

# Farmers' perceptions of fall armyworm pest management practices in Bali, Indonesia

RATNA KOMALA DEWI<sup>1,\*</sup>, I NYOMAN GEDE USTRIYANA<sup>1</sup>, ZULAZMI<sup>2</sup>, I KADEK WISMA YUDHA<sup>2</sup>

<sup>1</sup>Department of Agribusiness, Faculty of Agriculture, Universitas Udayana. Jl. P.B. Sudirman, West Denpasar, Denpasar 80234, Bali, Indonesia.

Tel.: +62-361-222450, \*email: ratnadewi61@gmail.com

<sup>2</sup>Department of Agroecotechnology, Faculty of Agriculture, Universitas Udayana. Jl. P.B. Sudirman, West Denpasar, Denpasar 80234, Bali, Indonesia

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**Abstract.** Dewi RK, Ustriyana ING, Zulazmi, Yudha IKW. 2026. Farmers' perceptions of fall armyworm pest management practices in Bali, Indonesia. *Asian J Agric* 10 (1): g100171. <https://doi.org/10.13057/asianjagric/g100171>. Maize crops in Bali, Indonesia, are widely affected by the fall armyworm (FAW) (*Spodoptera frugiperda*), causing significant economic losses. This study aimed to assess farmers' perceptions of fall armyworm infestation and its perceived economic impacts, and to document pest management practices among maize farmers in Bali. This study used survey data obtained from 200 farmers from April 2024 to May 2025 across 9 districts and 1 city in Bali and was analyzed using descriptive statistics. Farmers' education levels ranged from elementary school to bachelor's degree, with most farmers having more than 10 years of farming experience. Approximately 52% of farmers reported 50-75% crop losses due to fall armyworm infestation during the dry season, which is perceived to affect farmers' income. Most farmers perceived fall armyworm as a major threat to maize production. A total of 78% of farmers were able to correctly identify FAW, and 77% agreed that infestation reduces income. Emamectin benzoate was the most commonly used pesticide (28%) in pest management practices. The widespread use of synthetic pesticides was reported, often without adequate personal protective equipment, and pesticide application was not always aligned with recommended guidelines. These findings suggest the need for practical interventions, including farmer training and extension programs that can be implemented by the local government to improve pest management practices and reduce the impact of fall armyworm in Bali.

**Keywords:** Bali, fall armyworm, maize, pest management practices, *Spodoptera frugiperda*

## INTRODUCTION

Agriculture plays a major role in the Indonesian economy, employing approximately 30% of the national workforce, equivalent to about 40.64 million people. In Bali, the agricultural sector accounts for 19.89% of total employment, employing approximately 16.12 thousand individuals. Maize is one of the main staple crops in Indonesia after rice and serves as an important source of food and income for rural populations (Ihdhinashita et al. 2023). However, maize production systems are increasingly challenged by the invasion of destructive insect pests, which threaten food security, reduce yields, and increase production costs (Day et al. 2017; Early et al. 2018; Sesay et al. 2024). One such pest is the fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), which has recently invaded Indonesia and is now widely reported in maize-growing regions, including Bali.

Previous surveys conducted across Bali have shown that this pest is widely distributed across major agro-ecological zones, raising concerns among farmers about its perceived economic impacts on maize production (Supartha et al. 2021; Yudha et al. 2024). At the farm level, farmers perceive that fall armyworm infestation increases labor requirements, contributes to yield losses, and raises production costs, which are perceived to affect household income and livelihood stability (Kansiime et al. 2019;

Kalyebi et al. 2023). More broadly, agricultural systems are increasingly threatened by invasive species, defined as non-native organisms that establish in new environments and cause adverse impacts on agriculture, ecosystems, and human livelihoods. The spread of invasive species has been accelerated by global trade, transportation, and climate variability (Rai and Singh 2020; Sesay et al. 2024).

In Indonesia, *S. frugiperda* was first reported in early 2019 on maize plants in Sumatra (Sartiami et al. 2020), followed by its detection in West Java, including Bandung, Garut, and Sumedang (Maharani et al. 2019). Subsequent studies reported its spread to Bali, where it was observed attacking various maize types across all districts (Supartha et al. 2021). As a highly polyphagous pest, *S. frugiperda* feeds on a wide range of host plants, with reports indicating more than 186 host species and up to 353 species in broader reviews (Montezano et al. 2018). Yield reductions associated with this pest have been widely reported across different agroecological contexts (Kansiime et al. 2019; Togola et al. 2025). Furthermore, climatic conditions in tropical regions, including Indonesia, are considered highly suitable for the establishment and persistence of this pest (Early et al. 2018; Sesay et al. 2024).

