 | |

* Significant at $\alpha = 0.05$.

In the statistical analysis, the Kolmogorov-Smirnov normality test was applied to test the normal distribution of the data for four variables. The null hypothesis (H0) for the normality test implies that the population was normally distributed, while the alternative hypothesis (H1) means the opposite. This test showed that the data were not normally distributed, and all four variables had significant values less than the reference alpha value (0.05), which means rejecting the null hypothesis (Table 4).

The Kolmogorov-Smirnov normality test can be used for a single sample to determine whether the distribution of scores in the sample matches the distribution of scores in a given theoretical or empirical population. Thus, the null hypothesis was expected to be rejected. Compared to the other types of inferential statistical tests, the goodness-of-fit test is, to some extent, unique because researchers mostly expect to retain the null hypothesis or to prove that the sample comes from a specific type of distribution (for example, a normal distribution). Alternatively, by using most other inferential tests, the researcher expects to reject the null hypothesis or demonstrate that one or more samples are not from a specific or similar population. It is important to highlight that the alternative hypotheses for a goodness-of-fit generally do not specify the alternative distribution. It would be the most likely distribution for the data if the null hypothesis is rejected. The Kolmogorov-Smirnov normality test is used at least on continuous and ordinal data types [23].

Since the data were not normally distributed, the Kruskal-Wallis test was employed. The Kruskal-Wallis test is a statistical analysis for non-parametric data [23, 24]. The comparison between the groups can be solved using this test since the data did not meet the assumptions of the variance analysis [24]. The sample groups were divided into different commodities. Therefore, the hypotheses of the study were symbolized with the equations below:

1. $H_1: \theta_1 = \theta_2 = \theta_3 = \theta_4 = \theta_5$, as the null hypothesis, which means that the median of the population grouped by commodities is equal.
2. $H_1: \theta_1 \neq \theta_2 \neq \theta_3 \neq \theta_4 \neq \theta_5$ , as the alternative hypothesis, which means there is a difference between at least two of the k = 5 population's medians.

The Kruskal-Wallis test result showed a significant difference, so further testing was required. A post-hoc test using the Mann-Whitney U test was employed to analyse the difference across the commodity groups. All statistical tests were conducted using SPSS Version. 28.

## 3. RESULTS

### 3.1 Descriptive analysis of farmers' characteristics and pesticide-use practices

Farmers' characteristics, such as age, education level, farming experience, gender, land ownership, and household size, have been examined in various studies, for example, in studies on adoption, production efficiency, or agricultural production. In this study (Table 5), the average age of all respondents was 47.07 years. Rice farmers have the highest age average of 50.37 years, whilst potato farmers are the youngest group, with an average of 40.84 years. Yet the age interval of farmers amongst commodities was nearly similar. The average length of formal education is 8.88 years. Oil palm and rice farmers had a higher average formal education than the rest of the population, with 10.50 and 10.34 years, respectively. Meanwhile, red chilli farmers had the lowest average education level by 7.08 years. According to the descriptive analysis, all the farmers had a significant amount of farming experience. For example, shallot and rice farmers have been farming for more than 20 years, whilst the other groups have been farming for 14 to 18 years. On average, 78 percent are registered as both landowners and cultivators, but 22 percent only cultivate by renting, mortgaging, or sharecropping from other farmers.

**Table 5.** Summary statistics of farmers' characteristics across commodities

| Variables | Rice | Maize | Shallot | Red Chili | Potato | Oil Palm | Average | SD* |
|---|---|---|---|---|---|---|---|---|
| Age (years) | 50.37 | 46.48 | 49.63 | 45.53 | 40.84 | 48.87 | 47.07 | 10.92 |
| Education (years) | 10.34 | 8.73 | 7.52 | 7.08 | 9.44 | 10.50 | 8.88 | 3.34 |
| Experience (years) | 22.65 | 14.17 | 21.27 | 18.92 | 15.24 | 17.27 | 18.66 | 11.99 |
| Land area (ha) | 1.05 | 1.20 | 0.59 | 0.49 | 0.95 | 2.55 | 1.01 | 1.30 |
| Farmers' status (%) | | | | | | | | |
| – Owner & cultivator | 75 | 78 | 57 | 90 | 81 | 100 | 78 | 13.31 |
| – Cultivator | 25 | 22 | 43 | 10 | 19 | 0 | 22 | 13.31 |
| Number of sources of pesticide information (unit) | 4.88 | 3.53 | 4.22 | 3.23 | 4.07 | 2.40 | 3.91 | 2.38 |
| Pesticide's efficacy (%) | 74.13 | 75.40 | 73.58 | 75.87 | 73.27 | 82.11 | 75.08 | 16.73 |
| Pests damage (%) | 50.15 | 59.45 | 74.64 | 57.93 | 47.16 | 58.08 | 57.30 | 22.44 |
| Diseases damage (%) | 44.13 | 45.18 | 59.41 | 60.08 | 65.86 | 60.00 | 56.97 | 23.57 |

Source: Primary data, 2020.
Note: SD* = Standard Deviation.

As can be seen in Table 5, the average amount of arable land managed by each farmer is approximately 1.01 ha, with oil palm farmers managing the largest average land at 2.55 ha/farmer. This result was unsurprising given that estate crop smallholders typically have larger farming areas in order to minimize production inefficiency. Horticulture farmers, such as red chili, shallot, and potato farmers, typically cultivate a smaller plot of land because horticulture farming is more intensive and requires more capital in terms of financial support. As a result, an expansion of arable land in horticulture will entail more input and labour costs.

The sources of pesticide information are shown in Table 5. Farmers revealed that they obtain information from various sources, including government extension agents, fellow farmers, formulators, field assistants, kiosks/retailers/ wholesalers, the internet, television, radio, and newspapers. Among all commodity groups, oil palm farmers used only about two information sources, whereas red chili and maize farmers used about three. Furthermore, rice, shallot, and potato farmers used more than four different sources to obtain pesticide information, indicating that they either have more access or try to gain as much insight as possible, even though the decision to use a pesticide is usually based on their own preferences.

Farmers claim that the pesticides they have used in the past had a high efficacy level, ranging from 73 to 82 percent.

Farmers of rice, maize, and shallots reported that the average damage caused by pests was more significant than that caused by disease, which ranged from 50 to 74 percent. Meanwhile, farmers of red chili, potato, and oil palm confirmed the opposite, with disease-causing more damage (60-65 percent) than pest attacks.

When it comes to pesticides, farmers are attached to different brands, with variations between them. Some farmers purchase and apply more than 15 brands for their plots, while others purchase no more than five brands in one cropping season. Although most farmers can recall and identify the brands they have used, some have had difficulty providing brand information. This farmer group is classified as misidentification, and identifying the market brand is complex (Figure 3).

The results of identifying the use of pesticides based on their types, such as insecticides, fungicides, and herbicides, show variations in different commodities and locations. Insecticides are the most widely used type of pesticide by farmers in almost all commodities except oil palm, with the highest use in red chili in Garut and rice in Sergai, with 4 and 3 brands per farmer, respectively. Pesticide types are almost identical in different locations, for example, among potato farmers, who use four types of pesticides. In this commodity, the use of insecticides and fungicides is relatively balanced, with about two brands used by each farmer (Figure 4).

Some respondents had been involved in pesticide training, with rice farmers having the most involvement (77 percent), while only 40 percent of oil palm farmers had ever attended a training (Table 6). The average participation rate among all farmers in training was 59 percent, with the remaining respondents (41 percent) never receiving pesticide training. This result also revealed that farmers may not have received adequate training. Farmers have been farming for decades (see Table 5), but this does not correspond to participation in pesticide training or the opportunity to participate in pesticide training. As a result, farmers have limited knowledge of pesticides.

