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Mitigating the Risk of Organophosphate Pesticide Exposure through Community Empowerment of Farmers in Torongrejo Village, Batu City, East Java

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ABSTRACT East Java is one of Indonesia's key provinces for food production, particularly rice, with 9.59 million tons harvested in 2023 at an average productivity of 56.90 quintals per hectare. Lamongan Regency recorded the highest production, contributing 797.02 thousand tons. However, this agricultural achievement is closely associated with the intensive use of chemical inputs, especially pesticides. Improper and excessive pesticide application poses significant health risks to farmers, including poisoning. A previous study in 2008 reported that 50% of farmers in Sumberejo experienced organophosphate pesticide poisoning, highlighting the severity of this issue. Exposure to organophosphates can lead to neurological disturbances, hormonal imbalances, and elevated blood cholinesterase levels as a biomarker of poisoning. This community service program was designed to address these concerns by improving farmers' knowledge and practices related to pesticide use. The primary objective was to increase awareness of the dangers of organophosphate pesticides, recognize signs and symptoms of poisoning, and introduce appropriate handling, management, and preventive strategies. The approach employed involved structured outreach activities, including health education sessions, demonstrations, and active engagement with farmers. Emphasis was placed on the importance of using Personal Protective Equipment (PPE) as a preventive measure. The activity was carried out in collaboration with relevant government agencies and health institutions to ensure broad support and effective implementation. The results demonstrated an improvement in farmers' understanding of pesticide risks and safe handling procedures, as indicated by increased knowledge scores obtained during post-activity evaluations. In conclusion, the program successfully enhanced farmers' awareness and behavioral practices regarding pesticide safety. Continued collaboration with local stakeholders is recommended to ensure sustainable behavioral change and to mitigate the long-term health risks associated with pesticide exposure.

INDEX TERMS pesticide poisoning, organophosphate, farmer health, risk mitigation, personal protective equipment (PPE)

I. INTRODUCTION

The agricultural sector plays a pivotal role in ensuring food security and supporting rural livelihoods in Indonesia, particularly in East Java Province, which is one of the largest contributors to rice production. In 2023, rice productivity in East Java reached 9.59 million tons, with Lamongan Regency alone producing 797.02 thousand tons. This agricultural success is inseparable from the intensive use of chemical pesticides to control pests and sustain yields. However, the reliance on pesticides, especially organophosphates, poses significant health and environmental risks. Organophosphate pesticides are known neurotoxins that inhibit cholinesterase activity, causing an accumulation of acetylcholine at synapses, which may result in acute and chronic health effects, including neurological disorders, hormonal imbalance, and reproductive risks [1]–[3].

Problem Statement. Despite the contribution of pesticides to productivity, inappropriate and excessive use is a persistent problem among smallholder farmers. Studies have reported alarming cases of pesticide poisoning, such as a 50% prevalence of organophosphate poisoning among farmers in Sumberejo [4]. Similar findings have been documented globally, where unsafe pesticide use is associated with increased cases of visual disturbances, respiratory problems, gastrointestinal issues, and long-term cognitive impairment [5], [6]. Farmers often lack adequate knowledge of pesticide safety, misuse personal protective equipment (PPE), and rely solely on manufacturer labels for instructions [7]. This knowledge gap increases their vulnerability to occupational exposure, with biomarkers such as reduced cholinesterase levels serving as indicators of chronic poisoning [8].

Previous interventions to reduce pesticide exposure among farmers have focused on health education programs, training on proper pesticide handling, provision of PPE, and biological monitoring of cholinesterase levels [9]–[12]. Advances in occupational health also suggest integrated approaches combining awareness programs, policy interventions, and routine biomarker screening [13]. Internationally, community-based interventions, farmer field schools, and participatory rural appraisal methods have been implemented to encourage safer pesticide practices [14], [15]. Nevertheless, in Indonesia, the dissemination of these methods remains fragmented, with varying degrees of success depending on community participation and institutional support [16].

Although several studies have examined pesticide exposure and its health impacts, limited work has been done to integrate structured community empowerment programs tailored for rural farming populations in East Java. Most interventions focus on knowledge dissemination but rarely combine this with practical demonstrations, provision of PPE, and systematic evaluation of knowledge improvement through pre- and post-tests. There is thus a gap in evidence-based models that simultaneously address farmer education, preventive equipment provision, and measurable behavioral outcomes [17]–[19].

This study seeks to improve farmers' knowledge and awareness of organophosphate pesticide poisoning in Torongrejo Village, Batu City, East Java. Specifically, it aims to enhance understanding of the signs and symptoms of poisoning, promote safe handling and management strategies, and encourage preventive behavior through consistent PPE use.