Recent studies have emphasized that the rapid spread and high adaptability of *S. frugiperda* make it difficult to control, particularly in tropical and Southeast Asian regions where frequent outbreaks have been reported (Rane et al. 2023; Kusano et al. 2025). In many parts of Indonesia,

including Bali, pest control practices remain highly dependent on chemical pesticides. While chemical control may provide rapid suppression of pest populations, inappropriate or excessive use can lead to environmental contamination, health risks, and pesticide resistance (Paredes-Sánchez et al. 2021; Li et al. 2022; Pathak et al. 2022; Zhou et al. 2025). Integrated Pest Management (IPM) strategies are therefore increasingly recommended to reduce reliance on chemical inputs and promote sustainable pest control (Zhou et al. 2024).

Despite the growing body of literature on the biology, ecology, and control of *S. frugiperda*, there remains limited empirical evidence on how farmers perceive this pest, how they interpret its impacts, and how these perceptions relate to their management decisions, particularly in local contexts such as Bali (Kansiime et al. 2019; Kalyebi et al. 2023). Much of the available information on farmers' pest control practices and the underlying reasons for their choices remains insufficiently documented. Such information is essential for researchers, policymakers, and extension agencies seeking to design sustainable and context-specific pest management interventions.

This study does not aim to quantify field-level crop damage or yield loss through direct measurements. Instead, it focuses on farmers' perceptions of fall armyworm infestation and its perceived impacts on maize production. Therefore, the aim of this study was to examine farmers' perceptions of fall armyworm infestation and document pest management practices among maize farmers in Bali. The findings of this study are expected to contribute to the development of farmer-centered and locally appropriate strategies for managing *S. frugiperda*.

## MATERIALS AND METHODS

### Study area and research design

This study was conducted in major maize-growing areas across 9 districts and 1 city in Bali, Indonesia. Bali was selected due to the widespread occurrence of fall armyworm (*S. frugiperda*) infestation and its importance as a maize-producing region. A cross-sectional survey design was adopted to assess farmers' perceptions of *S. frugiperda* infestation, its perceived impacts on maize production, and pest management practices employed by farmers. The study focused on farmers' subjective experiences and decision-making processes rather than direct field-based quantification of pest damage.

### Sampling procedure and respondent selection

A total of 200 maize farmers were interviewed. The sample size was considered adequate for exploratory and descriptive research. A purposive (non-random) sampling approach was employed to ensure that respondents had direct and recent experience with maize cultivation and fall armyworm infestation. Farmers were selected from different districts based on maize production areas and the confirmed presence of FAW infestation. The respondents were distributed across districts and the city based on the intensity of maize cultivation and FAW infestation.

Respondents were identified through secondary data obtained from local Agricultural Extension Offices and through direct field visits. This sampling approach was chosen because *S. frugiperda* infestation did not affect all farming households uniformly; therefore, targeting farmers with direct exposure to the pest allowed for more relevant and experience-based responses. However, purposive sampling may introduce selection bias and does not allow for full statistical representativeness. Therefore, the results should be interpreted as indicative rather than fully generalizable.

### Data collection

Data were collected between April 2024 and May 2025 using a semi-structured questionnaire. The questionnaire consisted of sections on socio-demographic characteristics, knowledge, perception, and pest management practices. Interviews were conducted through face-to-face interactions by trained enumerators using the local language to ensure clear understanding and accurate responses. The questionnaire was pre-tested in one district prior to the main survey to improve clarity, consistency, and logical flow. Data were recorded using the Open Data Kit (ODK) platform on tablet devices, enabling real-time data validation and reducing data entry errors.

Target respondents were household members responsible for agricultural decision-making, including crop selection, pest management, and input use. In cases where the primary farmer was unavailable, the spouse or another household member involved in farming decisions was interviewed.

### Measurement of knowledge, perception, and practices

This study applied the Knowledge-Perception-Practice (KPP) framework to analyze farmers' responses. Similar approaches have been used in perception-based agricultural studies (Schreinemachers et al. 2015). Knowledge was assessed based on farmers' ability to recognize *S. frugiperda*, its developmental stages, and associated damage symptoms. Respondents were shown photographs of the pest at different life stages and images of characteristic feeding damage, and were asked whether they were familiar with the pest and whether it had a local name.

