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Grasshopper diversity in organic and conventional farm lands in Batu City, East Java, Indonesia

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Abstract. *Qurotaayunina RP, Leksono AS, Suheriyanto D, Panhwar WA. 2026. Grasshopper diversity in organic and conventional farm lands in Batu City, East Java, Indonesia. Biodiversitas 27 (3): d270339. https://doi.org/10.13057/biodiv/d270339.* Grasshoppers are sensitive to environmental changes and can serve as effective bioindicators in agroecosystems. This study assessed their abundance, diversity, and community composition across different farm types and sampling times in organic and conventional farming systems, and evaluated their indicator potential. Surveys were conducted at six sites: Organic Fruit (OF), Conventional Fruit (CF), Organic Paddy (OP), Conventional Paddy (CP), Organic Vegetables (OV), and Conventional Vegetables (CV). At each site, sampling was performed using sweep nets across five plots during morning, noon, and afternoon periods. Data were analyzed using Generalized Linear Mixed Models to test differences in abundance, species richness, diversity, and dominance. Community similarity was evaluated using the Bray-Curtis index, species-environment relationships using Canonical Correspondence Analysis (CCA), and indicator species using the Indicator Value (IndVal) method. A total of 25 species comprising 5,636 individuals were recorded. Farm type significantly affected all community parameters (abundance, species richness, dominance and diversity), while sampling time influenced only abundance and species richness, with no significant interaction effects. The highest abundance, richness, and diversity were observed in organic fruit and organic paddy systems, whereas the lowest values occurred in conventional vegetable fields. Community composition was shaped by farm type and wind speed. Several species were found to have potential as group or individual indicator species, such as *Anaxipha* sp., and *Phlaeoba infumata* in OF; *Caryanda spuria* and *Tagasta marginella* in CF; *Conocephalus fasciatus* and *Atractomorpha angusta* in OP; and *Oxya hyla* in CP. No indicator species were identified in vegetable farms. Overall, the results demonstrate that organic farming supports higher grasshopper diversity and more structured communities, highlighting its importance for biodiversity conservation and the use of grasshoppers as ecological indicators.

Keywords: Agroecosystem, bioindicator, community composition, grasshopper diversity, species richness

INTRODUCTION

Agricultural intensification has been identified as one of the major drivers of global insect decline. In contrast, organic farming systems generally promote greater biodiversity by minimizing synthetic pesticide inputs and increasing vegetation diversity. A meta-analysis by Lichtenberg et al. (2017) and subsequent studies (Farooq et al. 2022; Huang et al. 2022) reported that organic farming can increase arthropod richness and abundance, including natural enemies. Organically managed fields have been reported to contain greater taxonomic richness and evenness across both ground-dwelling and vegetation-associated arthropods (Galloway et al. 2021). However, responses vary among taxa, and Orthoptera often show species-specific responses to agricultural management. These responses may be influenced by interactions between local farming practices, vegetation structure, and the surrounding landscape context (Conti et al. 2026). These findings highlight the strong influence of farming practices on arthropod community structure and ecosystem services within agroecosystems, including grasshoppers. Grasshoppers are particularly diverse and ecologically important among the Arthropods, with more than 6,700 described species worldwide (Song et al. 2018; Li et al. 2021; Guo et al. 2024). Due to their strong sensitivity to habitat alteration, vegetation structure, and microclimatic variation, grasshoppers are widely recognized as useful bioindicators of environmental conditions and land-use intensity (Samways et al. 2026).

For grasshoppers in particular, vegetation characteristics, land use, and microclimatic conditions are among the most important determinants of distribution and community structure (Leksono et al. 2020; Abrori et al. 2021; Khatimah et al. 2022). Despite increasing research on environmental drivers of grasshopper communities, several important knowledge gaps remain (Guo et al. 2024). First, many studies comparing organic and conventional farming focus on single crop systems or a limited range of taxa, making it difficult to generalize findings across diverse agroecosystems (Fess and Benedito 2018; Schrama et al. 2018; Ostandie et al. 2021). Second, relatively few studies simultaneously evaluate multiple crop commodities within the same landscape context, even though crop type can strongly influence vegetation structure, disturbance regimes, and resource availability. Third, temporal dynamics such as phenological variation and diurnal activity patterns are rarely incorporated into grasshopper community studies, even though these factors can influence species interactions and responses to microclimatic conditions. Fourth, although several studies on grasshoppers have been conducted in Indonesia, no study has compared paired organic-conventional systems across three crop commodities within an identical landscape context.

