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The Relationship Between Pesticide Exposure and Disturbances in Balance Function in Apple Farmers in Tulongrejo Village, Bumi Aji District, Batu City

Sylvia Nehemia Siregar[1*], Onny Setiani[1], Yusniar Hanani [1]

[1] Program Magister Kesehatan Lingkungan Fakultas Kesehatan Masyarakat, Universitas Diponegoro, Indonesia.

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Corresponding Author:
Sylvia Nehemia Siregar
nehemiasiregar@gmail.com

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Abstract: This study aims to analyze the morphological diversity and phylogenetic relationships of six species from the Annonaceae family at the Purwodadi Botanical Garden using a phenetic approach. The background of this research is based on the importance of character-based identification to support taxonomy, conservation, and plant classification within the Annonaceae family, which is known for its high diversity. The research began with field exploration and specimen identification, followed by morphological characterization focusing on stem, leaf, petiole, and flower traits. Data acquisition was conducted by direct observation and measurement using tools such as calipers, rulers, and color tables. The morphological data were analyzed using Hierarchical Cluster Analysis and Principal Component Analysis (PCA) with SPSS 25.00 software to determine phylogenetic relationships among the species. The results revealed two major clusters: the first includes *Mitrephora polyprena*, *Stelechocarpus burahol*, *Orophea enneandra*, and *Polyalthia bullata*, with a similarity index of 73.2%, and the second consists of *Annona muricata* and *Miliusa horsfieldii*, with 59.3% similarity. PCA results indicated that leaf width, leaf length, petiole length, leaf color, and stem surface were the most influential morphological traits. These findings demonstrate that the phenetic approach is effective for analyzing phylogenetic relationships and can contribute to conservation strategies and biodiversity management.

Keywords: Annonaceae; Biodiversity; Botanical; Phenetics.

Introduction

As a large agricultural country, Indonesia is one of the three largest pesticide users in the world in 2021, after Brazil and the United States. Indonesia's pesticide use was recorded at 283 kilotons in 2021. The amount of pesticide use in Indonesia has increased every year. Increased use of pesticides can increase the risk of exposure to pesticides which can cause various health problems such as imbalance (Alfakihuddin et al., 2023).

Almost 96% of farmers in Indonesia use chemical pesticides to control pests or plant-disturbing organisms (OPT) because they are considered effective, easy to use and economically profitable. Pesticides are widely used to protect crops and livestock from losses due to insects, weeds, and diseases, thereby helping to increase agricultural productivity. Currently, the use of pesticides is out of control, plants are still sprayed with pesticides regardless of whether or not there are pests (Purnamasari et al., 2020).

The use of pesticides has both beneficial and detrimental impacts. The beneficial impact is that it can increase agricultural products quickly and effectively, but if pesticides are used excessively, it will have a detrimental impact on the environment and the health of farmers (Djojosumarto, 2008). Horticultural crop

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farmers are at high risk of pesticide poisoning with long-term negative impacts (Tudi et al., 2021). The negative effects of long-term pesticide exposure can cause various health disorders, one of which is nervous system disorders (body balance disorders) (Samosir et al., 2017). This is related to the involvement of farmers in agricultural activities, such as spraying, preparing equipment for spraying, mixing pesticides, washing equipment/clothes worn when spraying, removing grass from plants, looking for pests, watering plants and harvesting. The effects of pesticide poisoning vary widely, ranging from headaches, nausea, pain and can even cause death. Pesticide poisoning can be acute, chronic or systemic which can attack the nervous system and cause balance disorders, immune system disorders, liver disorders, and hormonal imbalances (Nabila et al., 2016).

