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Enhancing Young Farmers' Capacity in Integrated Pest Management for Sustainable Agriculture: A Community-Based Training Approach

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ABSTRACT

Young farmers play a crucial role in promoting sustainable agriculture, yet many lack the necessary knowledge and skills to implement Integrated Pest Management (IPM) effectively. The overreliance on chemical pesticides in conventional farming has led to environmental degradation, increased pest resistance, and health risks. To address this issue, a community-based training program was conducted in Bungaraya, Indonesia, targeting young farmers from Sanggar Tani Muda and students from SMKN 1 Bungaraya, Siak, Indonesia. The training aimed to enhance their capacity in IPM. The program was implemented through seminars and hands-on workshops, covering key aspects of IPM such as pest identification, biological control, and the use of botanical pesticides. The impact of the training was assessed through pre-test and post-test evaluations, with statistical analysis using the Wilcoxon Signed-Rank Test indicating a significant improvement in participants' knowledge and skills (p-value = 1.86×10^{-9}). As part of the program's outputs, a training module on IPM was developed and published for broader dissemination. The results suggest that community-based training is an effective approach to equipping young farmers with the necessary competencies in sustainable pest management. Future initiatives should focus on scaling up similar training programs and ensuring continuous mentoring to support young farmers in transitioning towards environmentally responsible agricultural practices.

1. INTRODUCTION

Agriculture is a fundamental sector that supports global food security and rural livelihoods. However, modern agricultural practices often rely heavily on chemical pesticides to control plant pests and diseases. While pesticides have contributed to increased agricultural productivity, their excessive and indiscriminate use has led to severe environmental degradation, pesticide resistance, and human health risks (Purnama et al., 2025; Purnama et al., 2023; Pathak et al., 2022). Overuse of synthetic pesticides has been linked to soil degradation, water contamination, and biodiversity loss, which undermine the long-term sustainability of agricultural systems (Pretty & Bharucha, 2015). Moreover, continuous pesticide application has accelerated the development of pesticide-resistant pest populations, making pest control more challenging and increasing farmers' dependency on stronger chemical formulations (Pathak et al., 2022).

In response to these challenges, integrated pest management (IPM) has been widely recognized as a sustainable approach to pest control. IPM integrates biological, cultural, mechanical, and chemical control strategies to minimize pest damage while reducing reliance on synthetic pesticides (Angon et al., 2023; Purnama et al., 2024). Studies have shown that the implementation of IPM can significantly reduce pesticide use while maintaining or even increasing crop productivity (Pretty & Bharucha, 2015). However, despite these benefits, the adoption of IPM remains limited, particularly among young farmers, due to a lack of technical knowledge, training, and access to extension services (Carlisle et al., 2019).

Young farmers play a critical role in shaping the future of sustainable agriculture as they are generally more receptive to adopting new technologies and environmentally friendly practices (Phung & Dao, 2024). However, many young farmers in rural areas lack adequate training in IPM and continue to rely on conventional pesticide-based farming methods inherited from previous generations. The limited availability of practical, hands-on training programs has been identified as a significant barrier to IPM adoption, as many existing initiatives focus primarily on theoretical knowledge rather than applied field-based learning (Angon et al., 2023).

Symbiosis Civicus, June 2025, 2 (1):1-9
DOI: https://doi.org/10.32663/.....

This gap highlights the need for effective training programs that combine classroom-based education with practical field applications, allowing young farmers to develop the necessary skills to implement IPM successfully.

To address this gap, this study evaluates the effectiveness of a community-based training program designed to enhance young farmers' capacity in IPM. The program was conducted in Bungaraya, Indonesia, involving members of Sanggar Tani Muda and students from SMKN 1 Bungaraya. Training sessions consisted of seminars and hands-on workshops covering key aspects of IPM, such as pest identification, biological control methods, and the use of botanical pesticides. The impact of the training was assessed through pre-test and post-test evaluations, measuring the improvement in participants' knowledge and application of IPM principles.