Recent ecological syntheses emphasize that spatiotemporal heterogeneity in agricultural systems can strongly shape insect communities, yet empirical field studies integrating these multiple dimensions remain limited. Environmental variables such as temperature, humidity, soil moisture, vegetation cover, and habitat availability directly influence grasshopper survival, reproduction, and feeding behavior (Veran et al. 2015; Wang et al. 2021). In addition, several studies have developed predictive models and monitoring systems that integrate environmental variables to forecast grasshopper presence and population dynamics across landscapes (Kistner-Thomas et al. 2021; Geng et al. 2022). Because grasshoppers respond rapidly to environmental gradients, changes in land use, habitat fragmentation, and climate conditions can lead to substantial shifts in their community composition and spatial distribution.

Addressing these gaps is particularly important in tropical agricultural landscapes, where diverse crop commodities often coexist within heterogeneous mosaics and where insect biodiversity remains insufficiently documented. Therefore, a comprehensive assessment of grasshopper diversity in a regional landscape requires integrating multiple factors, including land-use type, farming management systems, crop species, and temporal dynamics. Based on these considerations, this study aims to analyze grasshopper diversity and community composition across multiple agricultural land-use types in Batu City, East Java, Indonesia, while evaluating the effects of farming system (organic vs. conventional) and diurnal sampling period. We hypothesize that the grasshopper community is significantly influenced by farm type, temporal variation and environmental factors. Farmlands applying the organic management system are expected to support the grasshopper diversity and community composition. The findings are expected to improve ecological understanding of Orthoptera communities in tropical agroecosystems and provide scientific insights to support sustainable agricultural management and biodiversity conservation.

MATERIALS AND METHODS

Study site

This research area was conducted in Batu City, East Java, Indonesia. This city area is located at an elevation of 625-924 m asl and has an average annual temperature of 14-23°C (BPS 2026). Elevation is relatively different among the study sites because each crop species requires a specific microclimate. It may become a limitation of this study. This research was conducted at six research locations (farm types): Organic Vegetables (OV), Conventional Vegetables (CV), Organic Paddy (OP), Conventional Paddy (CP), Organic Fruit (OF), and Conventional Fruit (CF) (Figure 1).

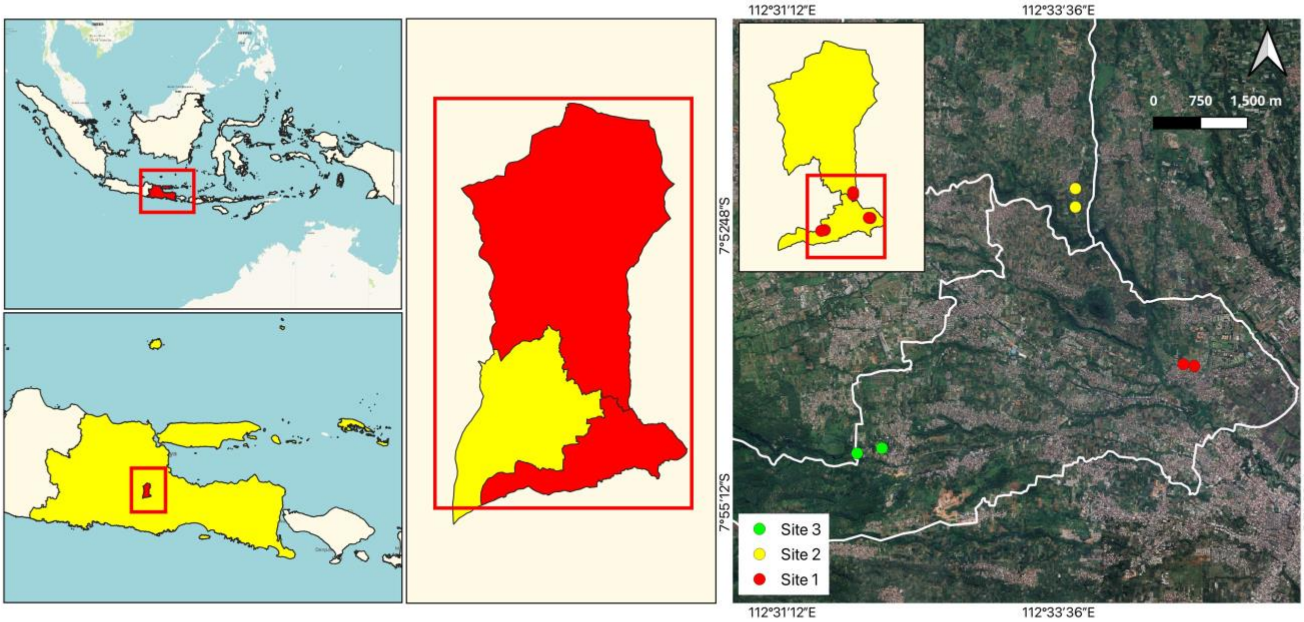

Figure 1. Location of the research in Batu City, East Java, Indonesia. Site 1: Paddies (Organic and Conventional), Site 2: Vegetable (Organic and Conventional), Site 3: Fruits (Organic and Conventional)