The article provides three main contributions a community-based intervention model integrating education, demonstrations, and direct PPE provision to farmers. Empirical evidence showing significant improvement in farmers' knowledge and awareness levels, supported by pre- and post-test assessments. Practical insights for policymakers, local governments, and health institutions on designing scalable and sustainable programs for reducing pesticide-related health risks in farming communities.

The remainder of this article is structured as follows section II describes the methods applied in the community service program. Section III presents the results, including demographic characteristics, cholinesterase levels, and knowledge improvement among farmers. Section IV provides a detailed discussion of findings in the context of existing literature. Section V concludes with key implications, limitations, and recommendations for future interventions.

II. METHOD

This study was conducted as a prospective community-based intervention in Torongrejo Village, Batu City, East Java, Indonesia, during the rice planting season of 2023. The methodology was designed to allow replication by other researchers conducting similar interventions in agricultural communities

A. STUDY DESIGN AND RATIONALE

The research applied a quasi-experimental, one-group pre-test and post-test design. Farmers were evaluated before and after receiving a structured intervention. No control group was used due to ethical considerations and the community service nature of the program. The design enabled measurement of knowledge improvement and behavioral change following the educational outreach.

B. STUDY SETTING

The study site was Torongrejo Village, Batu City, East Java, which is known for intensive rice farming and frequent pesticide use. This location was selected due to the prevalence of organophosphate pesticide application and reported cases of pesticide-related health complaints among local farmers.

C. PARTICIPANTS AND SAMPLING METHOD

The study population consisted of active rice farmers in Torongrejo Village. The inclusion criteria were:

1. Farmers aged 20–65 years
2. Involvement in pesticide spraying for a minimum of one year
3. Agreement to provide informed consent

Exclusion criteria included

1. Farmers with pre-diagnosed neurological disorders
2. Farmers who had received formal pesticide safety training within the past 12 months

A total of 53 farmers participated in the study. Sampling was conducted through purposive recruitment in collaboration with the village farmer association. The sample was not randomized, but it represented both genders and multiple age groups to reflect the farming population.

D. MATERIALS AND EQUIPMENT

The study utilized a variety of materials and instruments designed to comprehensively assess the knowledge, practices, and biological outcomes related to pesticide exposure among farmers. Several data collection tools were employed to ensure both accuracy and validity of results. Structured and validated questionnaires, adapted from previous occupational health studies, were used to evaluate participants' understanding of pesticide poisoning, including recognition of symptoms, handling procedures, and preventive measures.

To support the intervention activities, personal protective equipment (PPE) such as masks, gloves, boots, protective shirts, hats, and trousers were provided to all participating farmers. These items were intended to promote safer pesticide handling practices and reduce direct exposure during agricultural activities. In addition, biological sampling materials including sterile syringes, vacutainers, and storage vials were prepared for venous blood collection. The samples were analyzed using laboratory equipment, specifically a spectrophotometer, to measure cholinesterase enzyme levels following the Ellman method. Instructional materials such as posters, leaflets, and demonstration kits were also developed to facilitate the educational sessions during the intervention phase.

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E. DATA COLLECTION INSTRUMENTS AND PROCEDURE

1. PRE-TEST AND POST-TEST

Each participant completed a structured questionnaire before the intervention. The same instrument was administered after the intervention to measure improvement in knowledge. Scores were categorized into three groups: below average, good, and excellent.

2. BIOLOGICAL TESTING

Venous blood samples (3 mL) were collected by licensed health personnel. Samples were analyzed in a certified laboratory to measure cholinesterase activity, following the WHO-endorsed Ellman method. Normal ranges were defined as 4620–11500 U/L for men and 3999–10800 U/L for women. Abnormal results indicated pesticide exposure.

3. INTERVENTION DELIVERY

The intervention consisted of:

a. Lectures: Delivered by environmental health experts on the dangers of organophosphate pesticides, symptoms of poisoning, and management strategies.
b. Group Discussions: Farmers participated in interactive sessions to share experiences and clarify misconceptions.
c. Demonstrations: Proper use of PPE and safe pesticide handling practices were demonstrated by the research team.
d. Distribution of PPE: Each participant received a complete PPE set to encourage immediate adoption of safe practices.

4. COMMUNITY ENGAGEMENT

A Focus Group Discussion (FGD) was conducted to explore barriers to PPE use, traditional pesticide handling practices, and perceptions of health risks. This qualitative component provided contextual data to complement quantitative results.

