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Morisita Index Reveals Contrasting Pest Insect Distributions in Cocoa Agroforestry Systems Shaded by Papaya versus Banana

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Abstract

The distribution pattern describes how organisms are distributed within a population. Distribution patterns are divided into three types: clumped, uniform, and random. This study aims to analyse differences in the distribution patterns of pest insect genera between shaded cocoa farms with papaya trees and those with banana trees, and to examine the influence of temperature and humidity on increases in pest insect populations in cocoa farms. The research was conducted from January to March 2025. Various trapping methods used include yellow, pitfall, and light traps, as well as visual observations. The distribution pattern was analysed using the Morisita Index (Id), while the effects of temperature and humidity were tested with simple linear regression. Morisita Index values ranged from 0 to 0.99 under papaya (Id<1) and from 1.06 to 3.00 under banana (Id>1). Regression analysis indicated that temperature and humidity did not have a significant effect on pest insect populations, as reflected by p-values greater than 0.05 (temperature: p=0.330; humidity: p=0.728) and very low coefficients of determination (R^2=0.025 and 0.003, respectively).

Keywords: *shade management, Empoasca, microclimate, agroecological monitoring, Hemiptera*

Introduction

Insects on plants have two roles: some are beneficial, while others are harmful. The emergence of attacks by parasitic organisms or pests that damage plants can destabilise crop yields, thereby affecting farmers' economic returns. Efforts to identify these insects are necessary to understand and classify those that are beneficial and those that pose risks. Identification is one of the methods or actions taken to determine the description of a researched subject to establish its identity, with insects being one example. As a component of biodiversity, insects play an important role in the agricultural ecosystem as herbivores, parasitoids, predators, or bioindicators of the environment (Gulo & Harefa, 2023). The role of these insects is greatly influenced by environmental conditions and the agroecosystem management practices implemented by farmers.

Distribution patterns refer to the spatial arrangement of species or individuals within a community, describing how organisms are distributed within a population. Distribution patterns are divided into three types: random, clumped (or aggregated), and uniform (or evenly spaced). Each type of animal naturally has different distribution patterns depending on their reproductive models and environment; these patterns are also influenced by biotic and abiotic factors (Darnilawati et al., 2018). The spatial and temporal distribution of insects is related to their life cycles, morphological characteristics, habitat selection criteria (e.g., type and climatic conditions), and the timing of prey searching, reproduction, and host recognition. Insects always consider food, competition, and predation. The current natural conditions impact climate change, causing environmental temperature factors to become increasingly unpredictable day by day (Allifah et al., 2019). Spatial distribution patterns are a method to find out whether the distribution of species in one particular area is random, clumped, or uniform (Witno et al., 2019). The temporal distribution pattern refers to the arrangement and changes of data over time, especially in the context of monitoring how the distribution of entities evolves at different times (Teegavarapu, 2019).

A random pattern of individuals within a species in a habitat indicates environmental uniformity (homogeneity) and/or non-selective behavioural patterns. In other words, non-random patterns (clumped and uniform) indirectly suggest the presence of limiting factors affecting population existence. Clumping indicates that individuals aggregate in certain favourable habitats, driven by grouping behaviour, heterogeneous environments, reproductive strategies, and other factors. Uniform distribution results from negative interactions among individuals, such as competition for food or other specific resources (Kirana, 2015).

The Morisita Index (Id) is the most commonly used index for measuring the distribution pattern of a species because its results are not affected by differences in mean values or sampling unit sizes. The Morisita Index can very effectively indicate the distribution pattern of a species. This index is independent of the distribution type, the number of samples, and their mean values. Regardless of the sample size, the Morisita Index will provide relatively stable results. The three basic spatial patterns that have been recognized are random, clumped (or aggregated), and uniform (Mardiyanti et al., 2013).

