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Factors Related to Blood Cholinesterase Levels in Shallot Farmers in Enrekang Indonesia

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Abstract **Background:** Pesticides are chemical substances that, when not used according to prescribed standards, can negatively impact health and environmental quality, particularly soil and water ecosystems. **Method:** This study used a laboratory-based analytical observational design with a cross-sectional approach. The population consisted of 358 shallot farmers, with a sample of 188 selected through purposive sampling. Only farmers consenting to blood sampling were included in the study. OHS officers collected blood samples (0.01 cc each) using a cholinesterase test kit and subsequently analyzed at the Makassar OHS Laboratory. Data were analyzed using univariate and bivariate statistical methods. **Results:** The study revealed that 52.7% of respondents had normal cholinesterase levels, while 47.3% had abnormal levels. Regarding the pesticide dosage, 64.4% of respondents comply with recommended dosages, whereas 35.6% used improper dosages. 88.3% of respondents followed proper protocols for spraying techniques, while 11.7% did not. Correlation tests indicated significant associations among farmers between pesticide dosage and spraying techniques with blood cholinesterase levels. **Conclusions and Suggestions:** Pesticide exposure can manifest through observable symptoms, yet these signs are often underestimated, and individuals rarely seek medical attention. The potential impact of the research is preventive measure to pesticide exposure. The limitations of study is that the sampling technique still uses non-random sampling so that bias can occur. Further research is recommendation to be a longitudinal study to see the long-term effects and measurements can be done several times.

Keywords Farmers, Blood Cholinesterase, Pesticide

1. Background

Pesticides are chemical agents extensively used in agriculture to increase the production of safe and healthy crops while preventing pest infestations [1, 2]. As an integral part of agricultural practices [3], pesticides significantly affect the cultivation and yield of horticultural crops. They include chemical compounds, microorganisms, and viruses designed to eliminate pests and plant diseases [4]. Additionally, pesticides serve multiple functions, such as controlling weeds, defoliating plants, inhibiting undesired growth, and managing or promoting the growth of plants or specific plant parts, excluding fertilization [5, 6]. Beyond agricultural use, pesticides control parasites in pets and livestock and eradicate microscopic pests in water systems [7, 8]. Despite their economic benefits in improving crop quality and yield, pesticides pose significant environmental and human health risks, especially when used excessively or improperly. Overuse can degrade environmental quality, particularly soil and water, while affecting human health. Farmers often prioritize the economic advantages of pesticides without fully considering their long-term health and environmental consequences [9]. This practice not only exposes farmers to harmful effects but also diminishes the quality of agricultural land. Unsafe and excessive pesticide use can result in both acute and chronic health consequences. Acute pesticide poisoning typically presents with symptoms such as dizziness, nausea, vomiting, skin irritation, and, in some cases, vision impairment, depending on the type of pesticide [10, 11]. Chronic pesticide poisoning is insidious, with symptoms that may emerge only after prolonged exposure, making it challenging to detect. A hallmark of pesticide poisoning is reduction in cholinesterase enzyme activity, critical in nervous system function [12, 13]. Pesticide poisoning is often identified by a decline in cholinesterase levels of up to 30%. Health risk assessment questionnaires and interviews do not sufficiently assess pesticide exposure in farmers, but there must be blood cholinesterase level tests [14]. One of the main challenges in diagnosing this condition lies in its nonspecific symptoms, such as nausea, dizziness, and fatigue, which resemble common ailments and are frequently overlooked [15]. More pronounced clinical manifestations occur when cholinesterase activity declines by 50% or more.

Pesticide poisoning can be detected early through cholinesterase testing, which is critical for preventing chronic and potentially life-threatening health disorders [16-18]. The prevalence of pesticide poisoning in several regions of Indonesia is notably high. For instance, blood cholinesterase tests conducted on 347 farmers in Central Java revealed that 23.64% had moderate poisoning, while 35.73% had severe poisoning [19]. Chronic health conditions experienced by farmers are often linked to pesticide exposure, which commonly occurs during spraying activities. Toxic substances inhaled during spraying enter the lungs, damage tissue, and disseminate throughout the body via the bloodstream. Reduced cholinesterase activity in body tissues can result in poisoning symptoms, such as eye irritation causing excessive tearing and impaired muscle function leading to weakness [20].