Paired conventional fields cultivated the same crop as their organic counterparts. Research locations were selected based on crop group (vegetable, cereal, and fruit), the availability of adjacent organic and conventional land with the same crop type, land size, and the willingness of landowners to obtain permission. All research locations were situated at similar elevations/slopes, and in similar climate zones. Organic and conventional land types with the same farm types were spaced 100-200 m apart, separated by housing or vegetated green spaces (Table 1). In this study, the crop species and variety of organic and conventional land were the same, except for the rice type. None of the rice types met the criteria, so different varieties were used. It may also limit this study.

Each ecosystem examined in this study was differentiated based on farm type [including agricultural system (organic vs. conventional) and crop species], vegetation characteristics, and environmental conditions to assess how these factors influence or support grasshopper populations. Organic farming is defined as an agricultural system that prioritizes soil health, ecological balance, and biodiversity by avoiding synthetic fertilizers, pesticides, genetically modified organisms (GMOs), and antibiotics, while relying on spring or treated water, organic mulch, and organic weed control (Leksono et al. 2022; Gamage et al. 2023). In this study, all organic agricultural lands were certified by the Seloliman Organic Certification Board. Organic fertilizer (in compost or granular form) was applied once before replanting, while biopesticide (botanical or microbial pesticide) was applied twice a month. In case of severe pest attack, biopesticide was applied once a week. Weed control was done manually using hand collecting or a hoe. It was done once in the late crop vegetative stage.

In contrast, conventional farming systems rely on synthetic inputs, including fertilizers such as urea and NPK (Nitrogen, Phosphorus, and Potassium), as well as chemical pesticides applied throughout the growing cycle. In paddy fields, pesticides (e.g., Amistar and Landep™) were applied once per month or at each growth phase. Mustard greens were fertilized with NPK and potassium chloride on a weekly to biweekly basis, depending on plant condition, and reduced to biweekly applications during the dry season. Pesticides (e.g., abamectin, Curacron, and Starban™) were typically applied every two weeks or more frequently in response to pest outbreaks. Guava cultivation involved the use of Mono Potassium Phosphate and NPK fertilizers, applied monthly or every two to three weeks, while pest control included the use of Petrogenol™. This differentiation in management practices provides a basis for evaluating the ecological impacts of farming systems on grasshopper communities.

Grasshopper sampling and identification

Grasshopper sampling was conducted weekly from July to October 2025, resulting in 12 sampling events. On each sampling occasion, fieldwork was conducted at two locations per day, ensuring that all locations were surveyed across three different days each week. Specimens were collected using a sweep-net method with a 25-cm-diameter aerial insect net. At each location, sampling was performed within a 20 m² area using a cross-plot design consisting of five 2 m × 2 m plots. Just before the sampling process, a one-meter-high plastic banner was used to fence the plot to prevent grasshoppers from escaping. Each plot was sampled with 20 sweeps during three daily periods: morning, noon, and afternoon, corresponding to peak grasshopper activity periods as recommended by Sutherland (2006). Sampling was done 10 minutes per plot, consisting of 5 minutes of sweeping followed by 5 minutes of hand collecting. Plot positions were rotated among time periods, and the sampling order was alternated in subsequent weeks to maximize sampling results (Figure 2). Plot positions were done systematically. Collections were conducted across three crop phenological stages: vegetative, generative, and ripening, with four sampling weeks at each stage, with a total of 1080 sampling efforts (6 sites × 5 plots × 3 time × 12 weeks).

Table 1. Research locations in Batu City representing Organic Fruit (OF), Conventional Fruit (CF), Organic Paddy (OP), Conventional Paddy (CP), Organic Vegetables (OV), and Conventional Vegetables (CV)

Coordinate points	Elevation (m asl)	Research locations	Crop species and variety	Farm types
-7.877278, 112.562454	739	Bumiaji Village, Bumiaji District, Batu City	Mustard greens (*Brassica rapa* var. *chinensis*)	Organic (OV)
-7.874607, 112.562456	749	Bumiaji Village, Bumiaji District, Batu City	Mustard greens (*Brassica rapa* var. *chinensis*)	Conventional (CV)
-7.900257, 112.579674	625	Pendem Village, Junrejo District, Batu City	Cerealia paddy (*Oryza sativa* var. Mapan P-05)	Organic (OP)
-7.900003, 112.578078	627	Pendem Village, Junrejo District, Batu City	Cerealia paddy (*Oryza sativa* var. serang)	Conventional (CP)
-7.912135, 112.5344385	900	Tlekung Village, Junrejo District, Batu City	Fruit Guava (*Psidium guajava* var. sukun)	Organic (OF)
-7.912883, 112.530841	924	Tlekung Village, Junrejo District, Batu City	Fruit Guava (*Psidium guajava* var. sukun))	Conventional (CF)