Variations in vegetation composition and structure within a habitat shape insect distribution patterns by altering microhabitat characteristics, such as food sources, shelter, and microclimatic conditions that support certain insects. Variations in food availability, temperature, humidity, pH, and light intensity between microhabitats lead to differences in microarthropod diversity. In addition, micro and macro environmental factors such as litter thickness, climate, altitude, plant type, and land use also affect insect life (Suliati et al., 2025). The selection of papaya and banana shade trees in this study was based on differences in contrasting canopy structures. Papaya has a relatively sparse canopy with fingered leaves, allowing light to reach the cocoa plant, whereas bananas have wide, dense leaves, so the intensity of light entering the cocoa plant is lower. These differences affect the temperature and humidity under the canopy, which are important factors in determining the abundance and distribution patterns of insect pests. Planting papaya as a shade plant for young cocoa is believed by farmers to play a role in protecting from sunlight and distracting from attacks by leaf caterpillars and grasshoppers, which are important pests on young cocoa trees (Evizal & Prasmatiwi, 2023). Banana plants will provide shade after 6–9 months. Results from observations at the Indonesian Cocoa Research Centre, comparing golden bananas, Cavendish, and wood, showed that the growth of young cocoa was influenced by the banana cultivars planted. From the cocoa stem diameter benchmark, it appears that cocoa grown under golden bananas is slower in growth compared to those grown under planted plantain and Cavendish cultivars. The reason is that the intensity of light received by cocoa is higher as a result of the smaller figure (habitus) of golden bananas than wood and Cavendish bananas (Indah et al., 2021).

We hypothesized that (H1) pest insect distribution patterns differ significantly between papaya-shaded and banana-shaded cocoa, with a more uniform distribution expected under the relatively open papaya canopy due to more homogeneous microclimatic conditions; and (H2) temperature and humidity are positively correlated with pest insect population abundance. The study of the distribution patterns of insect pests in cocoa plantations with different shade tree species, namely papaya and banana, is urgent because differences in shade create distinct microhabitat conditions, thereby shaping their distribution across these lands. The results of this study are expected to support farmers in implementing more effective pest management strategies, particularly through targeted monitoring, optimized trap placement, and informed shade management decisions in cocoa plantations.

Materials and Methods

This research was conducted from January to March 2025. The study was conducted in an open field of cocoa plants at the Pasuruan Cocoa Technical Center (PCTC), owned by PT Mondelez International, located in Pasuruan Regency, East Java. Insect samples were collected from cocoa farms in Curahdukuh Village, Kraton District, Pasuruan Regency (112° 50' 3" East Longitude and 7° 38' 19" South Latitude). The cocoa plants used in this study were those still in the vegetative phase. There are shade plants on the research land, namely California papaya and Kepok Red banana. The selection of cocoa land shaded by papaya and banana trees was based on these trees' role as alternative host plants or food sources for certain pest insects, which may influence pest populations around the cocoa plants.

Research Design and Plot Layout

The cocoa land in this study consists of 6 plots: 3 shaded by papaya trees and 3 shaded by banana trees. The number of cocoa trees per plot was 192, with a planting distance of 2 m and an area of 34 m × 38.75 m. Insect population observations were conducted by visually counting insects visible to the naked eye in the field. Insect samples were collected by placing 19 traps per plot: 1 light trap, 9 yellow traps, and 9 pitfall traps, arranged in a diagonal pattern. The installation of yellow traps and pitfall traps is carried out for 24 hours from 06.00-06.00 WIB, while the installation of light traps is carried out from 18.00-06.00 WIB. The use of 19 traps per plot was chosen because it was sufficient to capture the variation in environmental conditions within the research site (Abhisa et al., 2026). Placing traps diagonally ensures they cover all parts of the land and capture differences in microhabitat conditions, thereby better illustrating the overall, unbiased distribution pattern of insects. Sampling was conducted at 7-day intervals over 8 weeks (8 sampling events). A total of 19 traps were installed in each plot across 6 plots, resulting in a total sampling effort of 912 trap-nights. The cocoa plants observed in this study were in the vegetative growth phase, with an approximate age of 8 months. The shade trees consisted of papaya (*Carica papaya* L.) and banana (*Musa paradisiaca* L.), estimated to be 10 months old. Papaya trees averaged 1.8–2 m in height, whereas banana trees averaged 3.4–3.6 m, resulting in distinct canopy structures. Pest insects were identified and distinguished from non-pest insects based on their feeding behavior and ecological role, particularly those known to cause direct damage to cocoa plants. Identification was conducted up to the genus level using standard taxonomic keys and supported by relevant literature. Insects classified as pests included those that feed on plant tissues such as leaves, stems, and pods, thereby potentially reducing plant growth and yield. Temperature and humidity measurements were taken using a digital thermohygrometer UYIGAO UA-963. The observations were made by placing the device in both fields at a safe, sheltered location, out of the rain. Temperature and humidity data were recorded daily for two months.