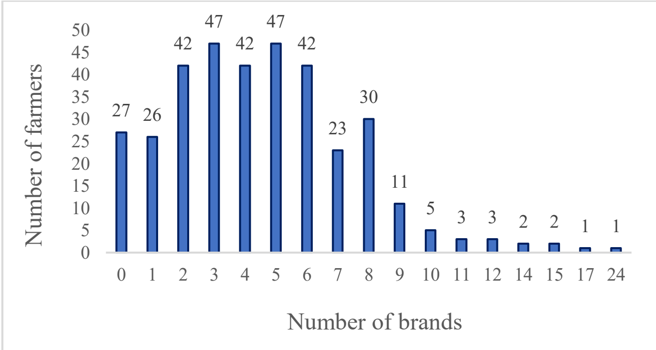


**Figure 3.** The average brands of pesticides used by farmers
Note: Zero represents the misidentification of brands by farmers and the difficulty in identifying the market brand

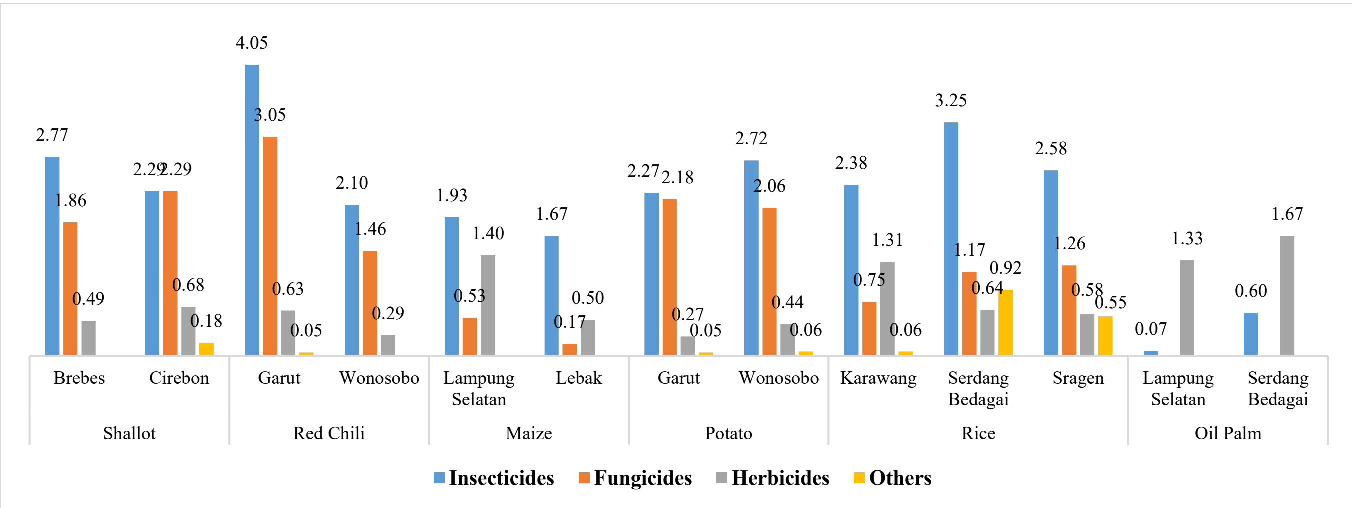


**Figure 4.** The average number of pesticide brands used per farmer based on the pesticide types

**Table 6.** Frequency distribution related to the pesticide trainings and farmers' attitude on using pesticides (%)

| No. | Variables | Rice (n=83) | Maize (n=60) | Shallot (n=63) | Red chili (n=60) | Potato (n=58) | Oil Palm (n=30) | Average of Total Farmers (N=354) |
|---|---|---|---|---|---|---|---|---|
| 1 | Pesticide training | | | | | | | |
| | Yes | 77.1 | 48.3 | 61.9 | 50.0 | 56.9 | 40.0 | 58.5 |
| | No | 22.9 | 51.7 | 38.1 | 50.0 | 43.1 | 60.0 | 41.5 |
| 2 | Purchasing purpose | | | | | | | |
| | Control | 13.3 | 33.3 | 28.6 | 1.7 | 0.0 | 50.0 | 18.4 |
| | Prevention | 86.7 | 66.7 | 71.4 | 98.3 | 100.0 | 50.0 | 81.6 |
| 3 | Pesticide mixing | | | | | | | |
| | Yes | 67.5 | 20.0 | 79.4 | 76.7 | 91.4 | 20.0 | 63.0 |
| | No | 32.5 | 80.0 | 20.6 | 23.3 | 8.6 | 80.0 | 37.0 |
| 4 | Pesticide rotation | | | | | | | |
| | Yes | 47.0 | 35.0 | 30.2 | 16.7 | 27.6 | 13.3 | 30.8 |
| | No | 53.0 | 65.0 | 69.8 | 83.3 | 72.4 | 86.7 | 69.2 |

Source: Primary data, 2020. Total respondents: 354 farmers.

**Table 7.** Farmer characteristics of two groups of doing crop rotation and mixing the brands

| Variables | No Rotation | Rotation | p-Value | No Mixing | Mixing | p-Value |
|---|---|---|---|---|---|---|
| N (farmers) | 245 | 109 | | 131 | 223 | |
| Age, mean (SD) | 47.4 (11.2) | 46.4 (10.4) | 0.64 | 47.8 (11.1) | 46.6 (10.8) | 0.34 |
| Education, mean (SD) | 8.7 (3.3) | 9.4 (3.4) | 0.061 | 9.3 (3.6) | 8.7 (3.2) | 0.11 |
| Gender (%) | 233 (95.1%) | 105 (96.3%) | 0.61 | 121 (92.4%) | 217 (97.3%) | 0.031* |
| Membership, mean (SD) | 3.9 (1.4) | 3.9 (1.1) | 0.60 | 3.9 (1.3) | 3.9 (1.4) | 0.87 |
| Experience, mean (SD) | 19.8 (12.1) | 18.3 (11.8) | 0.70 | 18.0 (13.0) | 19.0 (11.4) | 0.46 |
| Status (%) | 195 (79.6%) | 81 (74.3%) | 0.27 | 103 (78.6%) | 173 (77.6%) | 0.82 |
| Land size, mean (SD) | 1.1 (1.8) | 1.1 (1.6) | 0.84 | 1.5 (2.4) | 0.9 (1.1) | <0.001** |
| Commodities: | | | | | | |
| 1 rice (%) | 42 (17.1%) | 16 (14.7%) | <0.001** | 5 (3.8%) | 53 (23.8%) | <0.001** |
| 2 maize (%) | 50 (20.4%) | 10 (9.2%) | | 14 (10.7%) | 46 (20.6%) | |
| 3 shallot (%) | 44 (18.0%) | 19 (17.4%) | | 13 (9.9%) | 50 (22.4%) | |
| 4 red chilli (%) | 44 (18.0%) | 39 (35.8%) | | 27 (20.6%) | 56 (25.1%) | |
| 5 potato (%) | 39 (15.9%) | 21 (19.3%) | | 48 (36.6%) | 12 (5.4%) | |
| 6 oil palm (%) | 26 (10.6%) | 4 (3.7%) | | 24 (18.3%) | 6 (2.7%) | |
| Training (%) | 129 (52.7%) | 66 (60.6%) | 0.17 | 61 (46.6%) | 134 (60.1%) | 0.014* |
| Reading label (%) | 203 (82.9%) | 100 (91.7%) | 0.028* | 109 (83.2%) | 194 (87.0%) | 0.33 |
| Source of info, mean (SD) | 3.7 (2.5) | 4.1 (2.4) | 0.17 | 3.4 (2.6) | 4.1 (2.3) | 0.008* |
| Brand, mean (SD) | 4.4 (3.1) | 5.0 (3.2) | 0.078 | 3.1 (2.0) | 5.4 (3.4) | <0.001** |
| Number of pests & diseases, mean (SD) | 3.4 (2.1) | 4.0 (2.6) | 0.02* | 2.8 (1.9) | 4.1 (2.3) | <0.001** |
| Pests attack, mean (SD) | 57.9 (21.8) | 56.2 (23.8) | 0.55 | 59.0 (22.4) | 56.5 (22.5) | 0.39 |
| Diseases attack, mean (SD) | 59.4 (23.8) | 50.9 (22.0) | 0.026* | 57.3 (24.8) | 56.9 (23.3) | 0.91 |

Note: * and ** indicate statistical significance at the 5% and 1% level, respectively.