Perception was assessed through farmers' reported views on infestation severity, perceived yield loss, and the effectiveness of pest control measures. Farmers rated the seriousness of infestation and estimated the proportion of crop area affected using categorical and Likert-type response scales.

Practices were assessed based on reported pest management strategies, including pesticide use, frequency of application, choice of active ingredients, application methods, and use of personal protective equipment. This study did not quantify objective field-level crop damage using direct measurements. Instead, it focused on farmers' self-reported estimates and perceptions. Although such estimates may be less precise, they provide valuable insights into farmers' decision-making processes and behavioral responses.

### Data analysis

Descriptive statistical analysis was used to summarize farmers' socio-demographic characteristics, perceptions, and pest management practices. Frequencies and percentages were calculated to describe response patterns. The analysis focused on identifying general trends rather than testing statistical hypotheses or establishing causal relationships.

### Ethical considerations

Participation in the study was voluntary, and all respondents were informed about the objectives and procedures prior to data collection. Verbal informed consent was obtained from each participant. No personal identifiers were recorded, and all responses were treated confidentially. The data were used exclusively for academic research purposes.

### Methodological limitations

This study relies on self-reported data, which may be subject to recall bias and subjective interpretation. In addition, the purposive sampling design limits the generalizability of the findings. However, this approach is appropriate for exploratory and perception-based studies, particularly for newly invasive pests such as *S. frugiperda*, where understanding farmers' experiences and responses is essential for developing context-specific management strategies.

## RESULTS AND DISCUSSION

### Profile of corn farmers in Bali

The socio-demographic characteristics of the interviewed maize farmers in Bali are presented in Table 1. Of the 200 respondents, the majority were male (88%). This pattern is consistent with previous studies showing that agricultural decision-making in many developing regions is predominantly male-dominated (Kansiime et al. 2019). While only 12% were female. Most farmers had relatively low levels of formal education, with 44% having completed only elementary school, followed by junior high school (28%), senior high school (16%), and diploma or bachelor's degree (12%). In terms of farming experience, most respondents had been cultivating maize for more than 10 years (67%), while 22% had 5-10 years of experience and 11.5% had less than five years. All respondents (100%) were members of farmer groups (*subak*).

These characteristics indicate that maize farming in Bali was largely dominated by experienced farmers with relatively limited formal educational attainment. Lower educational levels may influence farmers' access to technical information and their understanding of more complex concepts such as economic thresholds, insecticide resistance, and Integrated Pest Management (IPM). However, long farming experience and strong participation in farmer groups represent important social capital that can facilitate knowledge exchange and collective learning. Therefore, farmer organizations provide a strategic

platform for extension programs aimed at promoting sustainable pest management.

Most farmers practiced monoculture cropping (89.5%), while only 10.5% applied intercropping systems. Monoculture systems were known to increase pest pressure by providing a continuous and uniform food source. Regarding pest recognition, 78% of farmers reported that they were able to identify *S. frugiperda*, while 16% were unable to identify it, and 6% were uncertain. This suggests that field experience plays a major role in building practical knowledge, although visual recognition alone does not necessarily reflect a deeper understanding of pest biology or appropriate management strategies.

### Farmers' perceptions of the economic impact of *Spodoptera frugiperda*

Farmers' perceptions of the economic impact of *S. frugiperda* infestation are summarized in Table 2. A large proportion of respondents (77%) strongly agreed that FAW infestation reduces their income, while 18.5% agreed. Similarly, 89% of farmers strongly agreed that *S. frugiperda* represents a serious threat to maize production, and 93.5% strongly agreed that FAW infestation reduces maize yields. These findings indicate that FAW is widely perceived as a major threat to farmers' livelihoods. Similar findings have been reported by Midega et al. (2018) and Kansiime et al. (2019), who found that farmers perceive FAW as a serious pest and respond with increased pest management efforts.