Morisita Index

The distribution pattern of insect pests in cocoa fields under the shade of papaya trees and cocoa fields under the shade of banana trees is calculated using the Morisita index formula (Awanni et al., 2024), namely:

$$\mathrm{Id} = \mathrm{N}[\frac{\sum x2 - \sum x}{(\sum x)2 - \sum x}]$$

Description:

Id : Morisita index
n : Number of plots
x : Number of individuals per plot
N : Total number of individuals with the following conditions: Id = 1 (Distribution pattern is random), Id > 1 (Distribution pattern is aggregated), and Id < 1 (Distribution pattern is uniform).

Data Analysis

The data from insect morphological identification were then analysed and quantitatively described. The data were analysed using Microsoft Excel 2021 and SPSS version 22, and the results were presented in tables. Quantitative distribution pattern analysis of insects was conducted using the Morisita index. The relationship among temperature, humidity, and insect diversity was analysed using simple linear regression.

Result and Discussion

Insect Genus, Population, and Composition

Pest insects found on shaded cocoa farms with papaya trees consist of 5 orders: Blattodea, Diptera, Hemiptera, Lepidoptera, and Thysanoptera. A total of 18 families were identified: Blattellidae, Agromyzidae, Cecidomyiidae, Ceratopogonidae, Culicidae, Drosophilidae, Tephritidae, Alydidae, Aphididae, Cicadellidae, Derbidae, Miridae, Psyllidae, Erebidae, Hesperiidae, Ustyurtiidae, Phlaeothripidae, and Thripidae. The number of genera found is 21, including *Blattella*, *Liriomyza*, *Monardia*, *Culicoides*, *Culex*, *Scaptomyza*, *Bactrocera*, *Leptocorisa*, *Aphis*, *Dysaphis*, *Hyperomyzus*, *Empoasca*, *Proutista*, *Orthotylus*, *Psylla*, *Amata*, *Pelopidas*, *Ustyurtia*, *Klambothrips*, *Frankliniella*, and *Thrips*. Pest insects found on shaded cocoa farms with banana trees consist of 4 orders: Diptera, Hemiptera, Lepidoptera, and Thysanoptera. A total of 18 families were identified: Agromyzidae, Cecidomyiidae, Ceratopogonidae, Drosophilidae, Psychodidae, Tephritidae, Alydidae, Aphididae, Cicadellidae, Derbidae, Diaspididae, Oxycarenidae, Psyllidae, Scutelleridae, Erebidae, Hesperiidae, Phlaeothripidae, and Thripidae. The number of genera found is 22, including *Liriomyza*, *Monardia*, *Culicoides*, *Scaptomyza*, *Lutzomyia*, *Bactrocera*, *Leptocorisa*, *Aphis*, *Dysaphis*, *Hyperomyzus*, *Empoasca*, *Maiestas*, *Proutista*, *Comstockaspis*, *Oxycarennus*, *Psylla*, *Chrysocoris*, *Sphrageidus*, *Erionota*, *Klambothrips*, *Frankliniella*, and *Thrips*. Given that the sampling effort was identical across treatments (912 trap-nights), the total number of pest insects recorded under banana shade (923 individuals) was approximately 34% higher than under papaya shade (689 individuals). This indicates that banana-shaded cocoa plots supported a higher pest insect abundance compared to papaya-shaded plots.

The most abundant genus on cocoa farms is *Empoasca*, with 360 individuals on shaded cocoa with papaya trees and 232 individuals on shaded cocoa with banana trees. This relates to environmental conditions that favour the development of the Hemiptera order, particularly *Empoasca*. *Empoasca* prefers planting conditions with protective (shade) trees. Consistent with Rasiska & Khairullah (2017), which shows that protected plants are dominated by the insect order Hemiptera, particularly the family Cicadellidae. Adult *Empoasca* have yellowish-green colouration and are 2.33–2.65 mm long (Indriati & Soeshanty, 2015). *Empoasca* has wing shapes that resemble houses and vestigial eyes. Its legs are green and covered with hairs resembling thorns (Bororing et al., 2021). Nymphs and adult *Empoasca* are found on the underside of leaves, especially at leaf tips, but under forced conditions, they are also often found on the upper surface, even if only briefly. The nymph and adult stages of *Empoasca* suck on the plant leaves, and at high populations, they can cause serious damage. A population density of three *Empoasca* individuals per shoot can already cause damage to the shoot, which initially appears pale, then turns yellow, and finally dries out. Heavy infestations can reduce production by 50% (Kusumadewa & Supatman, 2018).