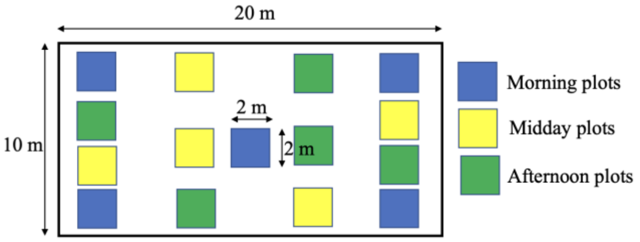

Figure 2. Research sampling area design

Captured specimens were euthanized in alcohol-charged killing jars, transported to the laboratory, and identified using standard taxonomic keys by Johnson (2008) and Tan (2012; 2017). Identification was based on morphological characteristics and subsequently verified by an expert (ASL). Voucher specimens were preserved in the insectarium of the Laboratory of Animal Diversity and Environmental Technology at Universitas Brawijaya (individual specimen codes: RP-25-0001 to RP-25-05636). Only representative specimens (fewer than 100 individuals) were preserved in the insectarium, while the remaining specimens were stored in glass jars. Each dried specimen was wrapped in sterile cotton wool, placed in a sealed plastic bag, and subsequently stored in a glass jar. Once the jar was filled, it was tightly sealed to preserve its contents.

Environmental abiotic factor measurement

Abiotic environmental variables measured at the study sites included air temperature, relative humidity, light intensity, and wind speed. Air temperature and humidity were recorded with a digital thermo-hygrometer (XON MED™ HTC-2), light intensity was measured with a digital light meter (Krisbow™), and wind speed was measured with digital anemometer (GM816). All measuring instruments were less than one year old at the time of data collection to ensure measurement reliability. Environmental variables were recorded at each plot three times per sampling day-morning (07:00), noon (11:00), and afternoon (15:00). All measurements were taken at a standardized height of 1 m above ground level. It may not fully represent microhabitat conditions experienced by all species.

Data analysis

Species diversity, dominance, and similarity of grasshopper composition were calculated based on the number of individuals. The first step, grasshopper diversity was analyzed using the Shannon-Wiener diversity index (H') (Li et al. 2024) with the formula:

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$$H' = -\sum_{i=1}^{s}(\rho i . ln . \rho i)$$

Where, H': Shannon-Wiener Diversity Index; Σ: Number of all species; ρi: Proportion of individuals of the i species (ρi: ni/N); ni: Number of individuals of the i species; N: Total number of individuals of all species; ln: Natural logarithm (log base e).

Dominance Index of Simpson (C) (Li et al. 2024) with the formula:

$$C = \sum_{i=1}^{s}\left(\frac{ni}{N}\right)^2$$

Where, C: Simpson's Dominance Index; Σ: Number of all species; ni: Number of individuals of species-i; N: Total number of individuals of all species; ni/N: Proportion of individuals of species-i (pi); S: Total number of species.

Community composition differences among sites were quantified using the Bray-Curtis dissimilarity index based on species abundance data. Dissimilarity in Grasshopper composition between locations was compared with the Bray-Curtis index (Leksono et al. 2022) with the formula as follows:

$$BC_{AB} = \frac{\sum_{i=1}^{p}|x_{Ai} - x_{Bi}|}{\sum_{i=1}^{p}(x_{Ai} + x_{Bi})}$$

Where, BC_{AB}: Bray-Curtis dissimilarity between site-A and site-B; X_{Ai}: Number of specimens of species at site-A (abundance); Xbi: Number of specimens of species at site-B (abundance); p: The sum of all species.

Percentage similarity was calculated by formula:

$$\text{Similarity (\%)} = (1 - BC_{AB}) \times 100\%$$

Thus, higher values indicate greater compositional similarity between sites. Hierarchical cluster analysis was subsequently performed using the Unweighted Pair Group Method with Arithmetic Mean (UPGMA) to generate a dendrogram illustrating patterns of community similarity among sites. Clustering was based on the Bray-Curtis similarity matrix.

Indicator Species Analysis was conducted following the Dufrêne and Legendre (1997) method implemented in PAST (Paleontological Statistics) software. Statistical significance of indicator values was evaluated using 999 Monte Carlo permutations, and species were considered significant indicators at $p<0.05$. Species Indicator Value Index with the formula:

$$IndVal_{ij} = Aij \times Bij \times 100$$

Where, $IndVal_{ij}$: Indicator values for species-i at site group j; A_{ij} (specificity): Measures how exclusively a species is found in a particular group (relative abundance); B_{ij} (fidelity): Measures how often a species is found within the group (frequency of occurrence).