**Table 1.** Self-reported socio-demographic profile of interviewed maize farmers in Bali, Indonesia

| Research variables                                | Bali (N=200) |
|---|--------------|
| Gender  |              |
| Male  | 176 (88%)    |
| Female  | 24 (12%)     |
| Education   |              |
| Elementary School                                 | 88 (44%)     |
| Junior High School                                | 56 (28%)     |
| Senior High School                                | 32 (16%)     |
| Diploma/Bachelor                                  | 24 (12%)     |
| Maize farming experience                          |              |
| <5 Years  | 23 (11.5%)   |
| 5-10 years  | 43 (22%)     |
| >10 years   | 134 (67%)    |
| Joining a farmer group                            |              |
| Yes   | 200 (100%)   |
| No  | 0            |
| Source of maize seeds                             |              |
| Local   | 14 (7%)      |
| Purchasing  | 112 (56%)    |
| Government assistance                             | 74 (37%)     |
| Maize planting pattern                            |              |
| Monoculture                                       | 179 (89.5%)  |
| Intercropping                                     | 21 (10.5%)   |
| Farmers' ability to identify <i>S. frugiperda</i> |              |
| Able  | 156 (78%)    |
| Not able  | 32 (16%)     |
| Don't know  | 12 (6%)      |

Note: Values in parentheses indicate percentages based on self-reported responses from interviewed farmers (N = 200)

The strong concern expressed by farmers may be related to the invasive nature of the pest, which is relatively new in the region and may be associated with limited prior experience in its management. In many cases, such conditions may be associated with increased perceived vulnerability and more intensive pest control practices. Most farmers disagreed that *S. frugiperda* reduces production costs, suggesting that FAW infestation is perceived as increasing expenditures rather than reducing them. This perception reflects the additional financial burden associated with repeated pesticide applications and the use of multiple products. Therefore, farmers' perceptions of economic loss may be associated not only with yield reduction but also with increased input costs.

### Seasonal perceptions of infestation severity

Farmers' perceptions of the severity of *S. frugiperda* infestation during the rainy and dry seasons are shown in Figure 1. In the dry season, 80% of farmers perceived FAW infestation as very severe, while in the rainy season this proportion was lower (60%). In addition, 28% of farmers in the dry season and 20% in the rainy season considered the infestation to be serious but manageable with appropriate control measures. These patterns suggest that farmers associate FAW infestation severity with seasonal conditions. This is reflected in the descriptive data, where a higher proportion of farmers reported severe infestation during the dry season compared to the rainy season. Environmental factors such as drought conditions may be related to farmers' perceptions of increased pest severity, although this study did not directly assess environmental variables. Seasonal risk perception may be associated with differences in pest management responses reported by farmers. However, these observations are descriptive in nature. Inferential statistical tests were not conducted; therefore, seasonal differences should be interpreted as indicative patterns rather than statistically confirmed relationships.

### Perceived yield losses due to FAW infestation

The distribution of perceived maize yield losses reported by farmers is presented in Figure 2. In the dry season, 12% of farmers reported yield losses of less than 25%, whereas in the rainy season this proportion was 4%. Yield losses of 25-50% were reported by 44% of farmers in the dry season and 32% in the rainy season. Most farmers reported losses in the range of 50-75%, with 52% in the dry season and 48% in the rainy season. Furthermore, 8% of farmers in the dry season reported losses exceeding 75%. These values represent farmers' self-reported perceptions rather than objective field measurements. Such perception-based estimates are important for understanding how farmers evaluate pest-related risks under field conditions. In the absence of systematic field-based assessments, farmers rely on their experiences to interpret infestation severity and potential impacts.

When perceived losses are high, increased pest management efforts were reported by farmers. However, this study did not statistically assess relationships between perceived losses and specific management practices;

therefore, these patterns should be interpreted as descriptive observations. Reported yield losses of 50-75% or higher should be interpreted with caution. Empirical field-based studies in other regions often report lower average yield reductions under controlled assessments (Baudron et al. 2019; Kansime et al. 2019). The relatively high values reported in this study may reflect perception-based estimates influenced by recall bias, seasonal variability, and subjective risk perception during severe outbreaks. Therefore, these figures represent perceived impacts rather than objectively measured yield losses.

### Pest management practices and dependence on chemical pesticides

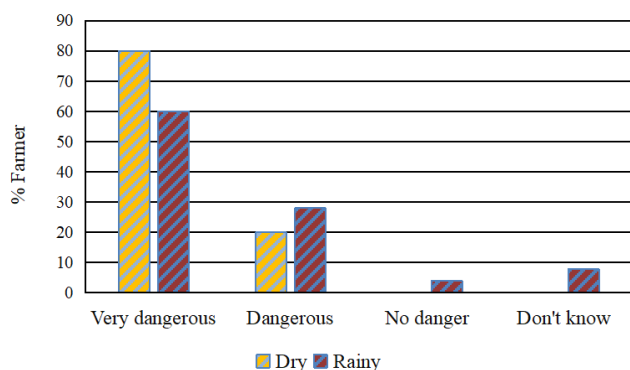
The types of pesticide active ingredients used by farmers to control FAW are shown in Figure 3. The most commonly used active ingredient was emamectin benzoate (28%), followed by methomyl (22.5%), cypermethrin (20.5%), lambda-cyhalothrin (18.5%), and carbofuran (10.5%). These results indicate that farmers commonly use various chemical pesticides to manage FAW under field conditions. However, this study did not evaluate the factors underlying pesticide selection and use patterns.