The order Diptera found in cocoa plantations includes the family Cecidomyiidae. The pest genus Monardia, from the family Cecidomyiidae, was found in cocoa plantations shaded by papaya trees (43 individuals) and by banana trees (83 individuals). The presence of Cecidomyiidae insects is caused by decaying plant parts. In accordance with the research of Kumolontang et al. (2017), Cecidomyiidae are insects that are small in size (0.5-3.0 mm). The modified mouthparts have long antennae consisting of 12-14 segments. Its wings are clear and rarely patterned. The legs are long and slender, without terminal hairs. This small insect is often found because of the abundance of decaying plant debris and the favorable conditions at the observation site that support its development. The results of the observation of the genus's participation in insect pest populations in cocoa fields are presented in Table 1.

Table 1. Genus, Role, and Population of Pest Insects on Shade Cocoa Land with Papaya Trees and Shade Cocoa Land with Banana Trees

No.	Classification			∑ Population (Heads)	
	Order	Family	Genus	Papaya	Banana
1.	Blattodea	Blattellidae	*Blattella*	1	0
2.	Diptera	Agromyzidae	*Liriomyza*	9	23
3.		Cecidomyiidae	*Monardia*	43	83
4.		Ceratopogonidae	*Culicoides*	38	35
5.		Culicidae	*Culex*	6	0
6.		Drosophilidae	*Scaptomyza*	8	4
7.		Psychodidae	*Lutzomyia*	0	1
8.		Tephritidae	*Bactrocera*	12	22
9.	Hemiptera	Alydidae	*Leptocorisa*	12	9
10.		Aphididae	*Aphis*	19	68
11.			*Dysaphis*	4	1
12.			*Hyperomyzus*	125	92
13.		Cicadellidae	*Empoasca*	360	232
14.			*Maiestas*	0	5
15.		Derbidae	*Proutista*	7	283
16.		Diaspididae	*Comstockaspis*	0	5
17.		Miridae	*Orthotylus*	4	0
18.		Oxycarenidae	*Oxycarenus*	0	4
19.		Psyllidae	*Psylla*	1	2
20.		Scutelleridae	*Chrysocoris*	0	11
21.	Lepidoptera	Erebidae	*Amata*	2	0
22.			*Sphrageidus*	0	2
23.		Hesperiidae	*Erionota*	0	16
24.			*Pelopidas*	10	0
25.		Ustyurtiidae	*Ustyurtia*	3	0
26.	Thysanoptera	Phlaeothripidae	*Klambothrips*	5	12
27.		Thripidae	*Frankliniella*	4	2
28.			*Thrips*	16	11
				689	923

The overall orders found on the cocoa land include five orders: Blattodea, Diptera, Hemiptera, Lepidoptera, and Thysanoptera. The highest individual counts for both lands were Hemiptera, at 77.21% on cocoa land shaded by papaya trees and 77.14% on cocoa land shaded by banana trees. The second most common order was Diptera, with 16.84% on cocoa land shaded by papaya trees and 18.20% on cocoa land shaded by banana trees. Other orders found on both cocoa land shaded by papaya trees and cocoa land shaded by banana trees include Lepidoptera, with percentages of 2.18% and 1.95%, respectively, and Thysanoptera, with percentages of 3.63% and 2.71%. On the other hand, the order Blattodea was found only on the cocoa land shaded by papaya trees, accounting for 0.15%. The percentage of individual insect orders on cocoa land is shown in Figure 1.