A study conducted by the South Sulawesi Provincial Health Office revealed that among 1,010 farmers whose blood cholinesterase activity was tested, 225 farmers (22.7%) were found to have experienced pesticide poisoning. Of these cases, 201 farmers (89.33%) had mild poisoning, 22 farmers (9.78%) had moderate poisoning, and two farmers (0.89%) had severe poisoning. Another study in Anggeraja revealed that farmers in the region used 63 types of pesticides, nine unregistered, while the remaining 54 were officially registered. Alarmingly, 65% of farmers in Anggeraja sprayed pesticides every two days, and 22% applied pesticide dosages that exceeded the recommended amount by 900%. Many farmers disregarded the label's dosage instructions, perceiving them as ineffective. Most farmers prioritize pesticide selection based on perceived effectiveness and frequently mix different pesticides due to uncertainty about the efficacy of a single product in pest control. However, complying with recommended dosages is essential to safeguard farmers from the health risks associated with excessive insecticide exposure. The inclination to maximize agricultural output without regard for potential health and environmental consequences exacerbates the problem. Commonly used pesticides in the region include chlorpyrifos (an organophosphate insecticide) and mancozeb (a carbamate fungicide), which are known to disrupt thyroid gland function and growth [21, 22].

The factors influencing pesticide poisoning incidents can be categorized into two main groups: internal and external factors. Internal factors include gender, age, genetic predisposition, level of knowledge, nutritional status, hemoglobin levels, and overall health conditions. On the other hand, external factors, which play a more significant role, include the type of pesticide used, dosage, frequency of application, working duration, length of spraying sessions, use of personal protective equipment (PPE), application techniques, exposure duration, plant height, ambient temperature, spraying schedules, and wind direction [23-25].

Farmers in Indonesia extensively use pesticides, but the effects of pesticides on farmers' long-term health, including damage to the nervous system and hematological system, have not been exposed to farmers [26]. Government, academia, and civil society have a role to play and are responsible for many cases resulting from pesticide exposure, so stakeholders need to be involved in providing understanding and increasing farmer awareness [27].

2. Research Methods

This study used a laboratory-based analytical observational design with a cross-sectional approach. This study aimed to determine the factors associated with blood cholinesterase levels in red onion farmers exposed to pesticides containing both organophosphates and carbamates. The research was conducted in Enrekang from August to September 2023. The study population consisted of 358 shallot farmers. Using purposive sampling because the sample was selected based on the respondent's willingness, 188 farmers who consented to blood sample collection were selected as respondents. Data collection involved blood cholinesterase testing, which was conducted by occupational health and safety (OHS) officers using a standardized cholinesterase test kit by Test-mate ChE Cholinesterase Test System (Model 400) specification. Blood samples of 0.01 cc of each sample were aliquoted into a microcentrifuge tube labeled and analyzed at the Makassar OHS Laboratory. The refrigerator is where microcentrifuge tubes are stored when they are not being analyzed. The researcher followed the instructions based on the Test-mate ChE Cholinesterase Test System (Model 400) instruction manual [28]. Cholinesterase levels between 5230–12920 U/L were classified as normal, while levels below this range were considered abnormal and complain or not complain criteria with Rules for using pesticides based on their type. Additional data on respondent characteristics, pesticide dosages, and spraying techniques were collected through interviews using a structured questionnaire. The questionnaire used has been tested for validity and reliability; all questions are valid and reliable with a Cronbach alpha value of 0.73. Data analysis was performed using univariate and bivariate statistical methods. Univariate analysis described the distribution of each variable, including respondent characteristics, pesticide dosages, spraying techniques, and cholinesterase levels. Bivariate analysis, conducted using SPSS version 26, examined the relationships between these variables. Results were presented in frequency distribution tables for clarity.