**Table 8.** The value differences of four variables across commodity groups using the Kruskal-Wallis test

| Variable | Asymp. Sig. (Kruskal-Wallis) | Std. Deviation | Minimum | Maximum | Group with the Highest Mean Rank | Group with the Lowest Mean Rank |
|---|---|---|---|---|---|---|
| Pesticide brands | < 0.001 | 2.92 | 1 | 24 | Potato | Oil palm |
| Cost of pesticides | < 0.002 | 0.19 | 0 | 100 | Red chili | Maize |
| Types of pests and diseases | < 0.003 | 2.07 | 1 | 11 | Rice | Oil palm |
| Seasonal purchasing | < 0.004 | 1.01 | 1 | 5 | Rice | Shallot |

As shown in Table 6, the purchase of pesticides primarily serves two purposes: controlling or preventing, which reflects a difference in attitude among farmers or between commodities. More than half (ranging from 67 to 100 percent) of farmers cultivating potato, red chili, rice, shallot, and maize said they bought pesticides primarily to prevent attacks. When purchasing pesticides, oil palm smallholders consider both control and prevention. Overall, 82 percent of farmers purchased pesticides for prevention and 18 percent for control, respectively. Pesticide mixing is a very common practice among farmers, as shown in Table 6. Almost two-thirds of farmers (63 percent) mixed the pesticides, except maize and oil palm farmers, who rarely did. During the interview, the variety of pesticide brands purchased by farmers for oil palm was limited. This result was also consistent with the previous description of pesticide mixing practice in Table 6. Most potato farmers (91 percent) used pesticide mixing, indicating that more pesticide brands and types were used. In the study area, more farmers (69 percent) did not rotate pesticides, while 31 percent used different pesticides for multiple planting seasons. Food crop farmers mostly implemented pesticide rotation, but only a small percentage of red chili farmers applied it. Oil palm farmers typically used only herbicides, whereas horticulture farmers used a wider range of pesticides.

Further descriptive analysis divided farmers into two groups based on the most common practices relating to pesticide use: commodity rotation and brand mixing (Table 7). The analysis showed very significant differences (p-value < 0.001) based on the commodity types in both practices, between a group of farmers doing rotation and not doing it, and between those doing brand mixing and not mixing. This means that farmers of each commodity act differently when rotating crops and mixing pesticide brands. When mixing the brands, there were considerable differences (p-value <0.001) between a group of doing and not doing depending on several characteristics, including land size, source of information, brands, and number of pests and diseases. The other two characteristics that generated less significance (p-value <0.05) between the group of mixing and not mixing were gender and participation in training. This means that male and female farmers act differently, or their experience in training participation would drive their preference when considering whether to mix the brands or not. In rotating the crops, besides the type of commodities, there were three other characteristics with different significance levels of p-value < 0.05, including reading the label, number of pests and diseases, and disease attacks. This means that farmers applying the crop rotation might consider those three characteristics.

### 3.2 Differences in farmers' behavior in pesticide usage across commodities

The Kruskal Wallis test analysis revealed that H0 was rejected for the four variables tested because the significance value was less than 0.05. This means that the values of the four variables differed significantly across commodity groups. The

Kruskal-Wallis test also revealed each variable's commodity ranking. Regarding pesticide brand variability, the potato farmer group ranked highest, while oil palm ranked lowest (Table 8). The pesticide cost variable showed that red chili farmers spent the most on pesticide purchases, while maize farmers spent the least on pesticide purchases. The quantities and prices of pesticides may impact pesticide costs (Table 8). The pest and disease types test results in Table 8 showed that rice farming had the most pest and disease attacks, causing farmers to use more pesticides. Meanwhile, the oil palm commodity was relatively unaffected by many types of pests and diseases, earning it the lowest rank in this variable. Rice farmers had the highest rank in the last variable. Instead of purchasing pesticides for a full year or multiple planting seasons, they preferred to buy pesticides as needed during each cropping season. The types of pests and diseases attacking rice cultivation were the highest and were also as diverse across crop seasons. This could be one of the reasons rice farmers buy pesticides on a seasonal basis. Shallot had the lowest rank, which means they frequently purchased pesticides in bulk and applied them for more than one season. This behavior is most likely influenced by the types of pests and diseases that attack in each season, which are relatively similar; additionally, to ensure pesticide supplies for the following planting seasons.

### 3.3 Differences in pesticide use based on four variables across commodity groups

Table 9 shows the results of the post-hoc test on the four variables across commodity groups. The significance value for the variable pesticide brands was less than alpha 0.05, indicating a significant difference between (1) rice farmers and maize farmers, as well as oil palm farmers; (2) maize farmers and the other four commodities (rice, shallot, red chili, and potato); and (3) oil palm farmers and the other four commodities (rice, shallot, red chili, and potato).

The difference in pesticide costs across commodity groups was also significant at alpha 0.05, explaining the differences between (1) rice farmers and red chili farmers; and (2) maize farmers and red chili farmers. It means that red chili farmers' pesticide expenditure differed significantly from food crops but not from other horticultural crops (Table 9). Furthermore, the post-hoc test on pest and disease types across commodity groups discovered a significant difference between (1) maize farmers and the other four commodity groups (rice, shallot, red chili, and oil palm); (2) red chili farmers and maize as well as oil palm farmers; (3) potato farmers and rice as well as oil palm farmers; and (4) oil palm farmers and the other five commodity groups (rice, maize, shallot, red chili, and potato). This result demonstrated that the types of pests and diseases attacking rice and maize were significantly diverse, even though both were food crops. Even though horticultural crops such as red chili, potato, and shallot are attacked by pests that differ significantly from those of food crops and estate crops (oil palm), there is no significant difference between horticultural crops. As shown in Table 9, there was a significant dissimilarity between (1) shallot farmers and rice farmers, as well as maize farmers; and (2) red chili farmers and rice farmers regarding the variable of seasonal purchasing.

Based on the pairwise comparison analysis presented in Table 9, the following is the grouping of commodities according to the four variables tested. The behavior of pesticide use varies across different commodity groups. In Group Commodity 1, which includes farmers cultivating rice, shallot, red chili, and potato, there is a notable diversity in pesticide brands used, reflecting the varied pest challenges these crops face. These farmers also incur significant pesticide costs, managing expenses for rice, maize, shallot, potato, and oil palm. The range of crops in this group leads to diverse pest and disease types, particularly affecting red chili, rice, shallot, and potato. Additionally, farmers in this group engage in seasonal purchasing, aligning their pesticide use with the growing cycles of red chili, maize, shallot, potato, and oil palm.