The objectives of this study are to assess the knowledge level of young farmers on IPM before and after training, evaluate the effectiveness of community-based training in enhancing their ability to implement IPM strategies and examine the potential for scaling up similar training programs in other farming communities. By addressing these objectives, this study contributes to the growing body of knowledge on agricultural education and capacity-building initiatives, offering insights into the role of structured training programs in promoting sustainable pest management practices among young farmers.

2. THEORY

Integrated pest management and its role in sustainable agriculture

Integrated pest management (IPM) is a strategic approach to pest control that combines multiple management practices to minimize economic, environmental, and health risks associated with excessive pesticide use. IPM integrates biological, cultural, mechanical, and chemical control methods to achieve long-term pest suppression while maintaining ecological balance (Angon et al., 2023). Unlike conventional pest control methods that rely heavily on chemical pesticides, IPM focuses on preventive measures, monitoring, and applying targeted interventions only when necessary. This approach not only reduces the negative environmental impacts of pesticides but also improves farm profitability by lowering input costs (Pretty & Bharucha, 2015).

One of the core principles of IPM is pest population monitoring, which involves identifying pests and their natural enemies to determine the economic threshold level (ETL) at which control measures should be implemented (Ehler, 2006). By relying on economic threshold levels, farmers can avoid unnecessary pesticide applications, thereby minimizing environmental contamination and reducing the risk of pesticide resistance among pests (Pathak et al., 2022).

Environmental and economic benefits of IPM

IPM has been widely recognized as an essential component of sustainable agricultural systems due to its ability to maintain crop yields while reducing pesticide dependency (Pretty & Bharucha, 2015). Studies indicate that farms that implement IPM can experience significant reductions in pesticide usage—by up to 50 percent—while maintaining or increasing yields (Angon et al., 2023). This is because IPM promotes ecosystem-based approaches, such as crop rotation, biological control, and habitat manipulation, which help prevent pest outbreaks rather than reacting to them with synthetic pesticides (Phung & Dao, 2024).

Economic analyses suggest that farmers who adopt IPM often achieve higher net returns due to reduced chemical input costs and improved pest control efficiency (Carlisle et al., 2019). Moreover, by preserving soil health and biodiversity, IPM contributes to long-term agricultural productivity, ensuring that farming remains viable for future generations.

Challenges in IPM adoption among young farmers

Despite its benefits, IPM adoption among farmers, particularly young farmers, remains limited due to various barriers, including lack of technical knowledge, limited access to extension services, and traditional farming practices that favor chemical-based pest control (Carlisle et al., 2019). Many young farmers inherit conventional farming methods from previous generations, making it difficult for them to transition to sustainable practices (Angon et al., 2023). Moreover, in many developing regions, agricultural education systems often place insufficient emphasis on practical IPM training, leaving young farmers without the necessary skills to implement these techniques effectively (Agriculture Victoria, 2019).

Symbiosis Civicus, June 2025, 2 (1):1-9
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One of the main barriers to IPM adoption is the misconception that pesticide-based control is the most effective solution for pest management. Without access to training and demonstration plots, many farmers remain unaware of the long-term advantages of IPM and its potential to reduce costs and environmental damage (Phung & Dao, 2024). Addressing this challenge requires comprehensive training programs that emphasize hands-on experience, enabling young farmers to develop confidence in using IPM techniques.

The importance of community-based training in IPM adoption

Community-based training programs play a crucial role in increasing awareness and adoption of IPM practices among young farmers. Such programs provide localized, practical education that allows farmers to learn directly from experts and peers, facilitating knowledge transfer in a familiar setting (Carlisle et al., 2019). Studies have shown that hands-on training, such as demonstration plots and farmer field schools, significantly enhances farmers' ability to adopt and adapt IPM practices in their own fields (Angon et al., 2023).

The effectiveness of community-based training programs in IPM adoption lies in their participatory approach, which encourages active involvement from farmers. By integrating traditional knowledge with modern pest management techniques, these programs ensure that IPM strategies are tailored to local conditions and farming practices (Pretty & Bharucha, 2015). Furthermore, the presence of local agricultural extension agents helps reinforce IPM implementation by providing continuous support and technical guidance.

