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Pesticide Spraying Practices and Hypertension Risk among farmers in Bumen Village, Indonesia

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This study investigated the association between pesticide spraying practices and hypertension in horticultural farmers in Bumen Village, Sumowono District, Indonesia. A cross-sectional study was conducted among 132 male farmers selected through purposive sampling. Data were collected through structured interviews, blood pressure measurements, and field observations. Logistic regression revealed that mixing ≥2 pesticide types (OR=4.828; p=0.028), spraying ≥4 times per week (OR=4.552; p=0.010), and incomplete PPE use (OR=3.551; p=0.015) were significantly associated with hypertension. These findings underscore the need for stricter pesticide regulation, improved PPE use, and regular health monitoring to reduce health risks among farmers.

Keywords: Hypertension, Perticide Exposure, Occupational Health, Personal Protective Equipment, Horticultural Farmers

INTRODUCTION

WHO estimates that pesticide poisoning affects up to five million farmers annually, with most fatalities occurring in developing countries (Ministry of Health of the Republic of Indonesia, 2019). In Indonesia, the heavy reliance on pesticides puts smallholder farmers at risk, especially when safety practices are inadequate (Prajawahyudo et al., 2022; Apriyuni et al., 2024). In Bumen Village, Central Java, pesticide spraying is part of daily agricultural routines. Yet, many farmers neglect proper protective measures, exposing themselves to long-term health risks such as hypertension (Arifah & Wijayanti, 2023).

Pesticide exposure has been linked to various metabolic disturbances, notably hypertension, through multiple exposure routes such as inhalation, ingestion, and skin contact (Athukorala et al., 2023; Dong & Yu, 2025). Mechanistically, compounds like organophosphates inhibit cholinesterase, causing acetylcholine buildup that disrupts vascular regulation and increases blood pressure (Mdeni et al., 2022). Yet, poor enforcement of safety regulations and low personal protective equipment (PPE) compliance among Indonesian farmers continue to increase health risks (Siregar et al., 2024)

Previous studies in developed countries have highlighted the impact of pesticide exposure on cardiovascular health (Tudi et al., 2022). However, limited research has explored the effects of intensive pesticide use on smallholder horticultural farmers in developing regions with weak regulatory enforcement. Most existing studies have assessed general pesticide exposure rather than specific spraying practices, such as the number of pesticide types used, spraying frequency, and PPE compliance (He et al., 2020). To address this gap, this study examines how specific pesticide spraying practices contribute to hypertension risk among horticultural farmers in Bumen Village, Indonesia.

Given the high frequency of pesticide use and low compliance with PPE among these farmers, we hypothesize that the number of pesticide types used, spraying frequency, and incomplete PPE compliance are significantly associated with an increased risk of hypertension. This study aims to analyze pesticide spraying practices as key occupational risk factors for hypertension. By identifying the occupational risk factors of hypertension related to pesticide spraying, this research provides scientific evidence to strengthen pesticide safety regulations and develop targeted health interventions for smallholder farmers. Findings from this study are expected to support evidence-based public health interventions through strengthened PPE enforcement, pesticide training, and routine hypertension screening for high-risk farming communities.

METHODS

This study employed a cross-sectional design to analyze the association between pesticide spraying practices and hypertension among horticultural farmers. The research was conducted in Bumen Village, Sumowono

District, Semarang Regency, Indonesia, from July to August 2023. The area is known for intensive pesticide use in small-scale horticultural farming. The study population comprised 195 male farmers actively involved in pesticide spraying. Using purposive sampling, 132 participants were selected based on the following inclusion criteria: (1) male, (2) aged 20–45 years, (3) actively spraying pesticides for at least one year, and (4) willing to participate. Exclusion criteria included a history of cardiovascular disease, ongoing hypertension treatment, or current use of antihypertensive medication.