Chronic effects of pesticides include weight loss, anemia, tremors, headaches, dizziness, anxiety, psychological disorders, nervous system disorders, chest pain, and irritability. The use of synthetic pesticides has continued to increase worldwide since 1940. The synthetic pesticides that are widely used by farmers in Indonesia are the organophosphate group. Pesticides that inhibit the cholinesterase enzyme, for example, pesticides from the carbamate and organophosphate groups. Diagnosis of poisoning symptoms with a cholinesterase test. Pesticide contamination that is not a cholinesterase inhibitor, for example, Insect Growth Regulator (IGR), triazine, abamectin, pyrethroids, sulfonylurea, thiourea, and others cannot be detected by a cholinesterase test. The cholinesterase enzyme that is not inactivated by organophosphate will hydrolyze acetyl choline (added as a substrate) into choline and acetic acid. The amount of acetic acid formed by blood cholinesterase activity can be measured for acidity using an indicator. Symptoms of organophosphate or carbamate poisoning will be seen if blood cholinesterase activity decreases by 30%. A decrease of up to 50% in pesticide users is the limit value and users are advised to stop doing activities related to pesticides (Dhamayanti & Saftarina, 2018).

Some organophosphate pesticides enter the human body through the digestive tract, respiratory tract or inhalation and through unprotected skin surfaces so that they can affect nerve function (one of which is body balance) (Pratama et al., 2021). Batu City is a horticultural area in East Java that produces various agricultural products, such as vegetables and fruits. The types of pesticides used to control pests on fruits in Batu City include organophosphates and carbamates (94.7%). The Health Office (2017) noted that cases of pesticide contamination in Batu City were mostly experienced by farmers, namely 82.7%. Based on the research and development of the Batu City Health Office in 2012 on 330 farmers spread across 3 sub-districts (Batu, Bumiaji and Junrejo Sub-districts), it was found that most farmers (73.5%) experienced mild poisoning (Fadlina, 2013).

A preliminary study conducted in November on 40 apple farmers by interviewing using a questionnaire sheet found that farmers who sprayed experienced symptoms of poisoning such as dizziness or headaches (7.5%), tremors (10%), frequent tingling (12.5), difficulty walking (5%). Pesticide use is 2-4 times spraying/week. Farmers spray when the plants are attacked by pests and diseases. The mixing of more than 2 types of pesticides in one spraying of plants. The mixture of pesticide types consists of insecticides and fungicides. The most widely used group of pesticides is organophosphate or carbamate. The use of PPE that is not good when spraying is also a risk factor for exposure to pesticides by farmers.

The impact of pesticide exposure to the nervous system, which can result in neurological disorders and impaired body balance. Neurological disorders in farmers can result in decreased cognitive function which can then lead to decreased performance and even decreased agricultural production. Impaired body balance causes a person to feel unbalanced, dizzy, have a sensation of movement, spinning, or floating due to disturbances in the nerves that control the body's balance itself and will have further impacts that result in limited activities in daily life.

Based on the description above, this study aims to analyze the relationship between agricultural activities, work period, length of work per day, type and dose of pesticides, frequency of spraying/week, habits and completeness of use of personal protective equipment (PPE), with neurological disorders and balance function in apple farmers in Tulongrejo Village, Bumiaji District, Batu City.

Method

The type of research conducted is observational analytic which aims to find the relationship between one variable and another. This study uses a cross-sectional study design, namely data collection for independent variables and dependent variables is carried out together, namely by conducting observations and measurements at the time of the independent variables in the form of agricultural activities, work period, length of work, type and dose of pesticides, frequency of spraying per week, and habits and completeness of PPE use. The population in this study were all farmers in Gondang Hamlet, Bumiaji District, Batu City with active members in farmer groups totaling 280 people. To

determine the number of samples needed in a small population, it can be determined using the Slovin Formula 1 (Pawestri & Sulistyaningsih, 2021).

$$n = \frac{N}{1+N\,(e^2)} \quad (1)$$

Description: n = sample size; N = population size; e = critical value (accuracy limit)

The sampling technique in this study was purposive sampling technique, namely by selecting research subjects based on the subjective considerations of the researcher, that the subject can provide adequate information to answer the research questions. The considerations were that the farmers were residents who lived and were farmers in Tulongrejo Village, willing to participate in the examination of cholinesterase levels in the blood and the Romberg test. The determination of the sample size in this study was adjusted to the inclusion criteria of the research subjects to be used as samples and analyzed by laboratory examination and medical examination.