This study employed a nested repeated-measure observational design. Differences in the number of individuals of each species, species richness, total abundance, evenness, and diversity among the locations and times were tested using Generalized Linear Mixed Models. The Generalized Linear Mixed Model (GLMM) was chosen because it can handle hierarchical structures, repeated measures (random effects), and count data. GLMMs combine the flexibility of non-normal distributions of GLMs with the handling of data correlation of Mixed Models. In addition to formal statistical testing, a histogram was used to visually inspect the distribution. A positively skewed histogram is often an early indicator that a Poisson or negative binomial distribution is more appropriate than a normal distribution. The same was done for the species richness parameter, which showed a similar trend. However, for the dominance and species diversity data, the distributions were better approximated by a normal distribution. In this analysis, farm type, time, and the land×time interaction were set as fixed factors; plot and weekly sampling were set as random effects, while species abundance, richness, evenness, and diversity were the targets. The GLMM analysis was conducted using SPSS version 25.

The level of similarity in grasshopper community composition across land and time was analyzed using UPGMA using the Bray-Curtis index. A Permanova test was performed to determine the significance level of the results. The relationship between grasshopper compositions and environmental factors was analyzed using Canonical Correspondence Analysis (CCA). Variables explaining most of the variation in the data were used to build the final model. Environmental factors, including temperature, humidity, wind speed, and light intensity, were treated as continuous variables, while time was treated as a categorical variable. Next, the species assemblages were clustered using k-means. The relationship between grasshopper composition and environmental factors was analyzed using Pearson's chi-square test, as the data were not normally distributed. The statistical validity of the resulting canonical axes was evaluated. The IndVal index was used to identify potential species as bioindicators. Statistical analysis for community comparisons was performed using PAST (Paleontological Statistics) version 4.17. Results were considered significant at $p<0.05$.

RESULTS AND DISCUSSION

The abundance of grasshopper species among research locations

Of the 1,080 sampling efforts conducted, grasshoppers were successfully collected in 1,044, while 36 yielded no specimens. In total, 5,636 grasshopper individuals were recorded across the 6 study locations. Species richness per location ranged from 6 to 17 species, out of a total of 25 species identified during the study. Five species, including *Atractomorpha lata*, *Paratettix curtipennis*, *Oxya hyla*, *Acrida turrita*, and *Atractomorpha sinensis* dominated the assemblage, accounting for 2,780 individuals (49.33% of the total abundance) (Table 2). Among those, *At. lata*, *Pa. curtipennis*, and *Ac. turrita* were recorded in all farm types, indicating broad ecological tolerance and adaptability to different crop species and management systems. In contrast, several species were restricted to a single land-use type. *Conocephalus fasciatus* and *Conocephalus melaenus* were found exclusively in OP; *Phlaeoba infumata*, *Thoradonta dentata*, and *Apalacris varicornis* occurred only in OF; while *Caryanda spuria*, *Tagasta marginella*, and *Phlaeoba fumosa* were confined to CF. The remaining species were distributed across two to five farm types. These patterns suggest that generalist species can exploit a broad range of environmental conditions and resources across different farming systems, whereas specialist species exhibit narrower habitat preferences and are likely more sensitive to land-use characteristics.

The abundance and diversity of grasshoppers in each study site

The analysis results showed that the study location factor had a significant effect on all community parameters, namely abundance (F: 252.68; p<0.001), taxonomic richness (F: 162.91; p<0.001), dominance (F: 39.12; p<0.001), and diversity (F: 253.48; p<0.001). The observation time factor only had a significant effect on abundance (F: 26.42; p<0.001) and effect on taxon richness (F: 3.96; p: 0.019), but that had no effect on dominance (F: 0.14; p: 0.872), or diversity (F: 2.13; p: 0.119). The interaction between location and time (l×t) did not show a significant effect on all parameters (p>0.05). The interaction between location and observation time (l×t) was not statistically significant for any parameter (p>0.05). However, the interaction effect on abundance approached significance (F: 1.81; p: 0.054) (compared with other variables), suggesting a potential trend in temporal variation across locations. Specifically, grasshopper abundance tended to peak in the afternoon on vegetable farms, whereas higher abundances were observed in the morning on rice and fruit farms; however, these differences were not statistically significant. Overall, these findings indicate that spatial variation (i.e., differences among locations) played a more substantial role in shaping grasshopper community structure than temporal variation or the interaction between space and time (Table 3).