Data were collected through structured interviews, direct field observations, and physiological measurements. A semi-structured questionnaire was used to collect information on sociodemographic and occupational variables, including age, years of spraying experience, types of pesticides used, spraying frequency, spraying duration, and PPE use. The questionnaire was adapted from a previously validated instrument developed by the Indonesian Ministry of Health and underwent face-validity testing with public health experts. Blood pressure measurements were taken using a Gluco Dr digital sphygmomanometer that had been calibrated in accordance with Indonesian Ministry of Health guidelines. Participants were seated at rest for at least five minutes, and two readings were taken at five-minute intervals, the average value was recorded. Hypertension was defined as systolic BP ≥140 mmHg and/or diastolic BP ≥90 mmHg. Field observations were conducted to assess actual pesticide spraying practices. "Incomplete PPE" was operationally defined as the absence of one or more of the following during spraying activities: gloves, goggles, respirator or mask, long-sleeved clothing, and boots. Farmers using only basic face masks or cloth coverings without full protective gear were categorized as having incomplete PPE use.

Statistical analysis was performed using SPSS version 26. Descriptive statistics were used to summarize participant characteristics and spraying behaviors. Associations between categorical variables and hypertension status were examined using chi-square tests. Multivariate logistic regression was applied to assess the relationship between pesticide spraying practices and hypertension. Statistical analysis was performed using SPSS version 26. Descriptive statistics were used to summarize participant characteristics and spraying behavior. The relationship between categorical variables and hypertension status was evaluated using the chi-square test, while odds ratios (OR) were calculated to determine the strength of the associations. Variables included in the logistic regression model for multivariate analysis were variables with a p-value < 0.25 obtained from bivariate analysis. A p-value <0.05 was considered statistically significant. Ethical clearance for this study was obtained from the Health Ethics Commission of Diponegoro University (Approval Number: 365/EA/KEPK-FKM/2023). All participants provided written informed consent before enrolment, and data confidentiality was maintained by research ethics guidelines.

RESULTS AND DISCUSSION

Participant Characteristics

A total of 132 male horticultural farmers participated in this study, with an age range of 26–59 years (mean = 46.91 years). The majority had been working as farmers for ≥10 years (94.7%), and most (90.2%) reported using ≥2 types of pesticides. Approximately 42.4% of farmers sprayed pesticides for ≥5 hours/day, while 53% sprayed ≥4 times per week. Additionally, 69.7% of farmers exhibited incomplete use of personal protective equipment (PPE), indicating poor adherence to safety measures. Blood pressure measurements indicated that 78% of participants had hypertension (BP ≥140/90 mmHg), highlighting a high prevalence of hypertension among horticultural farmers.

Table 1
Association Between Pesticide Spraying Practices and Hypertension Among Horticultural Farmers (Bivariate Analysis)

Variable	Incidence of Hypertension				*p-value*	OR value (95%CI)
	Yes		No			
	n	%	n	%		
Working period						
≥ 10 years	101	80.8	24	19.2	0.005	10.521 (1.924-57.542)
< 10 years	2	28.6	5	71.4		
The number of types of pesticides						
≥ 2 types of pesticide	98	82.4	21	17.6	0.001	7.467 (2.221-25.107)
< 2 types of pesticide	5	38.5	8	61.5		
Spraying duration						
≥ 5 hours/day	50	89.3	6	10.7	0.014	3.616 (1.360-9.617)
< 5 hours/day	53	69.7	23	30.3		
Spraying frequency						
≥ 4 days of the week	65	92.9	5	7.1	<0.001	8.211 (2.892-23.307)
< 4 days of the week	38	61.3	24	38.7		

Practical use of PPE						
Incomplete	81	88.0	11	12.0	<0.001	6.025 (2.484-14.610)
Complete	22	55.0	18	45;0		

Table 1 shows the associations between pesticide spraying practices and hypertension. Hypertension was significantly more prevalent among farmers with ≥10 years of experience (80.8%) compared to those with <10 years (28.6%) (p = 0.005; OR = 10.521). However, this association lost significance in multivariate analysis. Similarly, those using ≥2 types of pesticides had a higher hypertension prevalence (82.4%) than those using fewer types (38.5%) (p = 0.001; OR = 7.467). Farmers who sprayed ≥5 hours/day showed a prevalence of 89.3% compared to 69.7% among those spraying <5 hours/day (p = 0.014; OR = 3.616). Spraying ≥4 days/week was also significantly associated with hypertension (92.9% vs. 61.3%, p < 0.001; OR = 8.211). This factor also lost significance in multivariate analysis. Incomplete PPE use was associated with an 88% hypertension prevalence, versus 55% in those with complete PPE (p < 0.001; OR = 6.025).