The data processing and analysis techniques in this study used IBM SPSS Statistic 23 software. The collected data were processed using a computer including the following stages: *Editing:* used to check the completeness of the questionnaire and the collected data. The goal is to check and correct whether there is a lack of data, for example, empty questionnaire question items or errors in filling; *Coding:* making classifications and providing answer codes with the aim of making it easier to read the data; *Entry:* is the process of entering data obtained into a computer device which is then processed; and *Cleaning:* is the process of checking for errors, incompleteness. Then missing (lost data), varied and consistent data are carried out.

Data Analysis

Descriptive Analysis

The collected data is processed and analyzed descriptively against values or numbers including the mean, standard deviation, median, minimum and maximum values for the variables studied and presented in a frequency distribution table.

Inferential Analysis

Inferential analysis is to prove whether or not there is significance between the independent and dependent variables, namely to test the relationship between agricultural activities, work period, length of work per day, type and dose of pesticides, frequency of spraying, habits and completeness of PPE use with neurological disorders and disorders of body balance function in apple farmers in Tulungrejo Village, Bumiaji District, Bota City. The statistical test in this study is Chi-square with 2x2 cross tabulation, but if there is an expected frequency of, 5 in the crosstab then the fisher exact test is used. The Chi-square test is used to test relationships when the variables are on a categorical (nominal) scale.

Result and Discussion

Based on the results of the study conducted in Tulogorejo Village, Bumiaji District, Batu City, the characteristics of the respondents were classified based on gender, age group, and education level. All respondents in this study were male (100%), while there were no female respondents. Based on age group, most respondents were in the 40-59 years age range, which was 41 people (33.4%). The 20-39 years age group was 20 people (27%), while the age group over 60 years was recorded at 13 people (17.7%).

According to data from the Central Statistics Agency (BPS) in 2021, the majority of farmers in Indonesia are not from the young generation (Mardiyanti et al., 2023). As many as 38.02% of farmers are included in generation X (aged 41-56 years), followed by the baby boomer generation (aged 57-75 years) with a percentage of 34.41%. Generation Y or millennials (aged 25–40 years) contributed 21.92% of the total farmers, while farmers from the pre-boomer generation accounted for 3.38%. Farmers from generation Z and post-Z were recorded at 2.24% and 0.02% respectively (Pertiwi et al., 2024).

From the data, there were 32 people (43.2%) of junior high school (SMP) education, followed by 22 respondents (29.7%) with elementary school education, and 17 respondents (13%) with no formal education. Meanwhile, only 3 people (4.1%) completed their education up to senior high school (SMA), and there were no respondents with a bachelor's degree. so it can be concluded that the quality of human resources in the agricultural sector is still relatively low. In fact, as explained by Mance et al. (2025), education and health are closely related to economic growth. Education plays an important role in driving economic development because it can influence the way individuals think. Farmers with higher levels of education tend to have more open and innovative thinking compared to farmers with lower educational backgrounds (Gusti et al., 2021).

Relationship of Cholinesterase Levels with Disturbances in Balance Function in Apple Farmers

The results of the analysis of Table 1 show that of the 7 respondents with abnormal cholinesterase levels, 71.4% experienced impaired balance function, while of the 67 respondents with normal cholinesterase levels, only 34.3% experienced impaired balance function. Statistical analysis showed a p value of 0.05, indicating a relationship between cholinesterase levels and impaired balance. The prevalence ratio (PR) value of 4.107 with a

95% confidence interval of 0.854–19.763 indicates that respondents with abnormal cholinesterase levels have a risk of approximately 4 times greater experiencing impaired balance compared to respondents with normal cholinesterase levels.