In contrast, Group Commodity 2, which focuses on maize and oil palm, presents a more specialized pesticide use pattern. For this group, the cost of pesticides is primarily driven by red chili production, known for its high susceptibility to pests. Farmers in this group also face particular pest and disease challenges related to maize and potatoes. Seasonal purchasing of pesticides is more concentrated on rice, reflecting a structured approach to pest control during the rice-growing season.

Finally, Group Commodity 3, focusing solely on oil palm, demonstrates the most targeted pesticide use. The types of pests and diseases faced are specific to oil palm, requiring specialized solutions. Seasonal purchasing is not mentioned for this group, suggesting a more consistent need for pest control throughout the year, with less variation in pesticide use compared to other groups. Overall, the differences in pesticide use across these groups highlight the impact of crop diversity on pest management strategies and costs.

**Table 9.** Difference of four variables in pesticide use across commodity groups

| | Rice | Maize | Shallot | Red Chili | Potato | Oil Palm |
|---|---|---|---|---|---|---|
| 1. Pesticide brands | | | | | | |
| Rice | | ** | | | | ** |
| Maize | ** | | ** | ** | ** | |
| Oil palm | ** | | ** | ** | ** | |
| 2. Cost of pesticides | | | | | | |
| Rice | | | | ** | | |
| Maize | | | | ** | | |
| 3. Types of pests and diseases | | | | | | |
| Maize | ** | | ** | ** | | ** |
| Red chili | | ** | | | | ** |
| Potato | ** | | | | | ** |
| Oil palm | ** | ** | ** | ** | ** | |
| 4. Seasonal purchasing | | | | | | |
| Shallot | ** | ** | | | | |
| Red chili | ** | | | | | |

Note: ** = the pairwise comparison has a difference for α value of 0.05.

## 4. DISCUSSIONS

Based on the descriptive analysis of farmers' characteristics (Table 5), all farmers are classified as working age groups [25], indicating the ability to run farms in the long term. The use of production inputs is differentiated by age variations, and age has a significant impact on agricultural output [26]. One of the most critical factors influencing farm productivity is education. Farmers who respond pass the minimum requirement of basic formal education, demonstrating that they are literate farmers (have reading and writing skills). Achieving a certain level of education will help farmers manage information and implement it in their farming [27]. However, the study finds a slightly different result in oil palm farmers with the highest average formal education.

Longer farming experience leads to accumulated knowledge and skills, which allegedly can influence farming productivity. Study [28] stated that farming experience over time has a significant impact on technology adoption. However, in this study, having a long farming experience does not necessarily indicate that farmers are willing to use pesticides in the best way possible. Farmers with an average of 18 years of experience, for example, do not fully practice proper pesticide mixing and rotation. Table 7 corroborates that farmer age does not significantly influence rotation and mixing behavior.

Farmers' decisions to use more inputs may be influenced by their land status. Study [29] underlined the significant and positive impact of land ownership and land area on increasing technical efficiency and affecting output value. Land ownership and land area have a significant and positive impact on increasing technical efficiency and influencing output value. Other studies found that increasing farm size has the opposite effect on pesticide use, with the quantity of pesticides decreasing [8, 30]. Meanwhile, the farmers' status in this study demonstrates that not all farmers manage their own land. Landowners may apply more or fewer pesticides depending on short-term land productivity [4]. Farmers acting as owners make the decisions about how to manage their farms, including whether to buy and use more pesticides or less. Some cultivators receive information about pesticide use from landowners.

The use of pesticides corresponds to the control of pests and diseases. Pest and disease attacks have occurred in all the respondents' farms. On the other hand, the average damage caused by pests and diseases is nearly identical. This value is predicted based on farmers' perceptions of what would happen if they did not use the current type and amount of pesticide that they are using. Each pesticide has a different level of efficacy. The efficacy of pesticides based on farmers' perceptions is also investigated because it can help explain why they buy a specific brand or type of pesticide. The positive view of farmers toward pesticide efficacy is one of the factors that affected the perception of the adoption of practices of pesticide safety [31]. However, because there is a perception gap between extension agents and farmers on efficacy, farmers' perceptions may lead to a false notion of pesticide efficacy [32].

Aside from analysing farmers' idiosyncratic, two related issues were also collected and analysed: pesticide training attended by farmers and farmers' attitudes toward pesticide use (Table 5). Training is a non-formal education that aims to improve farmers' knowledge and skills in applying pesticides safely and correctly. This study's training information excludes unintentional informal consultations or meetings. Knowledge, behavior, and beliefs differ significantly between pesticide training participants and non-participants [33], and the attendance of horticulture farmers in training has a positive impact on aspects of pesticide use [30]. Study [34] revealed that only about 29 percent of farmers in Iran have ever received pesticide management training, and the training intervention has helped to improve farmers' attitudes toward pesticide management.

Ideally, training would educate farmers on the best practices for using pesticides safely, wisely, and correctly. This study discovered that more than half of farmers had attended training on pesticides; however, they continued to use pesticides in an unsafe, unwise, and improper manner, as revealed by three defined attitudes in Table 6. The first attitude investigated in this study is about purchasing for control or prevention. This preventive action implies that farmers applied pesticides before the attack. Farmers concerned about pest and disease attacks in previous seasons or by the experiences of fellow farmers, usually practice this habit. They typically apply a lower dose of pesticide, which is then increased in response to an increase in the number of pest and disease attacks. Farmers plan to avoid the loss in advance because it will be more difficult to control after the outbreak, or result in a higher risk of loss. In other words, actions for prevention will result in a greater use of pesticides than actions for control. This precaution will eventually become a farmer's habit, providing them with a sense of security in ensuring their harvest yield.

The second attitude concerns pesticide mixing (Tables 6 and 7). Pesticide mixing is motivated mainly by the perceived need to enhance pest and disease control and reduce labor costs. However, it is associated with potential risks. Inappropriate mixing can reduce pesticide efficacy [35, 36] and lead to excessive residues and environmental pollution risks [37]. In addition, pesticide mixing is sometimes associated with potential hazards when farmers mix pesticides. Farmers do not always wear standard personal protective equipment, which can endanger their health due to pesticide exposure [10, 38-40]. Nonetheless, the main concern is mixing pesticides according to the instructions to maintain the efficacy level of active ingredients in pesticide products and avoid pest and disease resistance. As a result, farmers' knowledge and skills in pesticide handling are critical, as well as promoting training programs that emphasize the environmental and health consequences of unsafe mixing practices. Strengthening farmers' understanding of the linkage between mixing behavior, residues, and environmental risks is crucial for promoting safer and more sustainable pest management.

The last attitude discussed in Table 6 and Table 7 is regarding pesticide rotation. However, pesticide rotation was less common, with only 31% of farmers rotating different pesticides across multiple planting seasons. This study suggests that one reason for the limited practice of pesticide rotation is that farmers often use the same pesticides for different commodities planted in the previous season. Additionally, in some cases, the lack of rotation is due to farmers relying on only one type of pesticide to control pests, reducing the need or incentive to rotate pesticides. Study [41] stated that pesticide rotation is one of the effective methods of delaying pest-resistant emergence. This statement is also supported by the study [42]. The study emphasizes that rotating insecticides is an important part of resistance management. At the same time, this practice will help delay the development of resistance to one or more insecticides used.

Most farmers may be unaware of the importance of pesticide rotation in preventing resistance. In this study, rotating pesticides does not refer to the mode of action but rather to pesticide brand loyalty. In other words, farmers appear to use the same brands over long periods of cultivation. Similarly, a study of rice farmers' satisfaction and loyalty to specific pesticide brands in West Java province, Indonesia, found that only 11% of farmers become switch buyers, while the rest are habitual to committed buyers [43].