3. Results

3.1. Univariate Analysis

3.1.1. Respondent Characteristics

From table 1, it is found that the target groups involved in solving problem are mostly male (100 people), accounting for 53,2%; the average age is between 41-50 years (66,5%); and the education levels with low level (highest elementary school and equivalent) are 140 people (74,5%).

Table 1. Distribution of Respondents Based on Characteristics of Shallot Farmers in Enrekang, 2023

Characteristics	n	%
1. Gender		
Male	100	53.2
Female	88	46.8
2. Age		
30 – 40	16	8.5
41- 50	125	66.5
>50	47	25.0
3. Education levels		
Low levels	140	74.5
High levels	48	25.5

Source: Primary Data, 2023

3.1.2. Blood Cholinesterase Levels

From table 2, the cholinesterase levels of most people are normal (99 people, 52,7%), with a normal value range between 5230-12920 U/L.

Table 2. Distribution of Respondents Based on Blood Cholinesterase Levels of Shallot Farmers in Enrekang, 2023

Cholinesterase Levels	n	%
Abnormal (<5230 - 12920 U/L)	89	47.3
Normal (5230 - 12920 U/L)	99	52.7
Total	188	100

Source: Primary Data, 2023

3.1.3. Pesticide Dosage

According to Table 3, 121 people (64.4%) maintained pesticide dosage with the range of 0.5–1.5.

Table 3. Distribution of Respondents Based on Pesticide Dosage Used by Shallot Farmers in Enrekang, 2023

Pesticide Dosage	n	%
Not in accordance (> 1.5)	67	35.6
In accordance (0.5 – 1.5)	121	64.4
Total	188	100

Source: Primary Data, 2023

3.1.4. Spraying Techniques

Table 4 shows that the spraying techniques of 166 people (88,3%) are in the direction of the wind.

Table 4. Distribution of Respondents Based on Spraying Techniques Used by Shallot Farmers in Enrekang, 2023

Spraying Technique	n	%
Not in accordance (against the wind)	22	11.7
In accordance (in the direction of the wind)	166	88.3
Total	188	100

Source: Primary Data, 2023

3.2. Bivariate Analysis

3.2.1. Relationship between Pesticide Dosage and Blood Cholinesterase Levels

The chi-square results from Pesticide Dosage and Blood Cholinesterase Levels were shown in table 5. The pesticide dosage was associated with the Blood Cholinesterase Levels (P=0,001).

3.2.2. Relationship between Spraying Techniques and Blood Cholinesterase Levels

The chi-square results from Spraying Techniques and Blood Cholinesterase Levels were shown in table 6. The Spraying Techniques was associated with the Blood Cholinesterase Levels (P=0,024).

Table 5. Distribution of Respondents Based on the Relationship between Pesticide Dosage and Blood Cholinesterase Levels of Shallot Farmers in Enrekang, 2023

Pesticide Dosage	Cholinesterase Levels				Total		*P Value*
	Abnormal		Normal				
	n	%	n	%	n	%	
Not in accordance	35	52.2	32	47.8	67	100	0.001
In accordance	54	44.6	67	55.4	121	100	
Total	88	47.3	99	52.7	188	100	