Table 1. Distribution of the Relationship between Cholinesterase Levels and Impaired Body Balance Function in Apple Farmers in Tulongrejo Village, Bumiaji District, Batu City

Kadar Cholinesterase	Balance Function Disorders				Total		p value
	Yes		No				
	N	%	N	%	N	%	
Abnormal	5	71.4	2	28.5	7	100	0.05
Normal	23	34.3	44	65.7	67	100	
PR= 4.107 ; 95% CI= 0.854 -19.763							

The results of this study are in line with those conducted in Magelang. A significance value of 0.000 (p <0.05) was obtained, indicating a relationship between blood cholinesterase levels and body balance disorders. The odds ratio (RP) result of 3.600 with a 95% Confidence Interval (CI) = 2.218 - 5.844, indicates that farmers with abnormal cholinesterase levels have a risk of more than 3.6 times greater than farmers with normal cholinesterase levels (Rotich, 2018).

Relationship between Farmer Activities and Body Balance Function Disorders in Apple Farmers

Horticultural farmers are at high risk of experiencing pesticide poisoning with long-term negative impacts (de Graaf et al., 2022; Zhou et al., 2024). The negative effects of long-term pesticide exposure can cause various health disorders, one of which is nervous system disorders (body balance disorders). This is related to the involvement of farmers in agricultural activities, such as spraying, preparing equipment for spraying, mixing pesticides, washing equipment/clothes used when spraying, removing grass from plants, looking for pests, watering plants and harvesting.

The results of the chi square analysis in table 2 show that Based on the data, of the 5 respondents who carried out farmer activities well, 80% experienced impaired balance function, while only 20% did not experience impaired body balance function. Meanwhile, of the 69 respondents who did not carry out farmer activities well, 34.8% experienced impaired balance and 65.2% did not experience impaired balance function. The statistical test showed a p value of 0.04, which means that there is a significant relationship between activities as a farmer and impaired balance function. However, the PR value is 0.876 with a 95% confidence interval of 0.749–1.025.

Table 2. Distribution of the Relationship between Farmer Activities and Body Balance Function Disorders in Apple Farmers in Tulongrejo Village, Bumiaji District, Batu City

Farmer Activities	Balance Function Disorders				Total		*p value*
	Yes		No				
	N	%	N	%	N	%	0.04
No	24	34.8	45	65.2	69	100	
Yes	4	80	1	20	5	100	
PR= 0.876 ; 95% CI= 0.749-1.025							

A higher frequency of spraying can increase the risk of poisoning. Therefore, spraying must be carried out in accordance with existing provisions, by limiting contact to a maximum of twice a week (Samosir et al., 2017). Based on the results of observations in the field, factors that influence cholinesterase levels include work period, work hours, healthy lifestyles, and the level of farmer knowledge regarding the importance of using personal protective equipment (PPE) that meets standards (Ananda, 2024).

The higher the frequency of pesticide spraying carried out by a person, the greater the risk of exposure to poisoning. Therefore, spraying should be carried out in accordance with the established usage guidelines. Direct contact with pesticides is recommended not to exceed two times a week to minimize health risks (Benbrook et al., 2021).

Based on the results of observations in the field, almost all respondents did not carry out the pesticide spraying procedure correctly, such as not washing their hands with soap and running water and not immediately cleaning the equipment and clothes used. As a result, pesticide residues remain on the body and clothes, and have the potential to be inhaled, which can increase the risk of poisoning and disrupt the body's balance function.

Relationship between Work Period and Body Balance Function in Apple Farmers

Working period is the length of time a person works in one year, because pesticides are accumulative in the body, the longer the person works, the more pesticides will be in their body which will eventually cause various adverse health effects, one of which is disruption to the central nervous system in the form of impaired body balance (Maksuk et al., 2023).