The study reveals significant differences in the behavior of pesticides used among farmers across various commodity groups in Indonesia, notably in the number of pesticide brands, costs, pest and disease types, and seasonal purchasing behaviors. One of the reasons, in addition to increased pesticide use, could be the availability of pesticide brand options. Regarding differences in the number of pesticide brands used, this study reveals that potato farmers use the most pesticide brands due to a high incidence of pests and diseases. In contrast, oil palm farmers face fewer pest types like beetles and fungi (Ganoderma), and rely primarily on herbicides for weed control [44]. Weed is one of the main obstacles to increasing the potential yield of oil palm production in Indonesia [45]. According to study [46], oil palm farmers extensively use herbicides for weed control.

Further analysis reveals that rice, shallot, red chili, and potato farmers use a larger number of pesticide brands (Table 10). Farmers cultivating rice, shallot, red chili, and potato tend to purchase more pesticide brands due to the increased number of pest and disease attacks. On the other hand, oil palm and maize farmers choose fewer pesticide brands because maize and oil palm farming are not as intensively maintained as the other commodities in the research location. Pests and diseases do not attack these two plants as frequently or as frequently as they do rice, chili, shallot, and potato. Two maize commodity research sites exist in the Provinces of Lampung and Banten. Maize farmers in Lampung work more intensively in farming management than farmers in Banten, located near a forest and are not being treated optimally. As a result, the use of pesticides differs between the two locations. Furthermore, the majority of the damage to maize farming is caused by uncontrollable animal attacks (wild boars and monkeys). Meanwhile, the research locations for oil palm commodities (Lampung and North Sumatra Provinces) share similarities in farming patterns and farmers' pesticide use behavior, primarily for weed control.

**Table 10.** The grouping of commodities based on the four variables examined

| Variables in Pesticides | Group Commodity 1 | Group Commodity 2 | Group Commodity 3 |
|---|---|---|---|
| Pesticide's brands | Rice, Shallot, Red Chili, Potato, | Maize, Oil palm | |
| Cost of pesticides | Rice, Maize, Shallot, Potato, Oil palm | Red Chili | |
| Types of pests and diseases | Red Chili, Rice, Shallot, Potato | Maize, Potato | Oil palm |
| Seasonal purchasing | Red Chili, Maize, Shallot, Potato, Oil palm | Rice | |

Pesticide brands purchased by horticulturists (shallot, red chili, and potato farmers) and rice farmers are more diverse. Insecticides, fungicides, and herbicides are the three types of pesticides that all respondents commonly use. In contrast, farmers rarely use molluscicides and bactericides due to the rarity of attacks from these pests and disease types. Furthermore, according to interviews, each farmer who grows red chili and potatoes buys six pesticide brands on a regular basis, whereas those who grow rice and shallots buy five. Farmers of maize and oil palm, on average, use three and two brands, respectively. Insecticides, more than any other type, contribute significantly to the variety of pesticide brands. Even though oil palm farmers use only one insecticide brand, the other farmer groups purchase 2-3. Similarly, farmers who plant red chili and potato crops use a lot of fungicides. Many vegetable farmers spray insecticides and fungicides excessively or on a regular basis [18, 47], whereas oil palm and maize farmers use more herbicide brands than the other farmer groups. A study [16] supported these findings, indicating that 60-90% of horticultural farmers in East Java use at least 6 to 9 pesticide brands. This intensive use underscores the need for improved pesticide management to avoid resistance, environmental harm, and health risks, advocating for more efficient and sustainable practices.

A horticultural commodity such as chili has higher operational costs compared to rice and maize. The extended chili planting season, which can last for multiple harvests, often necessitates more pesticides. Additionally, chili farmers are accustomed to using various brands of pesticides. This finding is consistent with a study [15], which revealed that the longer growing season of crops leads to a higher frequency of pesticide applications per season, as observed in tomato farming in Ethiopia.

Further interviews with farmers found that horticultural farmers incur a higher proportion of pesticide costs per hectare, amounting to 43% of total farming costs during the rainy season and 39% during the dry season. This aligns with using a greater variety of pesticide brands and higher doses compared to farmers of staple crops and plantations. It was also discovered that the pesticide costs remain similar during both planting seasons. Farmers attempt to manage fluctuations in pesticide costs by adjusting dosages, mixing products, and seeking price differences for purchasing pesticides. However, these efforts may increase the risk of farmers using counterfeit pesticides, which are generally cheaper.

According to study [48], the percentage of pesticide use could increase or decrease in line with the expansion or reduction of cultivated land areas. Various previous studies conducted in different regions of Indonesia have found that land ownership status affects pesticide costs. For example, rice farmers in Jember who own their land incur higher pesticide costs than tenant farmers and sharecroppers, at 2.3%, while tenant farmers and sharecroppers spend 0.9% and 1.7% of their total farming costs on pesticides, respectively [49]. The use of superior seed varieties can also contribute to the rise in pesticide costs. For instance, the cultivation of high-yield maize varieties in Gorontalo requires 43% higher pesticide costs compared to local varieties [50]. Although farmers often complain about pesticide costs, their proportion is still lower compared to input costs for fertilizers and quality seeds. For example, highland potato farming requires pesticide costs amounting to 3.8% of the total farming costs [51], while garlic farming in highland areas of several central districts involves substantial pesticide use, consuming 5.33-12.15% of total farming costs [52]. However, chili farmers in Jember, East Java, spend 8.65% of their total costs on pesticides, which is higher than their seed costs of around 4.58% [53].

Production function analyses of rice [54-56], maize in Gorontalo [50], large red chili in East Java [53, 57], and shallots in Lampung [58] show that pesticide costs significantly and substantially affect agricultural production. However, increased pesticide costs in other studies do not always improve crop conditions. For example, the increase in pesticide costs had no significant effect on the production of horticultural crops such as shallots [59], tomatoes [60], oil palm [61], or rice in Jember [49]. This indicates that the impact of pesticide costs on the production of various commodities in Indonesia yields conflicting research findings.

In terms of differences in the type of pests and diseases, this study confirms that rice crops have the most variety of pests and diseases, while oil palm has the least. Pests and diseases vary by crop, and those that attack rice crops may not be found in horticultural crops, but the same types of pests and diseases may be found in both shallot and red chili. These phenomena necessitate a different approach to control and manage pests and diseases, such as selecting the appropriate pesticides. As a result, farmers' knowledge of identifying pests and diseases is critical, which leads to the selection of the appropriate pesticides.

The findings from Tables 9 and 10 highlighted that pest and disease management strategies vary significantly across different commodity groups due to the diversity of crops and their specific vulnerabilities. For Group Commodity 1, which includes a range of crops such as red chili, rice, shallot, and potato, farmers face a wide array of pests and diseases, necessitating a comprehensive and adaptable approach to pest management. This complexity requires tailored solutions for each crop, involving research investments, pest-resistant varieties development, integrated pest management techniques, and farmer education. In Group Commodity 2, which focuses on maize and potato, the shared pests and diseases simplify pest management to some extent. However, targeted strategies are still needed to address specific issues for each crop. Research should focus on identifying and managing these unique threats. Meanwhile, Group Commodity 3, dealing solely with oil palm, faces more specialized pest and disease challenges, allowing for the development of highly focused management strategies. This specialization means fewer types of pesticides may be used, but solutions need to be tailored specifically to the needs of oil palm cultivation. Overall, these findings suggest that resource allocation, research, and policy should be tailored to the specific needs of each commodity group to manage pest and disease challenges effectively.