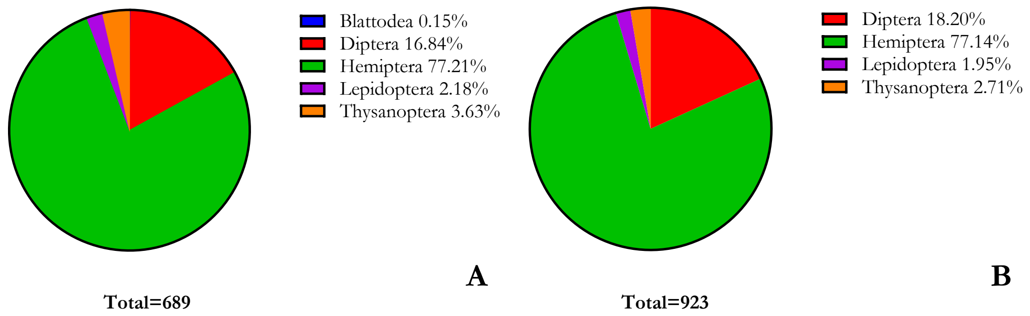

Figure 1. Percentage of the Number of Pest Insect Individuals in Shaded Cocoa Land with Papaya Trees and Shaded Cocoa Land with Banana Trees Based on Order. (A) Shaded with Papaya; (B) Shaded with Banana.

This is in line with what was explained by Alrazik et al. (2017) that the number of species and individuals of insects of the order Hemiptera is more than found compared to other orders. This may be because these insects are common, and many of their families are active on the soil surface. According to Suhanda et al. (2025) Hemiptera are cosmopolitan (able to live in diverse environmental conditions), so their distribution depends not only on environmental physical and chemical factors but also on the availability of food in the area.

Distribution Pattern of Pest Insects on Cocoa Land

Observing insect distribution patterns is important for determining appropriate monitoring and control strategies for cocoa plantations. The results of the research conducted by Wiryadiputra (2014) obtained the results that the distribution of pests in the observed crops followed the distribution of clusters and matched the negative binomial law. In a population distribution model where pests are clumped, the appropriate sampling method for monitoring purposes is systematic (regular). The results of observing the distribution patterns of pest insects on cocoa farms shaded by papaya trees and cocoa farms shaded by banana trees were analyzed using the Morisita index. The observation results show that the distribution patterns of pest insects on cocoa farms shaded by papaya trees and by banana trees fall into three categories: clumped, uniform, and random. Based on Morisita index calculations, the distribution of pest insects on cocoa farms shaded by papaya trees shows a uniform pattern. The pest insects that exhibit a uniform distribution pattern on cocoa farms shaded by papaya trees are *Monardia*, *Bactrocera*, *Leptocorisa*, *Aphis*, *Hyperomyzus*, *Amata*, *Pelopidas*, *Klambothrips*, *Frankliniella*, and *Thrips*. According to Ilhamdi et al. (2024), This pattern can be caused by competition between individuals for limited resources. In tropical forest ecology, this uniform distribution may reflect species' adaptation to competitive pressures in heterogeneous environments.

Pest insects on cocoa plantations shaded by papaya trees also form clumped distributions. The pest insects with a clumped distribution pattern include *Liriomyza*, *Culicoides*, *Culex*, *Scaptomyza*, *Proutista*, and *Orthotylus*. According to Pratiwi and Widyastuti (2013) The clumped distribution pattern is the pattern of organisms or biota in a habitat that live in groups of a certain number. Clumped distribution occurs as a result of differences in response to the habitat. The clumped distribution pattern is common because individuals within a population tend to form groups.

Pest insects that have a random distribution pattern on shaded cocoa plantations with papaya trees are *Dysaphis*, *Empoasca*, and *Ustyurtia*. The random distribution pattern indicates that the distribution of individuals is not influenced by environmental factors or social interactions. According to Ilhamdi et al. (2024) This pattern is often found in species with high environmental tolerance that can survive in various habitat conditions. These results are supported by the findings of Basna et al. (2017) which states that random distribution patterns are often observed in insects with high dispersal capabilities. The distribution pattern of insect pests in cocoa fields shaded by papaya trees is shown in Table 2.