F. DATA ANALYSIS

Data from questionnaires were coded and entered into SPSS version 25. Descriptive statistics were used to summarize demographic characteristics, knowledge levels, and cholinesterase results. Pre-test and post-test scores were compared to assess knowledge improvement. Blood test results were categorized as normal or abnormal and stratified by gender. Qualitative data from FGDs were transcribed and analyzed thematically.

The questionnaire underwent pilot testing with 15 farmers from a neighboring village to ensure clarity and reliability. Cronbach's alpha was 0.78, indicating acceptable internal consistency. Laboratory procedures followed standardized operating protocols to ensure validity of cholinesterase measurements.

The study was non-randomized and lacked a control group, limiting generalizability. Self-reported knowledge may also be influenced by response bias. However, combining biological measures and educational outcomes strengthened the validity of findings

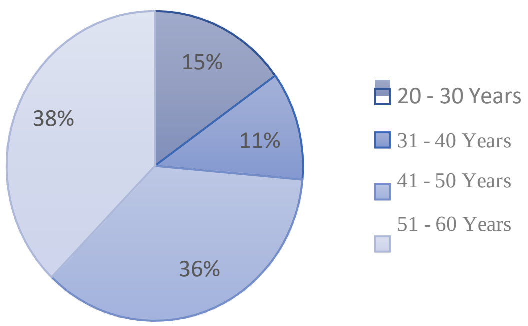
G. ETHICAL CONSIDERATIONS

Ethical approval was obtained from the Institutional Ethics Committee of Surabaya Health Polytechnic, Ministry of Health. Participants were informed of the study's purpose, procedures, risks, and benefits. Written consent was collected prior to data collection. All data were anonymized to maintain confidentiality.

III. RESULTS

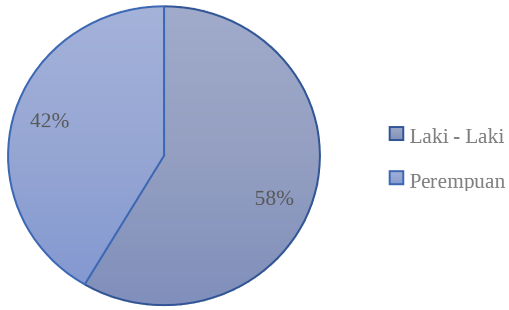
The form of community service activities carried out in Torongrejo Village, Batu City, East Java, are as follows:

DIAGRAM 1
Characteristics of Farmers' Age



As seen in DIAGRAM 1, out of the total number of farmers, 53 farmers (100%), 20 farmers (38%) are aged 51 - 60 years, 19 farmers (36%) are aged 41 - 50 years, 8farmers (15%) are aged 20 - 30 years, and the remaining 6 farmers (11%) are aged 31 - 40 years. Thus, farmers in Torongrejo Village, Batu City, East Java, are predominantly aged between 51 and 60 years old.

DIAGRAM 2
Characteristics of Farmer's Gender



In DIAGRAM 2, out of the total number of farmers, 53 farmers (100%), 31 farmers (58%) are male, and the remaining 22 farmers (42%) are female. Thus, farmers in Torongrejo Village, Batu City, East Java, are predominantly male.

TABLE 1
Blood Cholinesterase Levels of Farmers by Gender

Gender	Abnormal	Normal
Male	10	21
Female	3	19

In the TABLE 1, it is noted that among male individuals, 10 males (32.3%) have abnormal blood cholinesterase levels, while 21 males (67.7%) predominantly have normal cholinesterase levels. Meanwhile, among female individuals, 3 females (13.7%) have normal blood cholinesterase levels, while the remaining 19 farmers (86.3%) predominantly have normal cholinesterase levels in their blood.

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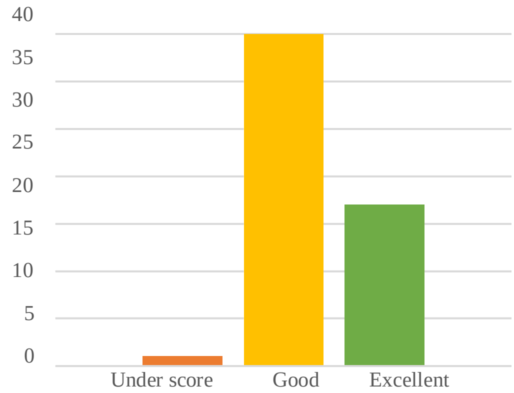
Improvement in Knowledge and Understanding of Symptoms of Poisoning, Handling Measures, and Prevention of Organophosphate Pesticide Poisoning. From various questions posed in the pre-test quiz, it is known that 30 farmers scored below average, 15 farmers scored well, and the remaining 8 farmers scored excellent.