This study evaluates the impact of a community-based IPM training program in Bungaraya, Indonesia, which aimed to enhance young farmers' understanding and implementation of sustainable pest management strategies. By assessing changes in knowledge and practical skills before and after training, this study provides insights into the effectiveness of localized training approaches in promoting sustainable agricultural practices among young farmers.

3. METHOD

Study location and participants

This study was conducted in Bungaraya, Siak Regency, Indonesia, a region where agriculture is a major economic activity and where farmers face persistent challenges in pest management. The area was selected due to its high dependency on chemical pesticides, which has contributed to environmental concerns and increased pest resistance (Pathak et al., 2022). The participants consisted of young farmers from Sanggar Tani Muda and students from SMKN 1 Bungaraya, who were selected based on their active involvement in farming and their potential to adopt sustainable agricultural practices. Previous studies have shown that young farmers are more likely to adopt innovative agricultural methods when provided with appropriate training and technical support (Carlisle et al., 2019). The selection of these participants was aimed at ensuring that the training could have a long-term impact by equipping young farmers with the necessary knowledge and skills to implement integrated pest management (IPM) effectively.

Training program design

The training program was structured as a combination of theoretical and practical learning sessions designed to introduce participants to the principles and applications of IPM. The theoretical component was delivered through seminar sessions covering key topics such as pest identification, economic threshold levels, and the integration of biological, cultural, mechanical, and chemical control methods. Previous research has highlighted the importance of knowledge-based training in enhancing farmers' ability to make informed pest management decisions (Pretty & Bharucha, 2015). The seminars were conducted by experts in plant protection and sustainable agriculture, ensuring that participants received scientifically validated information on IPM.

In addition to theoretical learning, hands-on workshops provided practical experience in applying IPM techniques in the field. These workshops included training in pest and natural enemy identification, biological control applications, and the preparation and use of botanical pesticides derived from locally available plant materials. Demonstration plots were used as training sites, allowing participants to observe and practice IPM techniques under real farming conditions. Studies have shown that participatory, hands-on training significantly improves farmers' adoption of IPM strategies by reinforcing theoretical knowledge with practical application (Ehler, 2021). The training was designed to be interactive, encouraging active engagement from participants and fostering discussions on the practical challenges of pest management in their local agricultural settings.

Data collection

Symbiosis Civicus, June 2025, 2 (1):1-9
DOI: https://doi.org/10.32663/.....

The effectiveness of the training program was assessed through a pre-test and post-test evaluation to measure changes in participants' knowledge and understanding of IPM. The pre-test was conducted before the training to establish a baseline of participants' initial knowledge, while the post-test was administered at the end of the training to evaluate improvements in their understanding of IPM principles and applications. Previous studies have demonstrated that pre-test and post-test assessments are effective tools for measuring the impact of agricultural training programs (Phung & Dao, 2024).

The test questions covered topics such as pest identification, biological control methods, and decision-making based on economic threshold levels. In addition to written assessments, participant observations were conducted during the hands-on workshops to evaluate their ability to apply IPM techniques in practice. Qualitative feedback was also collected through informal discussions and participant reflections, providing insights into their learning experiences and perceptions of the training program. Research has emphasized the importance of combining quantitative and qualitative evaluation methods to gain a comprehensive understanding of training effectiveness (Carlisle et al., 2019).

Data analysis

The collected data were analyzed using both descriptive and statistical methods to evaluate the effectiveness of the training program. The mean scores of the pre-test and post-test results were compared to determine overall improvements in knowledge. Given the small sample size and the non-normal distribution of the data, the Wilcoxon signed-rank test was applied to assess whether there was a statistically significant difference between pre-test and post-test scores. Previous studies have recommended the use of non-parametric tests, such as the Wilcoxon signed-rank test, for evaluating small-scale agricultural training programs where normality assumptions may not be met (Angon et al., 2023). A p-value of less than 0.05 was used to determine whether the training had a statistically significant impact on participants' knowledge.