Table 2. Distribution Pattern of Pest Insects on Shaded Cocoa Land with Papaya Trees

No.	Genus	Morisita Index (Id)	Morisita's Degree (Ip)	Distribution Pattern
1.	*Liriomyza*	1,08	0,02	Clumped
2.	*Monardia*	0,98	-0,87	Uniform
3.	*Culicoides*	1,04	0,01	Clumped
4.	*Culex*	1,40	0,08	Clumped
5.	*Scaptomyza*	1,39	0,08	Clumped
6.	*Bactrocera*	0,95	-0,91	Uniform
7.	*Leptocorisa*	0,95	-0,91	Uniform
8.	*Aphis*	0,93	-0,89	Uniform
9.	*Dysaphis*	1	0	Random
10.	*Hyperomyzus*	0,99	-0,85	Uniform
11.	*Empoasca*	1	0	Random
12.	*Proutista*	1,29	0,06	Clumped
13.	*Orthotylus*	1,50	0,08	Clumped
14.	*Amata*	0	-1,00	Uniform
15.	*Pelopidas*	0,87	-0,93	Uniform
16.	*Ustyurtia*	1	0	Random
17.	*Klambothrips*	0,90	-0,95	Uniform
18.	*Frankliniella*	0,50	-0,98	Uniform
19.	*Thrips*	0,93	-0,95	Uniform

Insect pests in cocoa fields shaded by banana trees predominantly exhibited a clumped distribution pattern. Insect pests that have a clumped distribution in cocoa fields shaded by banana trees include *Culicoides*, *Scaptomyza*, *Bactrocera*, *Leptocorisa*, *Aphis*, *Hyperomyzus*, *Empoasca*, *Maiestas*, *Proutista*, *Oxycarenus*, *Psylla*, *Chrysocoris*, *Sphrageidus*, *Erionota*, and *Klambothrips*. According to Nurmasari (2020), This form of clumped spread occurs at an advanced stage of pest infestation of a plantation. This means that this form of cluster spread occurs when a pest has been present in a plantation for an extended period. These conditions correspond to the environmental conditions at the location that support the species' thriving. The clumped pattern in the distribution reflects the concentration of individuals at a particular location. According to Ilhamdi et al. (2024) This pattern usually occurs due to abundant resources in a particular location or social interaction among individuals.

Insect pests in cocoa fields shaded by bananas also form a uniform distribution pattern. Insect pests with a uniform distribution pattern include *Liriomyza*, *Monardia*, *Comstockaspis*, *Frankliniella*, and *Thrips*. According to Lubis et al. (2021) The uniform distribution pattern results from competition among individuals for food, leading to interactions within the same area. This competition occurs because each individual insect wants to access the resources needed to survive. However, the distribution pattern can change with increased disturbance intensity, namely by altering habitat conditions. According to Awanni *et al.* (2024) If a habitat lacks host plants for insect pests to feed on, insects will likely be unable to survive. The distribution pattern of insect pests in cocoa fields shaded by banana trees is shown in Table 3.

The uniform distribution pattern in cocoa fields does not appear by chance, but is due to certain controlling factors, one of which is an evenly distributed feed source. Papaya trees have a relatively open canopy with palmate leaves that allow greater light penetration, producing more evenly distributed (dappled) light and relatively homogeneous microclimatic conditions (e.g., temperature and humidity) across the plot. Such environmental uniformity can lead to a more even distribution of resources and reduce localized resource concentration, thereby promoting a uniform distribution of pest insects. In contrast, banana plants possess large, broad leaves that form a denser canopy, resulting in deeper shade and greater spatial variation in light intensity, moisture, and temperature beneath the canopy. This creates a more heterogeneous microhabitat, where favorable conditions (e.g., higher humidity, shelter, and localized food availability) are unevenly distributed. As a result, pest insects tend to aggregate in specific, favorable patches, leading to a clumped distribution pattern. Thus, differences in canopy architecture between papaya and banana indirectly influence pest insect spatial distribution by shaping microclimatic heterogeneity and resource distribution within the cocoa agroecosystem. Dima *et al.* (2023) states that if the resources in a certain ecosystem are available evenly, the distribution pattern of insects is also uniform, or there is no centralization (grouping). Apart from an evenly distributed feed source, uniform distribution patterns can also arise from competition among individuals. Insect pests compete with one another for food, living space, and nesting sites. This competition causes family members to keep their distance from one another, so that the distance between individuals becomes relatively equal in the observation area. According to Adelliasari *et al.* (2025) Uniform distribution patterns indicate the presence of environmental limiting factors that affect species populations in the area. The identified distribution patterns of pest insects have important implications for pest management strategies in cocoa plantations. Under papaya shade, where pest insects tend to be uniformly distributed, systematic (grid-based) sampling is recommended to ensure representative monitoring across the field. In contrast, under banana shade, where pest insects exhibit a clumped distribution pattern, stratified random sampling targeting specific microhabitats is more appropriate to effectively detect pest aggregations. Furthermore, in banana-shaded systems, pest management should prioritize localized or spot treatments in aggregation zones rather than uniform application, in order to improve control efficiency and reduce unnecessary pesticide use.