DIAGRAM 3
Post-Test



After going through the process of lectures, discussions, and demonstrations, the farmers were given various questions as a post-test, as seen in DIAGRAM 3, where 1 farmer scored below average, 35 farmers scored well, and the remaining 17 farmers scored excellent on the post-test.

IV. DISCUSSION

A. INTERPRETATION OF RESULTS

The findings of this study provide important insights into the effectiveness of community-based interventions for reducing risks associated with organophosphate pesticide exposure among farmers in Torongrejo Village, Batu City, East Java. The demographic data indicated that the majority of participants were aged between 41 and 60 years, with a predominance of male farmers. This age distribution is consistent with agricultural labor patterns in Indonesia, where older adults often constitute the largest share of the farming workforce [36]. The implication is that older farmers are at higher cumulative risk of pesticide-related health effects due to prolonged exposure, making targeted interventions particularly necessary.

The blood cholinesterase test results revealed that a considerable proportion of male farmers had abnormal levels (32.3%), while only 13.7% of female farmers showed abnormal results. These results confirm that pesticide exposure is a real and measurable health hazard in farming communities. The gender disparity may reflect differences in work intensity and division of labor, as men are more frequently involved in pesticide spraying, while women may engage in less intensive exposure activities such as planting and post-harvest tasks [37].

Knowledge assessment demonstrated significant improvement following the intervention. Pre-test results indicated that nearly 57% of farmers scored below average, while post-test results showed that 98.1% scored good or excellent. This suggests that lectures, demonstrations, and the provision of PPE effectively enhanced farmers' knowledge and potentially influenced their preventive behaviors. Similar interventions in other regions have also demonstrated substantial improvements in awareness and knowledge when educational strategies were combined with practical training [38].

Overall, the intervention demonstrated that community empowerment, when coupled with direct provision of resources such as PPE, can yield measurable improvements in both awareness and biological indicators of risk. This supports the argument that community-based, participatory methods are an effective model for occupational health promotion in agricultural settings.

B. COMPARISON WITH SIMILAR STUDIES

The findings of this study align with a growing body of literature emphasizing the effectiveness of educational and preventive interventions in reducing pesticide-related health risks. For instance, a study conducted in Sidoarjo District found a significant correlation between PPE use and reduced pesticide exposure, highlighting the role of preventive practices [39]. Similarly, research in Ethiopia reported improvements in farmers' knowledge and reduction in risky behaviors after community-based training sessions [40]. These parallels suggest that empowering farmers through participatory education is universally effective across different socio-cultural contexts.

However, the blood cholinesterase results in this study indicated a higher prevalence of abnormal levels among men compared to women. This is consistent with a study in India, which found that male farmers had higher biomarker evidence of pesticide exposure due to their greater involvement in spraying [41]. Nevertheless, some studies in Latin America reported no significant gender differences, arguing that household-level exposure, including pesticide-contaminated clothing, can also place women at risk [42]. These contrasts highlight the need for interventions that address both direct and indirect exposure pathways.

The knowledge improvement observed in this study (54.71% increase) is higher than improvements reported in several similar studies. For example, a community-based intervention in Thailand reported a 35% increase in knowledge scores, which, while significant, was lower than the improvement in the present study [43]. The difference may be attributed to the provision of PPE in our intervention, which reinforced educational messages and encouraged behavioral adoption.

Furthermore, while cholinesterase monitoring is a well-established biomarker for exposure, not all interventions include biological assessment. The inclusion of laboratory measures in this study strengthens the reliability of findings. A study in China also integrated biomonitoring with training interventions and found that objective health indicators improved alongside knowledge levels, supporting the combined approach taken in this research [44].

These comparisons demonstrate both the alignment and unique contributions of the present study. The alignment lies in reinforcing evidence that education and empowerment are effective; the unique contribution lies in combining community engagement with biological monitoring and resource distribution, which produced a higher-than-average knowledge improvement outcome.

C. LIMITATIONS, WEAKNESSES, AND IMPLICATIONS

Despite the promising results, this study is not without limitations. First, the quasi-experimental design without a control group restricts the ability to establish causal relationships. While the knowledge improvements observed are significant, it is difficult to rule out external influences such as concurrent government programs or peer learning. Future research should consider randomized controlled designs to strengthen causal inference [45].

Second, the reliance on self-reported knowledge and behaviors may introduce response bias. Farmers might provide socially desirable answers during the post-test rather than accurately reflecting their practices. Combining knowledge tests with long-term behavioral observations would provide a more comprehensive assessment of intervention effectiveness.