Multivariate Analysis

Multivariate logistic regression was performed to determine the independent effects of pesticide spraying practices on hypertension after controlling for potential confounders. Only variables with significant bivariate associations were included in the model.

Table 2

Multivariate Logistic Regression Analysis of Pesticide Spraying Practices and Hypertension Among Horticultural Farmers

Variable	Coef (B)	p-value	OR	95% CI
Number of pesticide types	1.574	0.028	4.828	1.187-19.642
Spraying frequency	1.516	0.010	4.552	1.429-14.501
Practical use of PPE	1.267	0.015	3.551	1.285-9.809

Supplementary Data

Detailed information on all 49 pesticides used by farmers, including chemical group, and LD50 toxicity classification, is provided in the supplementary table. A summary of pesticide classification by chemical group is presented in Table 3.

Table 3

Types of Pesticides Used by Farmers in Bumen Village

Chemical Group	Number of Products	Toxicity Class	Example Brands
Organophosphates	12	II	Curacron, Rumba
Carbamates	5	Ib–U	Antracol, Dithane
Pyrethroids	6	II	Decis, Hoky
Avermectins	6	Ib	Abacel, Agrimec
Others (Fungicides/Herbicides)	20	U–III	Nativo, Roundup

Pesticide toxicity classification is based on active ingredients: Ia (extremely hazardous, oral <5 mg/kg, dermal <50 mg/kg), Ib (highly hazardous, oral 5-50 mg/kg, dermal 50-200 mg/kg), II (moderately hazardous, oral 50-2000 mg/kg, dermal 200-2000 mg/kg), III (slightly hazardous, oral >2000 mg/kg, dermal >2000 mg/kg), and U (unlikely to cause acute hazard, ≥5000 mg/kg).

Number of Types of Pesticides

The number of pesticide types used was found to be significantly associated with hypertension, with farmers using ≥2 types facing more than a fourfold increased risk. This aligns with findings from (Ledda et al., 2021), who reported that mixed pesticide exposure can induce oxidative stress and endothelial dysfunction, leading to elevated blood pressure. Similarly, Peng et al. (2024) identified a correlation between pesticide mixtures such as chlorpyrifos and fipronil and hypertension. In the Bumen Village context, pesticide mixing is often practiced to increase perceived effectiveness and reduce labor, though it inadvertently raises the risk of chemical interactions and systemic toxicity (Chen et al., 2024).

In Bumen Village, farmers commonly mix three or more pesticide products during each spraying session, combining insecticides and fungicides to simultaneously target multiple pests. For example, organophosphate-based products such as profenofos and chlorpyrifos were frequently used by local farmers. These compounds are classified as highly hazardous and are known to inhibit cholinesterase activity, resulting in acetylcholine accumulation and increased vascular tension (Li et al., 2020). Such unregulated mixing, often done to save time and labor, may inadvertently heighten exposure levels and help explain the elevated hypertension risk found in this study. Given that farmers often lack training on pesticide compatibility and risk assessment, this finding underscores the need for policy interventions. Local agricultural agencies could offer guidelines on safe pesticide combinations and promote the use of less hazardous

alternatives. Integrating this topic into farmer field schools or extension programs may reduce unsafe mixing practices (Goeb & Lupi, 2021).