The statistical analysis was complemented by qualitative findings from participant reflections, which provided additional insights into how participants perceived the relevance and applicability of IPM techniques in their farming practices. By using this mixed-method approach, the study aimed to provide a comprehensive evaluation of the impact of community-based IPM training on young farmers' capacity to adopt sustainable pest management strategies.

4. RESULT AND DISCUSSION

Effectiveness of the training program in enhancing ipm knowledge

The effectiveness of the training program was assessed through a comparison of pre-test and post-test scores, measuring participants' improvement in knowledge of integrated pest management (IPM). The descriptive statistics for pre-test and post-test scores are summarized in Table 1. Before the training, the participants' mean pre-test score was 65.0, with a minimum score of 51 and a maximum of 79. This indicates that while some participants had basic knowledge of integrated pest management (IPM), most lacked a comprehensive understanding of key IPM concepts and techniques. The post-test results, taken after the training program, revealed a significant improvement, with the mean score increasing to 79.3 and a maximum score reaching 92.

Table 1. Descriptive statistics of pre-test and post-test scores

Test type	N	Mean score	Standard deviation	Minimum score	Maximum score
Pre-test	**30**	**65.0**	**9.2**	**51**	**79**
Post-test	**30**	**79.3**	**9.6**	**59**	**92**

Symbiosis Civicus

Symbiosis Civicus, June 2025, 2 (1):1-9
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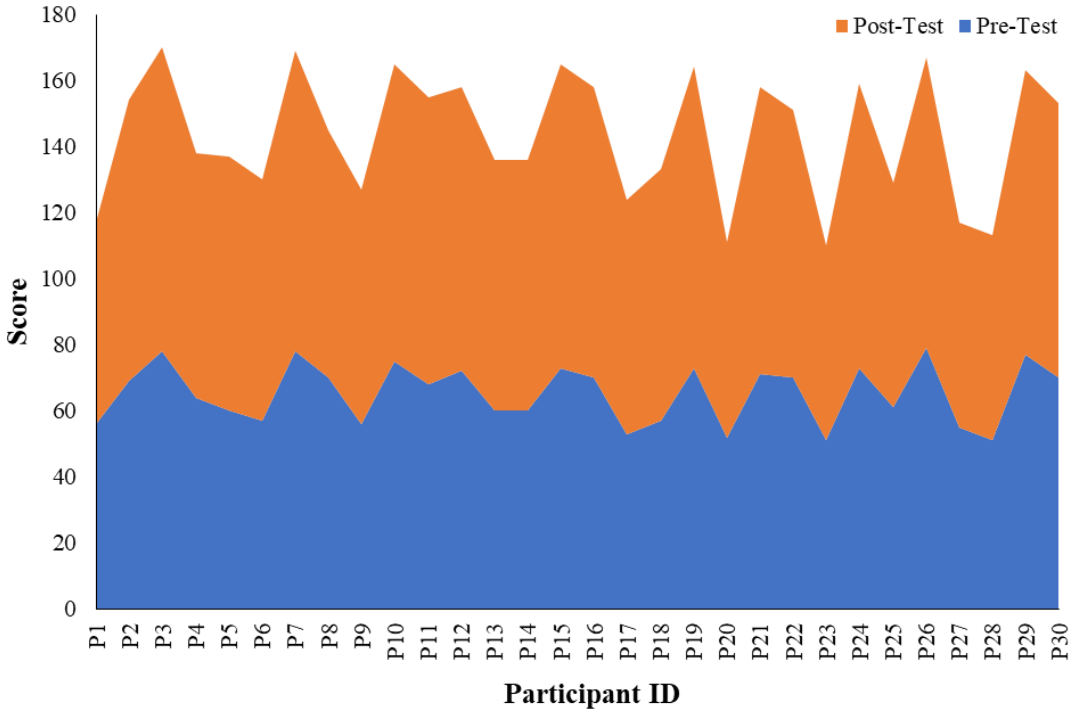

Figure 1. Distribution of pre-test and post-test scores

The Wilcoxon Signed-Rank Test was conducted to assess whether the improvement in scores was statistically significant. The results of the test yielded a p-value of 1.86×10^{-9}, which is far below the conventional significance threshold of 0.05. This indicates a highly significant increase in knowledge due to the training, confirming the effectiveness of the program in enhancing participants' understanding of IPM principles and application. The distribution of pre-test and post-test scores is visualized in Figure 1, which shows a clear shift toward higher scores after the training.