**P=0,001;*significantly, chi-square test

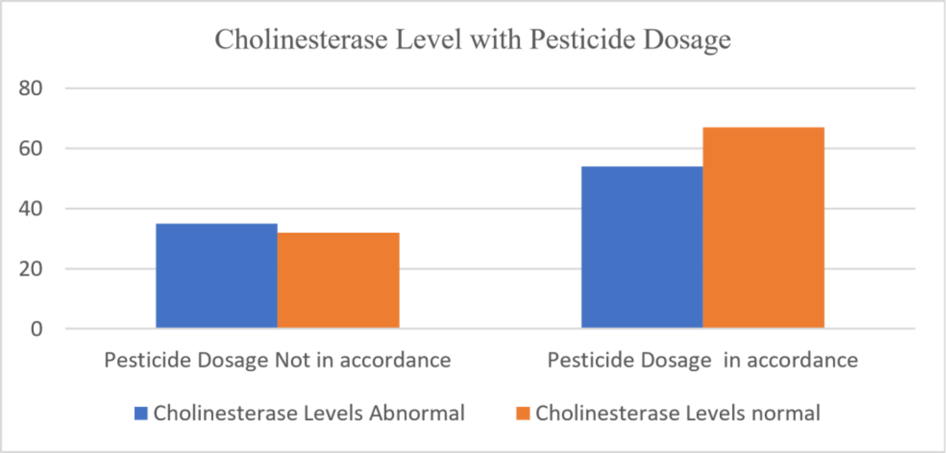

Figure 1. Cholinesterase Level with Pesticide Dosage

Table 6. Distribution of Respondents Based on the Relationship between Spraying Techniques and Blood Cholinesterase Levels of Shallot Farmers in Enrekang, 2023

Spraying Techniques	Cholinesterase Levels				Total		*P Value*
	Abnormal		Normal				
	n	%	n	%	n	%	
Not in accordance	13	59.1	9	40.9	22	100	0.024
In accordance	76	45.8	90	54.2	166	100	
Total	89	47.3	99	52.7	188	100	

**P=0,024;*significantly, chi-square test

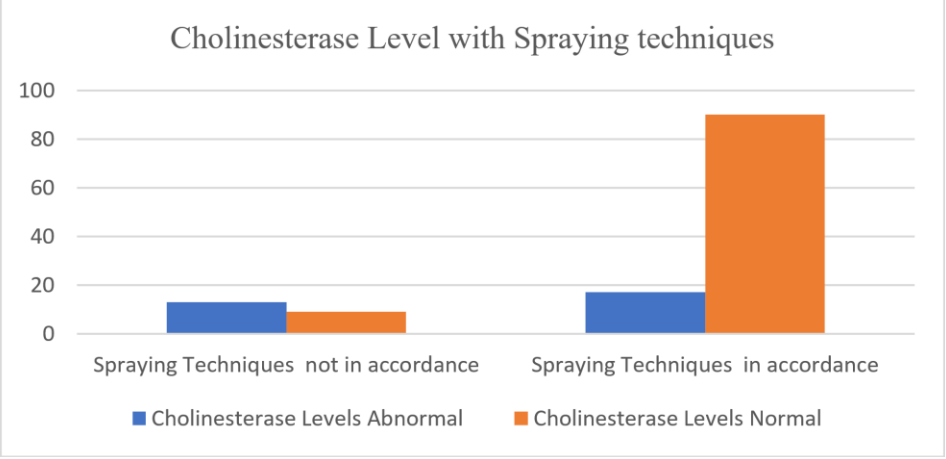

Figure 2. Cholinesterase Level with Spraying techniques

4. Discussion

4.1. Respondent Characteristics with Pesticide Dosage and Blood Cholinesterase Levels

Characteristics based on gender of onion farmers in Enrekang are dominated by men (53.2%), aged 41-50 (66.5%) and low education level (74.5%). This is related to pesticide doses and cholinesterase levels. Farmers' knowledge often causes overdosage in pesticide use [29, 30]. This can be seen from the level of education of onion farmers in Enrekang, which is dominated by low-level education and it is speculated that women are more prone to exposure to pesticides than men [31]. Related to age does not really affect the dose of pesticide and Blood Cholinesterase Levels.

4.2. Relationship between Pesticide Dosage and Blood Cholinesterase Levels

Excessive pesticide use is a significant indicator of reduced cholinesterase activity, which can result in toxicity and severe health consequences. Improper storage, handling, and disposal of pesticides exacerbate the risk, particularly for farmers in daily contact with these substances [21]. Frequent use of pesticides has been associated with an increase in poisoning cases globally, with an estimated 1 to 5 million cases annually, including approximately 220,000 fatalities due to pesticide poisoning [32, 33]. Key contributing factors include the application of high, non-recommended dosages. Symptoms of pesticide poisoning often include headaches, dizziness, tingling sensations, tremors, loss of balance, seizures, and diminished activity of acetylcholinesterase and related enzymes crucial for body movement [34].