This study also found differences in seasonal pesticide purchasing patterns. Rice farmers tend to buy pesticides for one season at a time, while shallot farmers prefer to buy in bulk to stock up for the next planting season. Rice farmers' seasonal purchasing habits differ significantly from the shallot and red chili farmers', implying that food crop farmers will purchase pesticides differently during each cropping season. Aside from the pests and diseases already discussed in Table 5, this behavior may be influenced by rice farmers' financial ability to purchase pesticides. Due to financial constraints, these farmers can only provide pesticides for one season. Another reason is that horticultural farmers admit that obtaining certain pesticides is difficult, particularly before planting season, due to high demand. To ensure pesticide availability for the following season, they purchase pesticides in bulk to meet the needs of multiple cropping seasons. This behavior is also associated with the intended use of pesticides, which is emphasized for prevention purposes (See Table 6).

Based on further interviews with the respondents, the primary reason for purchasing pesticides is influenced by popular pesticide brands among farmers. The main factors influencing pesticide purchase are quality and price. However, the horticultural and oil palm farmers regard price as a moderately significant factor in pesticide purchase, whereas rice and maize farmers are more price-sensitive. Quality is the primary consideration for selecting pesticides, aligning with the most frequently recognized purpose of pesticide use among farmers, which is prevention. This implies that, even in the absence of present infestations, there is a general feeling of unease over possible pest and disease dangers to crops. Farmers' experience and knowledge regarding pesticide efficacy contribute significantly, as those with positive experiences or a good understanding of pesticides are more likely to utilize them. Additionally, recommendations from agricultural extension workers or suppliers can influence farmers' decisions when selecting appropriate products. The pricing and accessibility of pesticides in the market are other important considerations; farmers are more likely to buy them if they are reasonably priced and easily available. Modern agricultural practices and the latest technologies also contribute to these decisions, as farmers who adopt new technologies often use pesticides to enhance crop yields. Economic pressures may drive farmers to purchase pesticides to mitigate the risk of crop failure. Finally, community habits and trends can impact this behavior, as farmers often follow practices prevalent among their peers.

## 5. CONCLUSION AND RECOMMENDATION

Farmers' internal characteristics range from age, education level, farming experience, cultivated land area size, and land status. They also demonstrate different attitudes toward pesticide use, such as the purpose of pesticides or the practice of pesticide mixing and rotation. While 63% of farmers engaged in pesticide mixing, this practice was most prevalent among potato farmers (91%) and rare among maize and oil palm farmers. Only 31% of farmers practiced pesticide rotation, mainly among food crop farmers, with low rates observed among red chili and oil palm farmers. Pesticide mixing, while motivated by the perceived benefits of enhanced pest control and reduced labor costs, poses potential health risks due to improper handling and lack of protective equipment and may also compromise the effectiveness of active ingredients, leading to pest and disease resistance. Conversely, pesticide rotation, though less common among farmers, is a crucial practice for resistance management; however, its limited adoption is often due to farmers' brand loyalty and reliance on a single type of pesticide. Significant factors influencing mixing behaviors included commodity type, land size, source of information, number of brands used, number of pests and diseases, gender, and training participation. Rotation practices were significantly influenced by commodity type, pesticide label attention, number of pests and diseases, and disease attacks. These findings suggest the need for tailored training and education programs that consider these factors to improve farmers' understanding and implementation of effective pesticide management practices.

Most farmers purchase pesticides for prevention rather than control, anticipating the worst effects of pest and disease attacks. They also use pesticides in combination, which is believed to be due to the variety of pests and diseases attacking their crops. Farmers, on the other hand, are generally not advised to mix multiple pesticides in a tank or drum on their own; instead, they should purchase and use registered commercial products containing two active ingredients. Pesticide rotation is still uncommon, with farmers typically using the same brands for multiple seasons. On the one hand, this practice reflected brand loyalty, but it also reflected a lack of understanding about the importance of pesticide rotation in avoiding pest and disease resistance. This finding is attributed to the low rate of farmer participation in training, where they could learn and gain useful knowledge and skills about the best pesticide application practices.

The statistical analysis of four variables, number of pesticide brands, pesticide costs, type of pests and diseases, and seasonal purchasing, demonstrates that the commodities differentiate smallholders' pesticide use behavior. Horticulture farmers and rice farmers were found to have similar behavior. Rice farmers, moreover, exhibit significantly different behavior in terms of cost and seasonal purchasing, among other variables. Farmers express a different choice for maize and oil palm crops than other commodity groups because farming for both commodities is not intensively managed.

This study recommends that a comprehensive approach is necessary to improve pesticide use practices among Indonesian farmers and promote safer, more sustainable agriculture. This should include tailored training programs designed to meet the specific needs of different farmer groups. Pesticide training must be designed by considering farmers' behavior across different commodities to enhance knowledge accumulation in a specific commodity that will benefit farming practice in the long run. For instance, horticulture farmers could benefit from learning about the safe and effective use of multiple pesticide brands and mixing practices. Modules should include proper mixing techniques, pest identification and management, and health and safety protocols. The organizer or facilitator of the training may involve collaboration among multiple stakeholders, including agricultural extension services and field assistants from pesticide companies who used to work closely with farmers. Furthermore, some farmers still require advisory assistance following the training. Therefore, service advisors are encouraged to consider farmers' unique characteristics and behaviors when it comes to pesticide use. By implementing these tailored training programs and supporting services, the aim is to enhance farmers' knowledge and skills, reduce the risks associated with pesticide use, and promote a more sustainable and productive agricultural sector in Indonesia.

## ACKNOWLEDGEMENT

The authors would like to thank the Indonesian Centre for Plant Variety Protection and Agricultural Licensing (PVPAL Centre), Ministry of Agriculture, for funding the research. We would also like to thank the extension officers in the study areas who assisted with the data collection and the farmer respondents willing to be interviewed. Last but not least, much appreciated for all researchers under the National Research and Innovation Agency, the Indonesian Agency for Agricultural Research and Development (IAARD), and the staff in the PVPAL Centre involved in this study.

## REFERENCES

[1] Istriningsih, Dewi, Y.A., Yulianti, A., Hanifah, V.W., et al. (2022). Farmers' knowledge and practice regarding good agricultural practices (GAP) on safe pesticide usage in Indonesia. Heliyon, 8(1): e08708. https://doi.org/10.1016/j.heliyon.2021.e08708

[2] Joko, T., Anggoro, S., Sunoko, H.R., Rachmawati, S. (2017). Pesticides usage in the soil quality degradation potential in Wanasari Subdistrict, Brebes, Indonesia. Applied and Environmental Soil Science, 2017: 5896191. https://doi.org/10.1155/2017/5896191

[3] Khan, M., Mahmood, H.Z., Damalas, C.A. (2015). Pesticide use and risk perceptions among farmers in the cotton belt of Punjab, Pakistan. Crop Protection, 67: 184-190. https://doi.org/10.1016/j.cropro.2014.10.013

[4] Migheli, M. (2017). Land ownership and use of pesticides. Evidence from the Mekong Delta. Journal of Cleaner Production, 145: 188-198. https://doi.org/10.1016/j.jclepro.2017.01.045

[5] Schreinemachers, P., Chen, H.P., Nguyen, T.T.L., Buntong, B., et al. (2017). Too much to handle? Pesticide dependence of smallholder vegetable farmers in Southeast Asia. Science of the Total Environment, 593: 470-477. https://doi.org/10.1016/j.scitotenv.2017.03.181

[6] Wang, J., Chu, M., Ma, Y. (2018). Measuring rice farmer’s pesticide overuse practice and the determinants: A statistical analysis based on data collected in Jiangsu and Anhui Provinces of China. Sustainability, 10(3): 677. https://doi.org/10.3390/su10030677