Spraying Frequency

Spraying frequency emerged as another dominant factor, with farmers spraying ≥4 times per week facing significantly higher odds of hypertension. This study has similarities with a study conducted by Saftarina et al. (2022) explained that there is a significant relationship between the frequency of spraying pesticides that do not meet health requirements with symptoms of pesticide poisoning, one of which is hypertension. The study conducted by Saftarina et al. (2024) also explained that a low frequency of spraying in one week reduces the risk of hypertension in farmers.

The number of spraying frequencies is influenced by the season because if the rainy season will be more pests that attack and make farmers spray more often (Materu et al., 2021). The more frequent the frequency of spraying, the higher the risk of farmers being exposed to pesticides, which will interfere with farmers' health (Curl et al., 2023). This should be a concern for farmers to pay attention to the frequency of spraying. It is better not to force it and can reduce the working time per day. This will reduce pesticide exposure to farmers and maintain crop quality (Zanin et al., 2022). This finding suggests that exposure reduction strategies should not only focus on pesticide selection but also workload regulation and scheduling. Community-level training programs could emphasize integrated pest management (IPM) approaches that reduce reliance on frequent spraying. Furthermore, policies that encourage cooperative pest control services may help reduce individual farmer exposure (Deguine et al., 2021).

Practical use of PPE

Incomplete PPE use was significantly associated with increased hypertension risk. Farmers who failed to use complete PPE were three times more likely to experience elevated blood pressure. This result has similarities with research conducted by Lari et al. (2023) explained that incomplete use of PPE is associated with a decrease in blood cholinesterase levels which is at risk of increasing hypertension. Another study by Bongakaraeng & Pesak (2023) explains that there is a significant relationship between incomplete use of PPE and blood cholinesterase levels which are at risk of hypertension.

Researchers found that farmers do not use complete Personal Protective Equipment (PPE) because they think it is not free when working. When wearing masks, farmers complained that it was difficult to breathe and hot because they were working under the hot sun. As for farmers who use masks, they are still not up to standard. Bumen Village farmers use masks made of cloth that cannot filter pesticide particles. Most farmers also do not use gloves when spraying. The practice of using incomplete PPE causes the body to be exposed directly without adequate protection so the risk of pesticide entry through the skin or respiratory tract becomes higher (Joko et al., 2020). Personal protective equipment (PPE) serves as a physical barrier between farmers and pesticides that can reduce direct exposure when they handle hazardous chemicals. By wearing PPE such as coveralls, gloves, and masks, farmers can prevent pesticides from adhering to the skin and entering the body through inhalation or direct contact (Garrigou et al., 2020). The use of proper PPE helps maintain normal cholinesterase levels by reducing the risk of inhibition of the enzyme that can occur due to pesticide exposure (Daulay et al., 2020).

To address this, local governments should consider subsidized PPE programs and context-appropriate PPE designs tailored for tropical farming conditions. Promoting PPE through community-led safety champions or farmer cooperatives may also enhance compliance. Furthermore, linking PPE use to farmer insurance or certification schemes could provide additional incentives (Zhang et al., 2019).

Contribution and Limitation

This study contributes empirical evidence on how specific spraying practices, pesticide mixing, spraying frequency, and PPE adherence are significantly associated with hypertension risk among smallholder horticultural farmers. These findings have direct implications for occupational health policy, especially in pesticide-intensive farming areas. However, the study has limitations. The cross-sectional design restricts causal inference, and self-reported data may introduce recall bias. Future research should incorporate biomarker-based exposure assessments and consider longitudinal designs to strengthen causal claims.

CONCLUSIONS

This study confirms that mixing multiple pesticide types, frequent spraying, and incomplete PPE use significantly increases the risk of hypertension among horticultural farmers. Organophosphates and carbamates exhibit high toxicity and elevate hypertension risk, and prolonged exposure exacerbates systemic toxic effects through inhalation, ingestion, and dermal absorption. Policymakers should implement stricter pesticide regulations, provide PPE subsidies, mandate occupational safety training, and conduct regular health screenings. Future research should incorporate biomarker assessments and investigate safer pesticide alternatives.

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