Table 3. Distribution of Relationship between Work Period and Body Balance Function Disorders in Apple Farmers in Tulongrejo Village, Bumiaji District, Batu City

Working time	Balance Function Disorders				Total		*p value*
	Yes		No				
	N	%	N	%	N	%	0.01
≥15 years	18	52.9	16	47.1	34	100	
<15 years	10	25	30	75	40	100	

PR= 1.848 ; 95% CI= 1.141-2.994

The results of the analysis of table 3 show that of the 34 respondents with a working period of more than 15 years, 52.9% experienced impaired balance function, while 47.1% did not experience impaired balance function. Meanwhile, of the 40 respondents with a working period of less than 15 years, only 25% experienced impaired balance and 75% did not experience impaired balance. The results of the statistical test showed a p value of 0.01, which means that there is a significant relationship between working period and impaired balance function. The PR value of 1.848 with a 95% confidence interval of 1.141–2.994 indicates that respondents with a working period of more than 15 years have almost 2 times higher risk of experiencing impaired balance compared to respondents with a working period of less than 15 years.

This study is in line with the results of previous studies, where the chi-square test showed a significance value of 0.015 (p <0.05). The findings indicate a significant relationship between the duration of pesticide spraying per day and body balance disorders in horticultural farmers (Naik et al., 2024).

Farmers with long working periods have a greater potential for long-term exposure to pesticides. This continuous exposure can cause bioaccumulation of hazardous substances in the body, which is at risk of causing chronic poisoning, especially in farmers who routinely spray pesticides. The longer the duration of involvement in spraying activities, the higher the frequency and intensity of contact with pesticides, thereby increasing the risk of poisoning (Chaudhry, 2024). Based on field observations, it is known that the average working period of farmers in the area reaches 20 years. This condition indicates the potential for long-term accumulation of exposure that can have a negative impact on body balance function.

Relationship between Working Time per Day and Body Balance Disorders in Apple Farmers

Working hours per day are the length of time a farmer works each day in hours and several days a week in units of days, so the longer the farmer's working hours in a day, the more pesticides will be received by the farmer's body, and will accumulate in several working days during a week, then it will accumulate over a longer period of time. WHO requires the length of work in a workplace that is at risk of pesticide poisoning, namely 5 hours per day or 30 hours per week.

Table 4. Relationship between Daily Working Hours and Body Balance Function Disorders in Apple Farmers in Tulongrejo Village, Bumiaji District, Batu City

Working time	Balance Function Disorders				Total		*p value*
	Yes		Tidak				
	N	%	N	%	N	%	0,04
≥5 hours	26	43.3	34	56.7	60	100	
<5 hours	2	14.3	12	85.7	14	100	

PR= 1.256 ; 95% CI= 1.029 – 1.535

Based on Table 4, the results of the analysis show that of the 60 respondents who worked more than 5 hours per day, 43.3% experienced impaired balance function and 56.7% did not experience impaired balance function. Meanwhile, of the 14 respondents who worked less than 5 hours per day, only 14.3% experienced impaired balance and 85.7% did not experience impaired balance function. The results of the statistical test showed a p value of 0.04, indicating a significant relationship between working time duration and impaired balance function. The PR value of 1.256 with a 95% confidence interval of 1.029–1.535 indicates that

respondents who work more than 5 hours per day have a risk of about 1.26 times greater for experiencing impaired balance compared to those who work less than 5 hours.

This study is in line with that conducted by Samosis in Ngablak District, Magelang Regency with the results of the study obtained a significance value of 0.015, this shows that there is a relationship between working hours per day and disturbances in the body balance of horticultural farmers. Based on the results of observations in the field, farmers carry out various activities such as spraying, mixing pesticides, preparing tools, planting, weeding, to harvesting. Spraying is generally done in the morning and evening. Most farmers do use personal protective equipment (PPE), but the type and method of use are not in accordance with the recommended standards, so they are still at risk of pesticide exposure. In addition, most farmers have working hours of more than 5 hours per day, with an average working duration of 6.53 hours. The length of spraying time is something that needs to be watched out for, because the longer a person is exposed to pesticides, the greater the possibility of poisoning, especially without optimal protection.

Relationship between the frequency of spraying per day and disturbances in the balance function of the body of apple farmers

The spraying time carried out by farmers is still within the normal range, which is 3 hours/day. Permenaker No. Per-03/Men/1986 states that in order to prevent unwanted effects, it is recommended not to exceed five hours per day in a week in a row when using pesticides.