[7] Joko, T., Dewanti, N.A.Y., Dangiran, H.L. (2020). Pesticide poisoning and the use of personal protective equipment (PPE) in Indonesian farmers. Journal of Environmental and Public Health, 2020(1): 5379619. https://doi.org/10.1155/2020/5379619

[8] Mariyono, J., Kuntariningsih, A., Kompas, T. (2018). Pesticide use in Indonesian vegetable farming and its determinants. Management of Environmental Quality: An International Journal, 29(2): 305-323. https://doi.org/10.1108/MEQ-12-2016-0088

[9] Mariyono, J., Kuntariningsih, A., Suswati, E., Kompas, T. (2018). Quantity and monetary value of agrochemical pollution from intensive farming in Indonesia. Management of Environmental Quality: An International Journal, 29(4): 759-779. https://doi.org/10.1108/MEQ-03-2017-0030

[10] Yuantari, M.G., Van Gestel, C.A., 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. Environmental Monitoring and Assessment, 187(3): 142. https://doi.org/10.1007/s10661-015-4371-3

[11] Sarkar, S., Gil, J.D.B., Keeley, J., Möhring, N., Jansen, K. (2021). The use of pesticides in developing countries and their impact on health and the right to food. European Union. https://www.europarl.europa.eu/RegData/etudes/STUD/2021/653622/EXPO_STU(2021)653622_EN.pdf.

[12] FAO. FAOSTAT. https://www.fao.org/faostat/en/#compare, accessed on

October 10, 2025.
[13] Atreya, K., Sitaula, B.K., Overgaard, H., Bajracharya, R.M., Sharma, S. (2012). Knowledge, attitude and practices of pesticide use and acetylcholinesterase depression among farm workers in Nepal. International Journal of Environmental Health Research, 22(5): 401-415. https://doi.org/10.1080/09603123.2011.650154
[14] Dasgupta, S., Meisner, C., Huq, M. (2007). A pinch or a pint? Evidence of pesticide overuse in Bangladesh. Journal of Agricultural Economics, 58(1): 91-114. https://doi.org/10.1111/j.1477-9552.2007.00083.x
[15] Mengistie, B.T., Mol, A.P.J., Oosterveer, P. (2017). Pesticide use practices among smallholder vegetable farmers in Ethiopian Central Rift Valley. Environment, Development and Sustainability, 19(1): 301-324. https://doi.org/10.1007/s10668-015-9728-9
[16] Sulistiyono, L., Tarumingkeng, R.C., Sanim, B., Dadang. (2012). Study on pesticides use in vegetable cultivation by IPM FFS and Non-IPM FFS farmers in East Java Province. Agri-Tek, 13(1): 82-93. https://id.scribd.com/doc/265045722/10-Luluk-sulistiyono-HAL-82-93-pdf.
[17] Skretteberg, L.G., Lyrån, B., Holen, B., Jansson, A., Fohgelberg, P., Siivinen, K., Andersen, J.H., Jensen, B.H. (2015). Pesticide residues in food of plant origin from Southeast Asia–A Nordic project. Food Control, 51: 225-235. https://doi.org/10.1016/j.foodcont.2014.11.008
[18] Ngowi, A.V.F., Mbise, T.J., Ijani, A.S.M., London, L., Ajayi, O.C. (2007). Smallholder vegetable farmers in Northern Tanzania: Pesticides use practices, perceptions, cost and health effects. Crop protection, 26(11): 1617-1624. https://doi.org/10.1016/j.cropro.2007.01.008
[19] Flor, R.J., Maat, H., Hadi, B.A.R., Then, R., Kraus, E., Chhay, K. (2020). How do stakeholder interactions in Cambodian rice farming villages contribute to a pesticide lock-in? Crop Protection, 135: 104799. https://doi.org/10.1016/j.cropro.2019.04.023
[20] Huang, Y., Luo, X., Li, Z. (2022). Substitution or complementarity: Why do rice farmers use a mix of biopesticides and chemical pesticides in China? Pest Management Science, 78(4): 1630-1639. https://doi.org/10.1002/ps.6781
[21] Damalas, C.A., Eleftherohorinos, I.G. (2011). Pesticide exposure, safety issues, and risk assessment indicators. International Journal of Environmental Research and Public Health, 8(5): 1402-1419. https://doi.org/10.3390/ijerph8051402
[22] Damalas, C.A., Koutroubas, S.D. (2016). Farmers' exposure to pesticides: Toxicity types and ways of prevention. Toxics, 4(1): 1. https://doi.org/10.3390/toxics4010001
[23] Sheskin, D.J. (2000). Handbook of Parametric and Nonparametric Statistical Procedures. 2nd ed. Chapman and Hall/CRC Press, USA.
[24] Bedoya-Marrugo, E.A., Vargas-Ortiz, L.E., Severiche-Sierra, C.A., Sierra-Calderon, D.D. (2017). Kruskal-Wallis test for the identification of factors that influence the perception of accidents in workers in the construction sector. International Journal of Applied Engineering Research, 12(17): 6730-6734. https://www.ripublication.com/ijaer17/ijaerv12n17_60.pdf.
[25] OECD. Working age population 2021. https://data.oecd.org/pop/working-age-population.htm, accessed on September 3, 2021.
[26] Guo, G., Wen, Q., Zhu, J. (2015). The impact of aging agricultural labor population on farmland output: From the perspective of farmer preferences. Mathematical problems in Engineering, 2015(1): 730618. https://doi.org/10.1155/2015/730618
[27] Paltasingh, K.R., Goyari, P. (2018). Impact of farmer education on farm productivity under varying technologies: Case of paddy growers in India. Agricultural and Food Economics, 6(1): 1-19. https://doi.org/10.1186/s40100-018-0101-9
[28] Paustian, M., Theuvsen, L. (2017). Adoption of precision agriculture technologies by German crop farmers. Precision Agriculture, 18(5): 701-716. https://doi.org/10.1007/s11119-016-9482-5
[29] Koirala, K.H., Mishra, A., Mohanty, S. (2016). Impact of land ownership on productivity and efficiency of rice farmers: The case of the Philippines. Land Use Policy, 50: 371-378. https://doi.org/10.1016/j.landusepol.2015.10.001
[30] 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. Journal of Cleaner Production, 200: 122-133. https://doi.org/10.1016/j.jclepro.2018.07.130
[31] Hashemi, S.M., Damalas, C.A. (2010). Farmers' perceptions of pesticide efficacy: Reflections on the importance of pest management practices adoption. Journal of Sustainable Agriculture, 35(1): 69-85. https://doi.org/10.1080/10440046.2011.530511
[32] Burleigh, J.R., Vingnanakulasingham, V., Lalith, W.R.B., Gonapinuwala, S. (1998). Pattern of pesticide use and pesticide efficacy among chili growers in the dry zone of NE Sri Lanka (System B): Perception vs reality. Agriculture, Ecosystems & Environment, 70(1): 49-60. https://doi.org/10.1016/S0167-8809(97)00159-X
[33] Damalas, C.A., Koutroubas, S.D. (2018). Farmers' behaviour in pesticide use: A key concept for improving environmental safety. Current Opinion in Environmental Science & Health, 4: 27-30. https://doi.org/10.1016/j.coesh.2018.07.001
[34] Sharifzadeh, M.S., Abdollahzadeh, G. (2021). The impact of different education strategies on rice farmers' knowledge, attitude and practice (KAP) about pesticide use. Journal of the Saudi Society of Agricultural Sciences, 20(5): 312-323. https://doi.org/10.1016/j.jssas.2021.03.003
[35] Cloyd, R.A. (2011). Pesticide mixtures. In Pesticides-Formulations, Effects, Fate, pp. 69-80. http://www.intechopen.com/books/pesticides-formulations-effects-fate/pesticide-mixtures.
[36] Moraes, H.M.F., Costa, J.O., Pereira, G.A.M., Souza, W.M., Silva, A.A., Paixão, G.P. (2019). Physical compatibility and stability of pesticide mixtures at different spray volumes. Planta Daninha, 37: e019214004. https://doi.org/10.1590/s0100-83582019370100125
[37] Tang, F.H.M., Maggi, F. (2021). Pesticide mixtures in soil: A global outlook. Environmental Research Letters, 16(4): 044051. https://doi.org/10.1088/1748-9326/abe5d6
[38] Istianah, Yuniastuti, A. (2017). Relationship of working

period, length of spraying, type of pesticide, use of PPE and pesticide management with poisoning incidence in farmers in Brebes. Public Health Perspective Journal, 2(2): 117-123. https://journal.unnes.ac.id/nju/phpj/article/view/13581/7479.