Frequent switching or mixing of insecticides without proper technical guidance may increase the risk of pest resistance and environmental contamination (Paredes-Sánchez et al. 2021; Pathak et al. 2022; Zhou et al. 2025). Figure 3 presents descriptive data on farmers' pesticide use patterns and should be interpreted as indicative rather than statistically comparative, as no measures of variability or inferential analyses were applied.

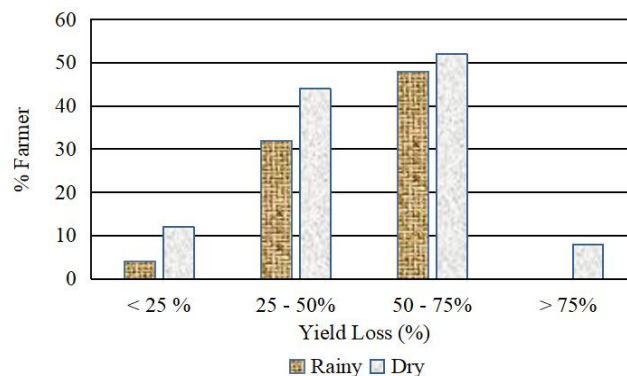
**Table 2.** Self-reported perceptions of maize farmers in Bali, Indonesia, regarding the economic impacts of *Spodoptera frugiperda*

| Research variables                                       | Bali (N=200) |
|--|--------------|
| <i>S. frugiperda</i> pest attacks reduce farmers' income |              |
| Strongly disagree  | 0            |
| Disagree   | 0            |
| No opinion   | 9 (4.5%)     |
| Agree  | 37 (18.5%)   |
| Strongly agree   | 154 (77%)    |
| <i>S. frugiperda</i> threat to maize production          |              |
| Strongly disagree  | 0            |
| Disagree   | 0            |
| No opinion   | 0            |
| Agree  | 22 (11%)     |
| Strongly agree   | 178 (89%)    |
| <i>S. frugiperda</i> reduces maize yields                |              |
| Strongly disagree  | 0            |
| Disagree   | 0            |
| No opinion   | 0            |
| Agree  | 13 (6.5%)    |
| Strongly agree   | 187 (93.5%)  |
| <i>S. frugiperda</i> reduces maize production costs      |              |
| Strongly disagree  | 121 (60.5%)  |
| Disagree   | 43 (21.5%)   |
| No opinion   | 0            |
| Agree  | 21 (10.5%)   |
| Strongly agree   | 15 (7.5%)    |

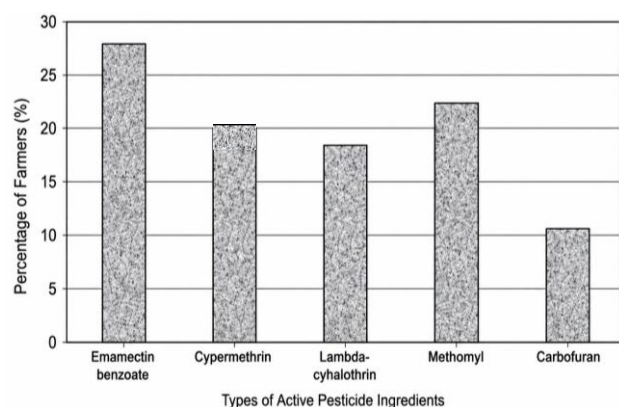
Note: Values in parentheses indicate percentages based on self-reported responses from interviewed farmers (N = 200)



**Figure 1.** Level of farmer perception regarding the seriousness of *Spodoptera frugiperda* pest on corn production in the rainy and dry seasons



**Figure 2.** Self-reported categories of perceived maize yield loss attributed to *Spodoptera frugiperda* infestation during the rainy and dry seasons (N = 200)



**Figure 3.** Farmers use several types of active pesticide ingredients to control *S. frugiperda* pests on corn plants in Bali, Indonesia

### Insecticide application methods and safety practices

Data on insecticide application methods, frequency, and safety practices are summarized in Table 3. Most farmers (77%) reported using more than one type of pesticide, and 77% applied pesticides more than twice per season. A large proportion of farmers (99%) reported not using personal protective equipment (PPE) during pesticide application. In addition, 61% of farmers reported applying pesticides in a targeted manner, while a considerable proportion still relied on random application.