Pesticides are categorized into three main chemical groups: organochlorines, cholinesterase inhibitors, and other types [35]. The use of organochlorines has declined due to their persistent residues in soil, animals, and plants, which accumulate over extended use [1]. In contrast, cholinesterase inhibitors, including organophosphates and carbamates, remain widely used in agriculture to control soft-bodied pests.

While pesticides offer benefits in pest control, their negative impacts on health and environmental quality are significant [36]. Organophosphate pesticides, are highly toxic due to their hazardous chemical properties [37]. Farmers who are regularly exposed to these substances face the most significant risk with exposure occurring through skin contact, inhalation, improper and inconsistent use of personal protective equipment (PPE)—including clothing [38]. The occupational hazard is profound, with thousands of farmers and agricultural workers experiencing pesticide poisoning daily.

According to Sekiyama [39], prolonged contact with pesticides and the use of improper dosages are significant indicators of pesticide poisoning. This study also revealed that farmers often face challenges in understanding the content and potential dangers of their pesticides, as most of the information is written in foreign languages. This language barrier complicates their ability to follow proper usage procedures. Additionally, farmers frequently rely on informal sources, such as advice from fellow farmers or instructions from pesticide sellers [40]. A prevalent issue is the lack of knowledge among farmers regarding the correct pesticide dosages. This often leads to the misconception that higher dosages result in greater efficacy, without considering the heightened risks to their health and the environment [41]. Pesticide dosage refers to the quantity of pesticides applied during spraying, directly influencing the effects. Using pesticides without complying with the recommended guidelines can lead to pest resistance and increase an acute and chronic health risk. The continuous and improper use of pesticides exacerbates pest resistance, leading to increased dosages, higher application frequencies, and more varied pesticide compositions. This escalation poses serious health risks and contributes to environmental pollution due to the accumulation of pesticide residues. The improper use of pesticides is a major contributor to environmental degradation, disrupting ecosystems, leaving harmful residues on crops and food products, and contaminating soil and water resources. Furthermore, excessive exposure to pesticides significantly increases the risk of poisoning, which can be severe and, in extreme cases, fatal to humans (death) [42, 43].

This study revealed that 35.6% of farmers use pesticides without complying with the recommended dosage and application guidelines, resulting in greater exposure to these hazardous chemicals. The use of improper dosages not only increases farmers' exposure but also leads to the accumulation of pesticide residues in the environment. Proper regulation and compliance with pesticide dosage guidelines are essential to increasing the safety of farmers and improving the quality of agricultural products [41]. A significant relationship has been found between pesticide dosage and farmers' blood cholinesterase levels [44]. Approximately 80% of pesticides sprayed fail to reach the target plants and instead accumulate in the soil. This misapplication reduces soil nutrient content and fertility over time. Repeated pesticide spraying can also alter soil pH, further degrading its fertility. Moreover, pesticide residues that seep into nearby rivers can contaminate water sources, negatively impacting aquatic life, such as fish and birds. Improper pesticide usage has a substantial environmental impact, estimated at 94.2% [45]. This suggests that adopting proper pesticide usage behaviors and methods can have a significantly positive effect on the environment. A study by Ibrahim [44] emphasizes that using pesticides in improper dosages can result in severe health problems, environmental pollution, and ecological damage. Farmers, as a high-risk group, are often unaware of the dangers posed by their activities on pesticide-contaminated agricultural land. These risks not only compromise their health, but affect beneficial soil microorganisms and pollute the environment, including soil and water ecosystems. Pesticides contain several active compounds: chlorinated hydrocarbons, organophosphates, and carbamide derivatives [46]. Physiological mechanisms: Pesticides are neurotoxic by inhibiting acetylcholinesterase (AChE) so that Blood Cholinesterase Levels decrease and cause acetylcholine to be unbound, and acute symptoms, including dizziness, nausea, difficulty breathing, and even death, are caused by the blockage of AchE [47].