All community parameters (abundance, taxa richness, dominance, and diversity) showed consistent patterns among management systems and crop types. The highest abundance was found in Organic Fruits (OF) (8.742±3.63), followed by Organic Paddies (OP) (7.932±3.294), while the lowest value was found in Conventional Vegetable (CV) (2.364±0.987) (Figure 3.A). For the same crop type, the organic system tended to support a higher abundance than the conventional system. The highest species richness was found in OP (6.403±0.273), followed by OF (6.235±0.267), while the lowest was found in CV (1.825±0.121) (Figure 3.B). The diversity index (H') value was also highest in OP (2.108±0.047), followed by OF (2.051±0.047), while the lowest value was also found in CV (0.909±0.05) (Figure 3.C). The results indicated that organic land, especially fruit and rice, had more species and a more even distribution of individuals.

In contrast, the dominance index shows the opposite pattern. The highest dominance values were found in CV (0.302±0.025), followed by OV (0.291±0.023), while the lowest was found in OP (0.058±0.022) (Figure 3D). The result indicated that the grasshopper community on the vegetable farm was dominated by a few species. Meanwhile, those in OP had a low Dominance value, indicating a more even distribution of individuals, species, and diversity. Overall, organic fruit and paddy farms consistently showed a more complex community structure (high abundance, richness, and diversity, and low dominance), whereas the vegetable farm showed a simpler, more dominated community structure.

Among the different sampling times, the abundance, species richness, and diversity were highest in the morning collection. The highest abundance was found in the morning (5.12±2.13), while the lowest was found in the noon (4.19±1.74) (Figure 4.A). The highest species richness was found in the morning (3.63±0.16), while the lowest was found in the noon (3.24±0.32) (Figure 4.B). The abundance and species richness differed significantly among sampling times, whereas species diversity and dominance did not (Figure 4.C and 4.D).

The analysis results showed that grasshopper composition clustered based on farm type with a significant level of similarity (F: 65.74; p: 0.0001, Total sum of squares: 2,883 Permutation N: 9999). The level of similarity of grasshopper community composition within the same crop type was >80%, indicating a very high level of similarity, except in the organic fruit land. In that land, the level of similarity of all communities was 77.68%, indicating a high level of similarity. The grasshopper assemblages in the organic fruit farm showed moderate similarity with those in the conventional farm (47.58%).

Table 2. Total number of grasshopper individuals collected from each research location

Species	Research locations						Total
	OV	CV	OP	CP	OF	CF	
Atractomorpha lata (Mochulsky, 1866) (***)	150	89	168	152	181	49	789
Paratettix curtipennis (Hancock, 1912) (***)	117	104	115	44	149	98	627
Oxya hyla (Serville, 1831) (***)	137	125	176	188	-	-	626
Acrida turrita (Linnaeus, 1758) (***)	93	11	56	33	94	83	370
Atractomorpha sinensis (Bolívar, 1905) (***)	-	-	126	83	135	24	368
Euparatettix sp. (**)	14	1	79	-	110	133	337
Oxya japonica (Thunberg, 1824) (***)	-	-	177	144	-	-	321
Atractomorpha crenulata (Fabricius, 1793) (***)	-	-	104	63	62	47	276
Anaxipha sp. (**)	-	-	-	-	241	3	244
Oxya chinensis (Thunberg, 1815) (**)	-	-	119	87	-	-	206
Atractomorpha angusta (Karsch, 1888) (**)	-	-	-	-	124	55	179
Cesasundana lorniensis (Tan, 2014) (ns)	-	-	94	4	34	43	175
Trilophidia annulata (Thunberg, 1815) (ns)	-	-	2	-	71	80	153
Conocephalus (*Anisoptera*) *fasciatus* (De Geer, 1773) (***)	-	-	148	-	-	-	148
Xenocatantops humilis (Serville, 1838) (ns)	-	48	6	-	12	63	129
Phlaeoba infumata (Brunner von Wattenwyl, 1893) (ns)	-	-	-	-	91	-	91
Sedulia specularia (Stål, 1875) (***)	-	-	2	-	87	-	89
Thoradonta dentata (Hancock, 1909) (***)	-	-	-	-	88	-	88
Apalacris varicornis (Walker, 1870) (ns)	-	-	-	-	86	-	86
Caryanda spuria (Stål, 1861) (*)	-	-	-	-	-	64	64
Tagasta marginella (Thunberg, 1815) (**)	-	-	-	-	-	62	62
Elimaea subcarinata (Stål, 1861) (ns)	-	-	3	-	17	40	60
Phlaeoba fumosa (Serville, 1838) (*)	-	-	-	-	-	60	60
Gesonula mundata (Walker, 1870) (***)	-	-	25	25	-	-	50
Conocephalus melaenus (Haan, 1843) (ns)	-	-	38	-	-	-	38
Total	511	378	1,438	823	1,582	904	5,636