[39] Shammi, M., Sultana, A., Hasan, N., Rahman, M.M., Islam, M.S., Bodrud-Doza, M., Uddin, M.K. (2020). Pesticide exposures towards health and environmental hazard in Bangladesh: A case study on farmers' perception. Journal of the Saudi Society of Agricultural Sciences, 19(2): 161-173. https://doi.org/10.1016/j.jssas.2018.08.005

[40] Yuantari, M.G.C., Widianarko, B., Sunoko, H.R. (2015). Pesticide exposure risk analysis against farmers' health. Jurnal Kesehatan Masyarakat, 10(2): 239-245. https://doi.org/10.15294/kemas.v10i2.3387

[41] Sudo, M., Takahashi, D., Andow, D.A., Suzuki, Y., Yamanaka, T. (2018). Optimal management strategy of insecticide resistance under various insect life histories: Heterogeneous timing of selection and interpatch dispersal. Evolutionary Applications, 11(2): 271-283. https://doi.org/10.1111/eva.12550

[42] Bryant, T., Reay-Jones, F.P.F. (2020). Insecticide resistance: Overview and management. Clemson (SC): Clemson Cooperative Extension, Land-Grant Press by Clemson Extension.

[43] Mustikarini, F., Retnaningsih, R., Simanjuntak, M. (2014). Satisfaction and loyalty to pesticides among paddy farmers. Jurnal Ilmu Keluarga dan Konsumen, 7(2): 93-102. https://doi.org/10.24156/jikk.2014.7.2.93

[44] Sumekar, Y., Riswandi, D., Widayat, D., Umiyati, U. (2021). The effect of paraquat dichloride herbicide for weed control in immature oil palm plantations. International Journal of Multidisciplinary Research and Growth Evaluation, 2(1): 248-251.

[45] Sidik, S., Purba, E., Yakub, E.N. (2018). Population dynamics of weeds in oil palm (*Elaeis guineensis Jacq.*) circle weeding area affected by herbicide application. IOP Conference Series: Earth and Environmental Science, 122(1): 012069. https://doi.org/10.1088/1755-1315/122/1/012069

[46] Seng, C.T., Yusop, N., Pauzi, S.A., Ramli, N.K.C.M., Aani, S.N.A., Sahal, M.S.A.M., Pahang, J.T., Purba, E., Sa'adah, N. (2024). Survey of herbicide-resistant weed management in oil palm estates from Peninsular Malaysia and Indonesia. Advances in Weed Science, 42: e020240030.

[47] 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. International Journal of Agronomy and Plant Production, 4(5): 873-883.

[48] Zhu, W., Wang, R. (2021). Impact of farm size on intensity of pesticide use: Evidence from China. Science of the Total Environment, 753: 141696. https://doi.org/10.1016/j.scitotenv.2020.141696

[49] Rondhi, M., Adi, A.H. (2018). The effects of land ownership on production, labor allocation, and rice farming efficiency. AGRARIS: Journal of Agribusiness and Rural Development Research, 4(2): 101-110. https://doi.org/10.18196/agr.4265

[50] Fadwiwati, A.Y., Tahir, A.G. (2013). Analysis of factors affecting maize production and farm income in Gorontalo Province. Jurnal Pengkajian dan Pengembangan Teknologi Pertanian, 16(2): 92-101. https://repository.pertanian.go.id/handle/123456789/1879.

[51] Somantri, R.U., Hadiyanti, D., Syahri. (2017). Potato farming in the highlands of South Sumatra. In Proceedings of the National Seminar on Developing Modern and Innovative Sustainable Agriculture to Support the ASEAN Economic Community (AEC), 83: 349-356. https://repository.pertanian.go.id/handle/123456789/6523.

[52] Kiloes, A.M., Hardiyanto. (2020). Feasibility of garlic farming at various output price levels. Jurnal Hortikultura, 29(2): 231-240. https://doi.org/10.21082/jhort.v29n2.2019.p231-240

[53] Ni'mah, N., Hariyati, Y., Agustina, T. (2017). Analysis of price and cost efficiency in red chili (*Capsicum annuum L*) farming in Wuluhan District, Jember Regency. Journal of Social and Agricultural Economics, 10(3): 43-52. https://jsep.jurnal.unej.ac.id/index.php/JSEP/article/view/7152/5356.

[54] Salam, M., Auliyah, N., Saadah, Tenriawaru, A.N., Diansari, P., Rahmadanih, Muslim, A.I., Ali, H.N.B., Ridwan, M. (2024). Determinants of rice production in Bantaeng Regency, Indonesia : In search of innovative sustainable farm management practices. Heliyon, 10(23): e40634. https://doi.org/10.1016/j.heliyon.2024.e40634

[55] Isnurdiansyah, I., Tinaprilla, N., Utami, A.D. (2025). Determinant factors of climate-smart rice cultivation production in Pasuruan: Translog production function approach. Journal of Indonesian Agribusiness, 13(1): 223-240. https://doi.org/10.29244/jai.2025.13.1.223-240

[56] Sumaryanto, Wahida, Siregar, M. (2016). Determinants of Technical Efficiency in Rice Farming on Irrigated Land. Jurnal Agro Ekonomi, 21(1): 72-96. https://repository.pertanian.go.id/handle/123456789/231

[57] Saptana, Daryanto, A., Daryanto, H.K., Kuntjoro. (2016). Production technical efficiency analysis in great red chili farming and farmers' behavior in dealing with risk. Jurnal Agro Ekonomi, 28(2): 153-188. https://repository.pertanian.go.id/handle/123456789/360

[58] Verdayanti, G., Affandi, M.I., Suryani, A. (2020). Analysis of income and economic of scale of onion farming in Metro City. Journal of Agribusiness Science, 8(2): 210-217. https://doi.org/10.23960/jiia.v8i2.4055

[59] Nurjati, E., Fahmi, I., Jahroh, S. (2018). Analyzing the efficiency of shallot production in Pati Regency using the Cobb-Douglas stochastic frontier production function. Jurnal Agro Ekonomi, 36(1): 55-69. https://doi.org/10.21082/jae.v36n1.2018.55-69

[60] Sita, B.R., Hadi, S. (2016). Productivity and factors influencing tomato (*Solanum lycopersicum Mill*) farming production in Jember Regency. Jurnal Sosial Ekonomi Pertanian, 9(3): 67-78. https://doi.org/10.19184/jsep.v9i3.6495

[61] Naufal, M., Waluyati, L.R., Darwanto, D.H. (2019). Performance of coconut palm oil farming in Dayun Village, Siak District. Jurnal Teknosains, 9(1): 77-85. https://doi.org/10.22146/teknosains.38976