4.3. Relationship between Spraying Techniques and Blood Cholinesterase Levels

Pesticide exposure among farmers can occur during various agricultural activities, including transporting pesticides to farmland, mixing solutions, spraying pesticides, and cleaning spraying equipment [1, 48]. Each of these activities poses a risk of pesticide exposure, either through direct skin contact or inhalation. Wind direction is critical during spraying, determining whether the pesticide mist drifts back toward the sprayer [49, 50]. Spraying conducted in the same direction as the wind minimizes the risk of exposure, while spraying against the wind increases the likelihood of the pesticide mist hitting the sprayer, thus heightening the risk of poisoning [51]. Pesticide spraying is among the riskiest activities for farmers, as it involves direct interaction with these chemicals. Improper spraying jeopardizes farmers' health and leaves harmful pesticide residues on plants, which can adversely affect consumers if ingested. Residues can gradually accumulate in the human body, potentially causing long-term health issues such as nervous system disorders, reproductive problems, and an elevated risk of cancer. Several factors must be considered to minimize exposure and health risks, including the choice of equipment and the timing of spraying. The optimal spraying times are when airflow rises, typically between 08:00–11:00 and 15:00–18:00. Spraying early in the morning, when dew is still present on leaves, should be avoided, as it inhibits pesticide absorption. Similarly, spraying during the midday heat is not recommended, as pesticides may evaporate rapidly, reducing their effectiveness. This study revealed that 11.7% of farmers sprayed pesticides without following proper guidelines, increasing their exposure risk. Pesticide exposure can occur through the skin, where chemicals are directly absorbed, through the respiratory system during inhalation of pesticide mist, or through the digestive system when contaminated hands touch food or beverages [29].

Farmers frequently combine more than three different pesticides in a single tank for one spraying session during the mixing process. This practice significantly increases the concentration of toxic chemicals elevating the risk of poisoning. Furthermore, many farmers do not use proper personal protective equipment (PPE) during spraying activities. Essential protective gear, such as hats, masks covering the mouth and nose, eye protection, gloves, long-sleeved shirts, long pants, and boots, is often neglected. Additionally, some farmers spray against the wind, further heightening their risk of direct pesticide exposure.

Pesticide exposure can actually be minimized with knowledge of the dangers of pesticides, government policies and regular medical check-ups.

5. Conclusions and Suggestions

Pesticide poisoning is closely associated with reduced levels of cholinesterase enzyme (CHE) in the blood. Certain types of pesticides have anti-CHE properties, which inhibit this enzyme's activity in the body. Such inhibition disrupts the nervous system, potentially leading to poisoning and even fatal outcomes. The presence of pesticide poisoning can be identified through CHE enzyme levels, where abnormally low levels are a strong indicator of exposure. Unfortunately, the signs of pesticide poisoning, such as headaches, fatigue, sweating, vomiting, blurred vision, and seizures, are often underestimated and not addressed by visiting hospitals or healthcare providers. This leads to many cases of poisoning going undetected, increasing the likelihood of long-term or chronic health effects. Farmers must strictly comply with recommended pesticide dosage to mitigate the risks of pesticide poisoning and maintain normal CHE levels. Neglecting these guidelines can harm individual health and environmental quality, particularly soil and water. Additionally, proper spraying techniques must be followed, ensuring that pesticides are applied in line with the wind direction to minimize skin contact and inhalation, which are common poisoning causes.

Limitation of the study includes cross-sectional design, only one measurement without control group, besides that, confounding variables such as personal protective equipment (PPE), frequency of exposure can give rise to bias. The future study has to investigate the blood Cholinesterase Levels by Longitudinal methods as a preventive measure. Population can also be added not only specifically to onion farmers but all farmers so that the diversity of data and research results can be generalized.

Ethical Approval

This study was reviewed and approved by the Ethics Committee of Universitas Muslim Indonesia, with recommendation number 622/A.1/KEP-UMI/IX/2023.

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