Table 3. Distribution Pattern of Pest Insects on Shaded Cocoa Land with Banana Trees

No.	Genus	Morisita Index (Id)	Morisita's Degree (Ip)	Distribution Pattern
1.	*Liriomyza*	0,98	-0,88	Uniform
2.	*Monardia*	0,99	-0,86	Uniform
3.	*Culicoides*	1,14	0,03	Clumped
4.	*Scaptomyza*	1,50	0,08	Clumped
5.	*Bactrocera*	1,64	0,15	Clumped
6.	*Leptocorisa*	1,50	0,10	Clumped
7.	*Aphis*	1,33	0,08	Clumped
8.	*Hyperomyzus*	1,16	0,04	Clumped
9.	*Empoasca*	1,06	0,01	Clumped
10.	*Maiestas*	1,20	0,04	Clumped
11.	*Proutista*	2,56	0,39	Clumped
12.	*Comstockaspis*	0,90	-0,95	Uniform
13.	*Oxycarenus*	3,00	0,33	Clumped
14.	*Psylla*	3,00	0,19	Clumped
15.	*Chrysocoris*	2,02	0,16	Clumped
16.	*Sphrageidus*	3,00	0,19	Clumped
17.	*Erionota*	1,38	0,08	Clumped
18.	*Klambothrips*	1,41	0,09	Clumped
19.	*Frankliniella*	0	-1,00	Uniform
20.	*Thrips*	0,82	-0,93	Uniform

Correlation of Temperature and Humidity on Insect Population

Temperature and humidity on land can affect insect populations. The correlation between temperature, humidity, and insect populations can be assessed using simple linear regression. According to Rahmawati et al. (2022), The purpose of simple linear regression analysis is to measure the strength of the relationship between two variables and show the direction of the relationship between the dependent variable and the independent variable. The regression results for temperature, humidity, and insect populations are presented in Table 4.

Table 4. The Relationship Between Abiotic Factors and Pest Insect Populations

Abiotic Factor	R^2	t - count	Sig	Remarks
Temperature	0.025	0.987	0.330	Not Significant
Humidity	0.003	-0.351	0.728	Not Significant

The regression analysis of the relationship between temperature and insect population yields a p-value of 0.330, which exceeds 0.05. This leads to the conclusion that the temperature variable does not have a significant effect on the increase in insect population. The R Square (R^2) value is 0.025. This indicates that the contribution or influence of temperature on the insect population is 2.5%, while the remaining 97.5% is contributed by other variables not included in the study (Sofyan et al., 2019).

The regression analysis of the relationship between humidity and insect population yields a p-value of 0.728, which exceeds 0.05. This leads to the conclusion that the humidity variable does not have a significant effect on the increase in insect population. The R Square (R^2) value is 0.003. This indicates that the contribution or influence of humidity on the insect population is only 0.3%, while the remaining 99.7% is contributed by other variables not included in the study (Sofyan et al., 2019).

The regression analysis of the relationship between temperature and humidity and the pest insect population indicates that neither variable has a significant effect on population changes. This is because insects are organisms that can adapt to the temperature in their environment (poikilothermic). According to Graha (2010) Insects are living things that can hibernate. When the ambient temperature is low, their body temperature drops, and their metabolic rate decreases or even becomes inactive.

Conclusion

The distribution patterns of pest insects in cocoa plantations vary with the type of shade tree, with a predominantly uniform distribution observed under papaya shade and a clumped distribution under banana shade. These differences have important implications for the development of targeted pest management strategies. Regression analysis further indicated that temperature and humidity did not significantly influence increases in pest insect populations. However, this study has several limitations, including relatively low replication, a short observation period, and restriction to a single study location, which may limit the generalizability of the findings. Therefore, future studies should explore seasonal variation, include a wider range of shade tree species, and consider the functional diversity of pest insects to better understand their ecological roles. In addition, future studies should incorporate continuous microclimate monitoring to elucidate indirect effects on pest population dynamics.

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