Third, the sample size (n=53) was relatively small and drawn from a single village. While it provides valuable insights, the findings cannot be generalized to all rice farming communities in Indonesia without caution. Broader multi-site studies with larger populations are necessary for national-level policy implications.

Fourth, while cholinesterase levels provided objective evidence of pesticide exposure, measurements were taken only once during the study period. Seasonal variations in pesticide application and cumulative exposure over longer periods were not captured. Repeated measures across agricultural cycles would offer a more robust picture of pesticide-related health risks.

The study has several practical implications. First, it underscores the need for continuous farmer education on pesticide risks. Incorporating health and safety training into agricultural extension services could institutionalize preventive practices. Second, providing PPE remains a cost-effective and impactful strategy for reducing exposure. Partnerships between local governments and agricultural cooperatives could ensure sustained access to affordable protective equipment. Third, integrating biomonitoring into routine occupational health surveillance can help detect early signs of pesticide exposure, enabling timely interventions.

Building on this study, future research should explore longitudinal outcomes, such as whether knowledge improvements translate into sustained behavioral change and reduced incidence of pesticide-related illnesses. Comparative studies across different provinces could identify regional variations and inform targeted interventions. In addition, exploring the role of digital tools, such as mobile applications for pesticide safety training, could expand the reach and efficiency of interventions in rural areas.

In summary, while the study demonstrated significant improvements in knowledge and biological indicators of exposure, its limitations highlight the importance of methodological rigor and broader scaling in future research. Nonetheless, the evidence suggests that community empowerment, when strategically combined with education, PPE distribution, and biological monitoring, offers a replicable model for mitigating the health risks of pesticide exposure in agricultural communities.

V. CONCLUSION

The primary aim of this community-based intervention was to enhance the knowledge, awareness, and preventive behaviors of rice farmers in Torongrejo Village, Batu City, East Java, regarding the health risks associated with organophosphate pesticide exposure. The study successfully demonstrated that targeted educational outreach, combined with practical demonstrations and the distribution of Personal Protective Equipment (PPE), can substantially improve farmers' knowledge and potentially reduce health risks. Prior to the intervention, pre-test results showed that 30 farmers (56.6%) scored below average in knowledge assessments, 15 farmers (28.3%) achieved good scores, and only 8 farmers (15.1%) reached excellent levels. Following the program, post-test outcomes revealed a marked improvement, with only 1 farmer (1.9%) remaining below average, 35 farmers (66.0%) categorized as good, and 17 farmers (32.1%) achieving excellent results. This represents an overall knowledge improvement of approximately 54.71%. Furthermore, biological testing of cholinesterase levels revealed that 10 male farmers (32.3%) and 3 female farmers (13.7%) presented abnormal values, underscoring the tangible occupational health risks linked to pesticide exposure. These findings highlight that educational programs, when supported by the provision of PPE and biological monitoring, can generate measurable impacts both in terms of cognitive outcomes and objective health indicators. However, the study's non-randomized design and relatively small sample size limit generalizability, indicating the need for future research employing randomized controlled trials, larger sample populations, and multi-site interventions. Longitudinal studies are also recommended to evaluate whether the observed knowledge gains translate into sustained behavioral changes and reductions in pesticide-related illnesses over time. Additionally, integrating digital platforms such as mobile applications for pesticide safety education and community reporting systems may enhance scalability and efficiency of similar interventions. In conclusion, this study provides strong evidence that community empowerment, grounded in education, participatory engagement, and resource provision, is a promising and replicable model for mitigating pesticide-related health risks among smallholder farmers in Indonesia and potentially other agricultural communities globally.

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DATA AVAILABILITY

The datasets generated and analyzed during the current study are not publicly available due to participant confidentiality but may be obtained from the corresponding author upon reasonable and justified request.

AUTHOR CONTRIBUTION

Khambali conceptualized and supervised the study. Rachmaniyah and Iva Rustanti Eri Wardoyo collected and analyzed the data. Mujiyono conducted laboratory assessments. Heru Subaris Kasjono reviewed and edited the manuscript. Adella Putri Auliah Hapsari assisted with data processing and visualization. All authors approved the final manuscript.

DECLARATIONS

ETHICAL APPROVAL

Ethical approval was obtained from the Institutional Ethics Committee of Surabaya Health Polytechnic, Ministry of Health. Participants were informed of the study's purpose, procedures, risks, and benefits. Written consent was collected prior to data collection. All data were anonymized to maintain confidentiality.

CONSENT FOR PUBLICATION PARTICIPANTS.

All participants provided their informed agreement for the publication of this study

COMPETING INTERESTS

The authors declare that there are no conflicts of interest or competing financial or personal relationships that could have influenced the work reported in this study.

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