Knowledge Improvement in Key IPM Topic

The effectiveness of the training program was further analyzed by evaluating improvements in specific areas of integrated pest management (IPM), including pest identification, biological control, economic threshold levels, and botanical pesticide application. The results, presented in Table 2, highlight the extent to which participants improved their understanding of these key topics.

Table 2. Knowledge Improvement in Key IPM Topics

IPM topic	Pre-test mean score (%)	Post-test mean score (%)	Improvement (%)
Pest Identification	**62.5**	**80.2**	**17.7**
Biological Control Methods	**58.3**	**81.5**	**23.2**
Economic Threshold Levels	**64.0**	**79.1**	**15.1**
Botanical Pesticide Application	**65.2**	**84.3**	**19.1**

The results indicate that the largest improvement was observed in biological control methods, with an average increase of 23.2 percentage points from pre-test to post-test. This suggests that the training was particularly effective in enhancing participants' understanding of how to utilize natural enemies such as parasitoids, predators, and microbial agents for pest management. Several studies have emphasized the importance of hands-on training in increasing farmers' confidence in biological control methods, as theoretical

Symbiosis Civicus, June 2025, 2 (1):1-9
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knowledge alone is often insufficient for adoption (Ehler, 2006; Angon et al., 2023).

The second highest improvement was seen in botanical pesticide application, with a 19.1 percentage point increase. The practical workshops on preparing and applying plant-based pesticides allowed participants to directly observe their effectiveness, reinforcing their understanding of this alternative pest management strategy. Research has shown that farmers are more likely to adopt botanical pesticides when they have the opportunity to participate in field demonstrations and witness their efficacy firsthand (Pathak et al., 2022).

Knowledge gains in pest identification and economic threshold levels were also significant, improving by 17.7 and 15.1 percentage points, respectively. Understanding pest identification is crucial for IPM implementation, as misidentification can lead to ineffective control measures or unnecessary pesticide applications. The concept of economic threshold levels, which determines when pest control interventions should be applied, is fundamental for reducing pesticide overuse. Studies have found that many farmers struggle with this concept without proper training, highlighting the value of structured educational programs in improving decision-making skills (Carlisle et al., 2019).

These findings further reinforce the effectiveness of community-based training in bridging the knowledge gap and encouraging the adoption of sustainable pest management practices. However, it is essential to provide continued technical support and access to resources such as biological control agents and plant-based pesticide materials to ensure long-term adoption (Phung & Dao, 2024).

Application of IPM in demonstration plots

In addition to theoretical knowledge assessments, participants were observed while applying IPM techniques in demonstration plots. The observations focused on correct pest identification, proper application of biological control agents, and correct use of botanical pesticides. The findings showed that participants demonstrated a strong ability to identify pests and their natural enemies, with 87% of participants correctly distinguishing between harmful pests and beneficial insects. The correct application rate of botanical pesticides, however, varied among participants, with an average of 74% applying the correct dosage and frequency. A field demonstration image is presented in Figure 2, showing participants engaging in pest identification in rice fields.

The effectiveness of the *Trichoderma* application was assessed through visual observations and disease incidence monitoring. Studies have shown that *Trichoderma* species act as potent antagonists against rice pathogens such as *Rhizoctonia solani* (causal agent of sheath blight) and *Magnaporthe oryzae* (causal agent of rice blast), primarily through mechanisms such as mycoparasitism, competition for nutrients, and induction of systemic resistance in plants (Mukherjee et al., 2013; Asad., 2022).