Table 5. Relationship between Spraying Time Per Day and Body Balance Function Disorders in Apple Farmers in Tulongrejo Village, Bumiaji District, Batu City

Spraying time	Balance Function Disorders				Total		p value
	Yes		No				
	N	%	N	%	N	%	
≥3 hours	18	31.6	39	68.4	57	100	0.04
<3 hours	10	58.8	7	41.2	17	100	

PR= 0.758 ; 95% CI = 0.561-1.026

From table 5, the analysis results show that of the 57 respondents who sprayed for more than 3 hours, 31.6% experienced impaired balance function and 68.4% did not experience impaired balance function. Meanwhile, of the 17 respondents who sprayed for less than 3 hours, 58.8% experienced impaired balance function and 41.2% did not experience impaired balance function. The statistical test results showed a p value of 0.04, indicating a significant relationship between the duration of spraying and impaired balance function. The PR value is 0.758 with a 95% confidence interval of 0.561–1.026.

Relationship between the Use of PPE and impaired body balance function in apple farmers

The use of personal protective equipment (PPE) that meets standards can significantly reduce the level of pesticide exposure in spraying farmers (Fizulmi & Agustina, 2024; Lari et al., 2023). According to the Regulation of the Minister of Manpower and Transmigration of the Republic of Indonesia Number PER.08/MEN/VII/2010, personal protective equipment is a device designed to protect workers by isolating part or all of the body from potential hazards in the work environment (Pratiwi et al., 2022).

Table 6. Relationship between Habits and Completeness of PPE and Impaired Body Balance Function in Apple Farmers in Tulongrejo Village, Bumiaji District, Batu City

Use of PPE	Balance Function Disorders				Total		*p value*
	Yes		No				
	N	%	N	%	N	%	
Incomplete	3	42.9	4	57.1	7	100	0.01
Complete	25	37.3	42	62.7	67	100	

PR= 1.232 ; 95% CI= 0.297-5.104

The results of the analysis of table 6 show that of the 7 respondents who used incomplete personal protective equipment (PPE), 42.9% experienced impaired balance function and 57.1% did not experience it. Meanwhile, of the 67 respondents who used complete PPE, 37.3% experienced impaired balance and 62.7% did not experience the disorder. The results of the statistical test showed a p value of 0.01, which indicates a significant relationship between the completeness of PPE use and impaired balance function. However, the PR of 1.232 with a 95% confidence interval of 0.297–5.104 indicates that the relationship is not statistically significant. This indicates a tendency for an increased risk of balance disorders in users of incomplete PPE (Tallo et al., 2022).

The results of this study are not in line with Minuddin's findings, which stated that farmers who did not use complete personal protective equipment (PPE) when spraying had a risk of up to 10 times higher of experiencing impaired cholinesterase enzyme activity compared to farmers who used complete PPE and according to procedures.

Based on the results of observations in the field, the majority of farmers had used complete personal protective equipment (PPE). However, most of the PPE used did not meet the established standards, so it could increase the potential for accumulation of high levels of cholinesterase in the body. The mismatch between the use of PPE and the established standards could increase the risk of pesticide exposure which would impact farmers' health.

Conclusion

There is a significant relationship between cholinesterase levels and impaired body balance function in apple farmers in Tulong Rejo Village, Bumiaji District, Batu City. There is a significant relationship between Spraying Activity and impaired body balance function in apple farmers in Tulong Rejo Village, Bumiaji District, Batu City. There is a significant relationship between Working Period and impaired body balance function in apple farmers in Tulong Rejo Village, Bumiaji District, Batu City. There is a significant relationship between Working Time and impaired body balance function in apple farmers in Tulong Rejo Village, Bumiaji District, Batu City. There is a significant relationship between spraying frequency and impaired body balance function in apple farmers in Tulong Rejo Village, Bumiaji District, Batu City. There is no significant relationship between Use of PPE and impaired body balance function in apple farmers in Tulong Rejo Village, Bumiaji District, Batu City.

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