Note: Research Locations are located in six farm type as follows: OV: Organic Vegetable, CV: Conventional Vegetable, OF: Organic Fruits, CF: Conventional Fruits, OP: Organic Paddies, CP: Conventional Paddies. The star symbol in the bracket following the species name indicated the significant means of abundance among the study sites at *: p≤0.05, **: p≤0.01, ***: p≤0.001, and ns: not significant. Statistical analysis of the number of individuals of each species was done using GLMM test

Table 3. Summary of F value followed by degree of significance using the Generalized Linear Mixed Model of the abundance, diversity, dominance, and taxa richness

Variables	Farm type (l) (df: 5)	Time (t) (df:2)	l×t (df:10)
Abundance	F: 252.68 (p<0.001)	F: 26.42 (p<0.001)	F: 1.81 (p: 0.054)
Taxa richness	F: 162.91 (p<0.001)	F: 3.96 (p: 0.019)	F: 0.20 (p: 0.997)
Dominance	F: 39.12 (p<0.001)	F: 0.14 (p: 0.872)	F: 0.53 (p: 0.868)
Diversity	F: 253.48 (p<0.001)	F: 2.13 (p: 0.119)	F: 0.73 (p: 0.694)

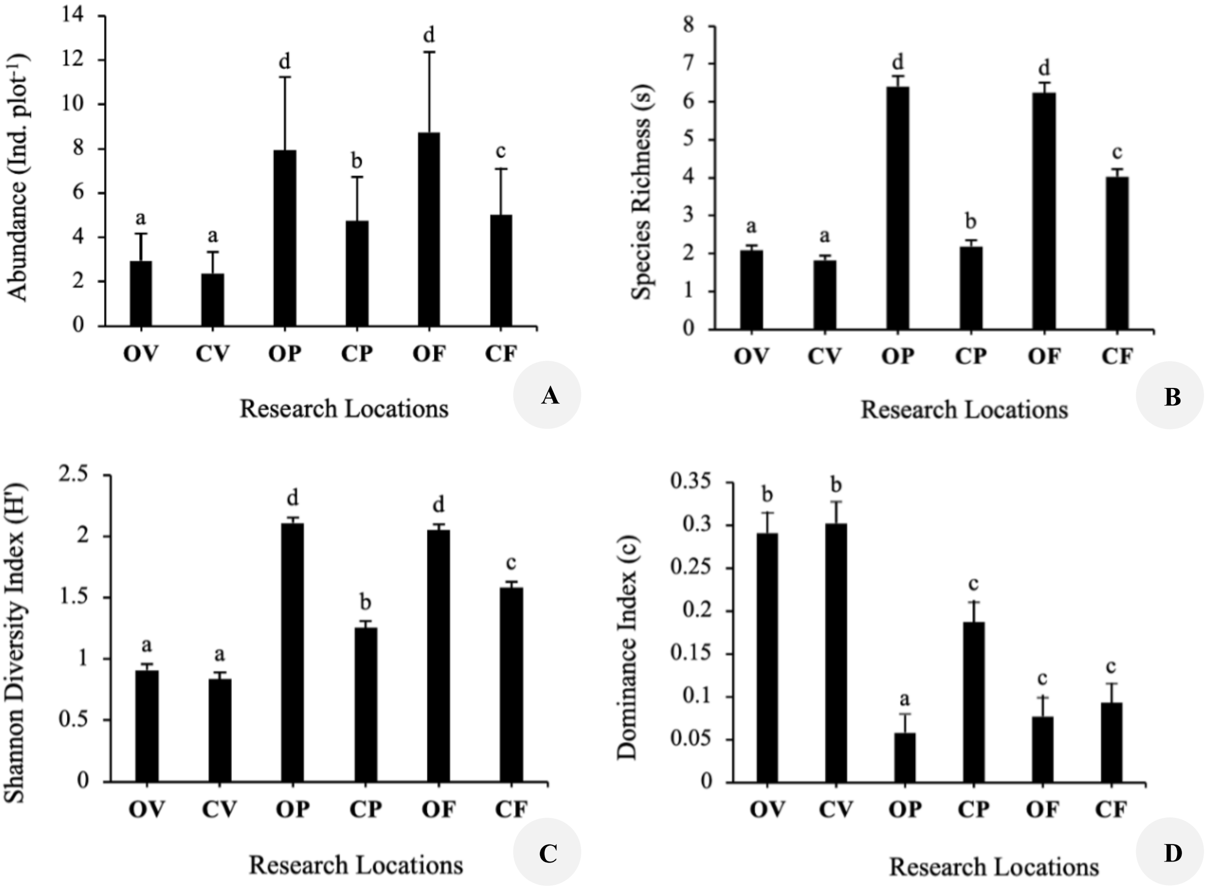

Figure 3. A. Grasshopper total abundance (mean±SE, n: 1044), B. Species richness (mean±SE, n: 1044), C. Species diversity (mean±SE, n: 940), species dominance (mean±SE, n: 940) in six farm types (OV: Organic Vegetable, CV: Conventional Vegetable, OF: Organic Fruit, CF: Conventional Fruit, OP: Organic Paddy, CP: Conventional Paddy). Note: samples containing a single individual were excluded from analysis because the Dominance value was not countable