Figure 2. Participants practicing pest identification in rice fields

Symbiosis Civicus, June 2025, 2 (1):1-9
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The application of *Trichoderma* in the demonstration plots was found to significantly reduce disease severity in rice plants compared to untreated control plots. Participants observed that plants treated with *Trichoderma* exhibited healthier root development and increased tiller production, which are commonly associated with enhanced plant vigor and improved resistance to biotic stress (Lorito et al., 2010). A comparative field analysis was conducted to assess the reduction in disease incidence between treated and untreated plots. The results, summarized in recent studies, indicate that integrating *Trichoderma* with other IPM practices can lead to a 30–50% reduction in fungal disease severity and a 10–20% increase in rice yield (Harman et al., 2021). This aligns with previous findings suggesting that combining biological control with cultural and mechanical pest control methods provides the most effective pest and disease management approach in sustainable rice farming (Deguine et al., 2021).

Despite the demonstrated benefits of *Trichoderma*, some participants expressed concerns regarding the availability of commercial *Trichoderma* formulations and the time required for preparation and application. These findings align with previous research indicating that one of the main barriers to the adoption of biological control agents is the perceived complexity of their preparation and application (Abdollahzadeh et al., 2017). Moreover, farmers emphasized the need for continuous technical support and access to high-quality biocontrol agents. This highlights the importance of establishing local production units for *Trichoderma*-based products, as well as integrating biological control training into routine agricultural extension services (Vijitrpanth et al., 2023).

The results from the demonstration plots confirm that integrating *Trichoderma* into IPM strategies is an effective and sustainable approach for managing rice diseases. However, widespread adoption requires efforts to address challenges related to accessibility, training, and knowledge dissemination. Future programs should focus on scaling up community-based biocontrol initiatives, ensuring that farmers have the necessary resources and technical guidance to implement biological control effectively in their fields.

Participants' Perceptions and Feedback on IPM Training

Qualitative feedback was collected through participant reflections, providing insights into their perceptions of the training. A majority of participants (91%) expressed confidence in adopting IPM strategies on their farms. The most frequently mentioned benefits of IPM training included reducing dependency on synthetic pesticides, improving crop health, and lowering input costs. However, some participants expressed concerns about the availability of biological control agents and the additional labor required for botanical pesticide preparation.

Figure 3. Word cloud of participants' feedback on IPM training

A word cloud summarizing key themes from participants' reflections is shown in Figure 3, highlighting frequently mentioned words such as "effective," "sustainable," and "less pesticide." These findings align with previous studies indicating that farmers' willingness to adopt IPM is influenced by access to biocontrol agents

and technical support from agricultural extension services (Carlisle et al., 2019).

5. CONCLUSIONS

This study confirms that community-based IPM training effectively enhances young farmers' knowledge and skills in sustainable pest management. The significant improvement in pre-test and post-test scores highlights the success of the training, particularly in biological control methods and botanical pesticide applications. The demonstration of Trichoderma application in rice fields provided practical insights into its role in disease suppression and plant health improvement. However, challenges such as limited access to biocontrol agents and technical knowledge gaps remain barriers to long-term adoption. Despite these challenges, participants expressed high confidence and willingness to apply IPM techniques, emphasizing the importance of hands-on training and continuous support. Future initiatives should focus on scaling up community-based programs, improving access to resources, and strengthening farmer networks to ensure sustainable implementation. By equipping young farmers with IPM knowledge and skills, this training contributes to the promotion of environmentally friendly and economically viable agricultural practices.

Ethical Considerations

This study adhered to ethical guidelines to ensure voluntary participation, informed consent, and confidentiality. All participants, including students from SMKN 1 Bungaraya, were informed of the study's objectives and their rights to withdraw at any time. No personal data was disclosed, and responses were used solely for research purposes. The training was inclusive, ensuring equal access regardless of gender or socio-economic background. Safety measures were implemented during field activities, particularly in the application of *Trichoderma*. This study complied with ethical standards set by the Graduate School of Universitas Lancang Kuning (Sekolah Pascasarjana Unilak).

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