These findings indicate a high reliance on chemical pesticides as a primary strategy for FAW management under field conditions. The use of multiple pesticides and frequent application was observed among respondents; however, this study did not assess the underlying reasons for these practices. Frequent and intensive pesticide use may be associated with potential health risks, environmental contamination, and the development of insecticide resistance (Paredes-Sánchez et al. 2021; Pathak et al. 2022; Zhou et al. 2025). The limited use of PPE reported in this study may also increase exposure risks for farmers. These findings can be interpreted within the Knowledge-Perception-Practice (KPP) framework.

Although 78% of respondents reported being able to identify *S. frugiperda*, the continued reliance on chemical insecticides and limited use of PPE suggest that knowledge recognition does not necessarily correspond to the adoption of safer or more sustainable practices. However, this study did not statistically assess relationships between knowledge, perception, and practices; therefore, these interpretations should be considered descriptive.

### Implications for sustainable pest management

The findings of this study highlight the importance of considering more sustainable approaches to FAW management in Bali. Farmers' perception of *S. frugiperda* as a major threat was accompanied by intensive pesticide use reported in this study. While pesticide use may provide short-term control, it may also be associated with potential economic, environmental, and health risks. The observed reliance on chemical pesticides may be related to several contextual factors. FAW is a relatively new invasive pest in the region, and farmers may have limited prior experience in managing it. Chemical insecticides are widely available and commonly used, although this study did not assess farmers' knowledge regarding recommended pesticide use or effectiveness. In addition, limited access to alternative control methods may contribute to continued reliance on chemical inputs.

Frequent and intensive pesticide applications may increase the risk of insecticide resistance and reduce long-term effectiveness (Paredes-Sánchez et al. 2021; Pathak et al. 2022; Zhou et al. 2025). In addition, prolonged exposure to chemical pesticides may pose risks to human health and contribute to environmental contamination.

Although this study did not directly assess extension services or training programs, strengthening farmer education and knowledge-sharing platforms may support improved pest management practices. Farmer groups (*subak*) may serve as potential platforms for knowledge exchange and collective learning. Community-based approaches may also facilitate coordinated pest management at the landscape level.

**Table 3.** Self-reported insecticide application practices for the management of *Spodoptera frugiperda* in Bali, Indonesia

| Research variables                         | Bali (N=200) |
|--|--------------|
| Pesticide application method               |              |
| Application of one type of pesticide       | 46 (23%)     |
| Application of several types of pesticides | 154 (77%)    |
| Frequency of Application Per Season        |              |
| Once                                       | 5 (2.5%)     |
| Twice                                      | 41 (20.5%)   |
| More than twice                            | 154 (77%)    |
| Using personal protective equipment        |              |
| Yes  | 2 (1%)       |
| No   | 198 (99%)    |
| Pesticide application methods              |              |
| Random application                         | 78 (39%)     |
| Targeted application                       | 122 (61%)    |

Note: Values in parentheses indicate percentages based on self-reported responses from interviewed farmers (N = 200)

### Limitations of the study

This study relied on perception-based and self-reported data rather than direct field measurements of FAW damage. Therefore, the reported yield losses and infestation severity should be interpreted as perceived impacts rather than objective estimates. Although farmers' perceptions provide important insights into how pest impacts are understood under field conditions, this study did not statistically assess relationships between perceptions and specific management decisions or behavioral responses. In addition, purposive sampling was used to select respondents, which limits the generalizability of the findings to the broader population of maize farmers in Bali.

In conclusion, this study shows that maize farmers in Bali perceive *S. frugiperda* as a major threat to production and income, and this perception was accompanied by a high reliance on chemical pesticides. Farmers commonly use multiple pesticide active ingredients under field conditions. However, frequent pesticide applications may be associated with potential health risks, environmental contamination, and insecticide resistance. These findings suggest that current FAW management practices may not be sustainable in the long term. Strengthening farmer education and promoting Integrated Pest Management (IPM) approaches may help reduce excessive pesticide dependence and support more sustainable pest management. Future studies are recommended to incorporate more robust sampling designs and inferential analyses to strengthen evidence-based FAW management strategies.

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