The similarity level of grasshopper communities in organic paddy fields was 87.55%, while in conventional fields it was 87.13%; and both types of land have a similarity level of 69.68%. The similarity level of grasshopper communities in organic Vegetable was 87.33%, while in conventional fields it was 87.23%; and both types of land have a similarity level of 73.39% (Figure 5 and Table 4). This pattern suggested that habitat conditions may play a role in shaping the similarities of grasshopper community structure among the study sites. The grasshopper communities found in the morning were more similar to those in the afternoon than those in the noon, and this was consistent for all farm types.

The Canonical Correspondence Analysis (CCA) revealed a total constrained inertia of 0.239. The first canonical axis (Axis 1) had an eigenvalue of 0.1694 and explained 83.03% of the relationship between grasshopper compositions and environmental factors, while the second axis (Axis 2; eigenvalue: 0.0254) explained 12.43% (Figure 6). Together, the first two axes accounted for 95.46% of the variation explained by environmental constraints, indicating that most of the structured species environment relationship was captured along the primary canonical gradients. Multivariate test indicated that the first axis was statistically significant based on Monte Carlo permutation tests (N: 999) (p: 0.011), indicating a significant correlation between grasshopper composition and one environmental factor. The second to fifth axes did not show significant correlations ($p>0.05$) between grasshopper composition and environmental factors. The distribution of species across quadrants demonstrated clear ecological segregation along environmental gradients. K-means clustering analysis showed that the grasshopper community was divided into four groups. The first group consisted of *At. lata*, *Pa. curtipennis*, *O. hyla*, *Ac. turrita*, *At. sinensis*, *Euparatettix* sp., *O. japonica*, *At. crenulata*, *O. chinensis*, *Ce. lorniensis*, *Co. fasciatus*, *G. mundata,* and *Co. melaenus*. Group I responded negatively to wind speed, but no significant correlation was observed. Group II composed of *Atractomorpha angusta*, *T. annulata*, *Ph. infumata*, *S. specularia, Th. dentata*, and *E. subcarinata*. Univariate test indicated that Group II had a positive significant correlation to wind speed ($\chi2$: 0.389; p: 0.002) (Table 5). Group III consisted of *Anaxipha* sp. and *Ap. varicornis*. Group III responded negatively to temperature and light intensity, but no significant correlation was observed. Group IV is composed of *X. humilis*, *Ca. spuria*, *Ta. marginella* and *Ph. fumosa*. Group IV responded negatively to temperature, humidity, and light intensity, but the correlation was not significant. Thus, these findings suggest that wind speed is an important environmental factor influencing grasshopper community composition.

Based on the results of the IndVal analysis, the identified indicator species showed varying levels of association at each farm type (Figure 7). In Organic Fruit (OF) land, several species had very high indicator values, namely *Anaxipha* sp. (Indval: 99%, p: 0.0001), *Ph. infumata* (Indval: 91.84%, p: 0.0001), *S. specularia* (Indval: 90.63%, p: 0.0001), suggesting a tight relationship between these species and the habitat conditions of the Organic Fruit. Meanwhile, on Conventional Fruits (CF), the species *Ca. spuria* (Indval: 66.67%, p: 0.0001) and *Ta. marginella* (Indval: 66.67%, p: 0.0001) had equally high indicator values, followed by *Ph. fumosa* (Indval: 66.67%, p: 0.0001), indicating that the environmental characteristics of this land are relatively specific to certain species groups.

Table 4. Similarity of grasshopper groups among the six farm types in the morning, noon and afternoon

Groups	BC similarity (%)
OFA-OFM	91.88
OFA-OFM-OFN	77.68
CFA-CFM	90.39
CFA-CFM-CFN	86.47
OFA-OFM-OFN-CFA-CFM-CFN	47.58
OPA-OPM	92.91
OPA-OPM-OPN	87.55
CPA-CPM	93.90
CPA-CPM-CPN	87.13
OPA-OPM-OPN-CPA-CPM-CPN	69.68
CVA-CVM	91.91
CVA-CVM-CVN	87.23
OVM-OVA	96.46
OVN-OVM-OVA	87.33
CVA-CVM-CVNM-OVN-OVM-OVA	73.39
All group	31.13

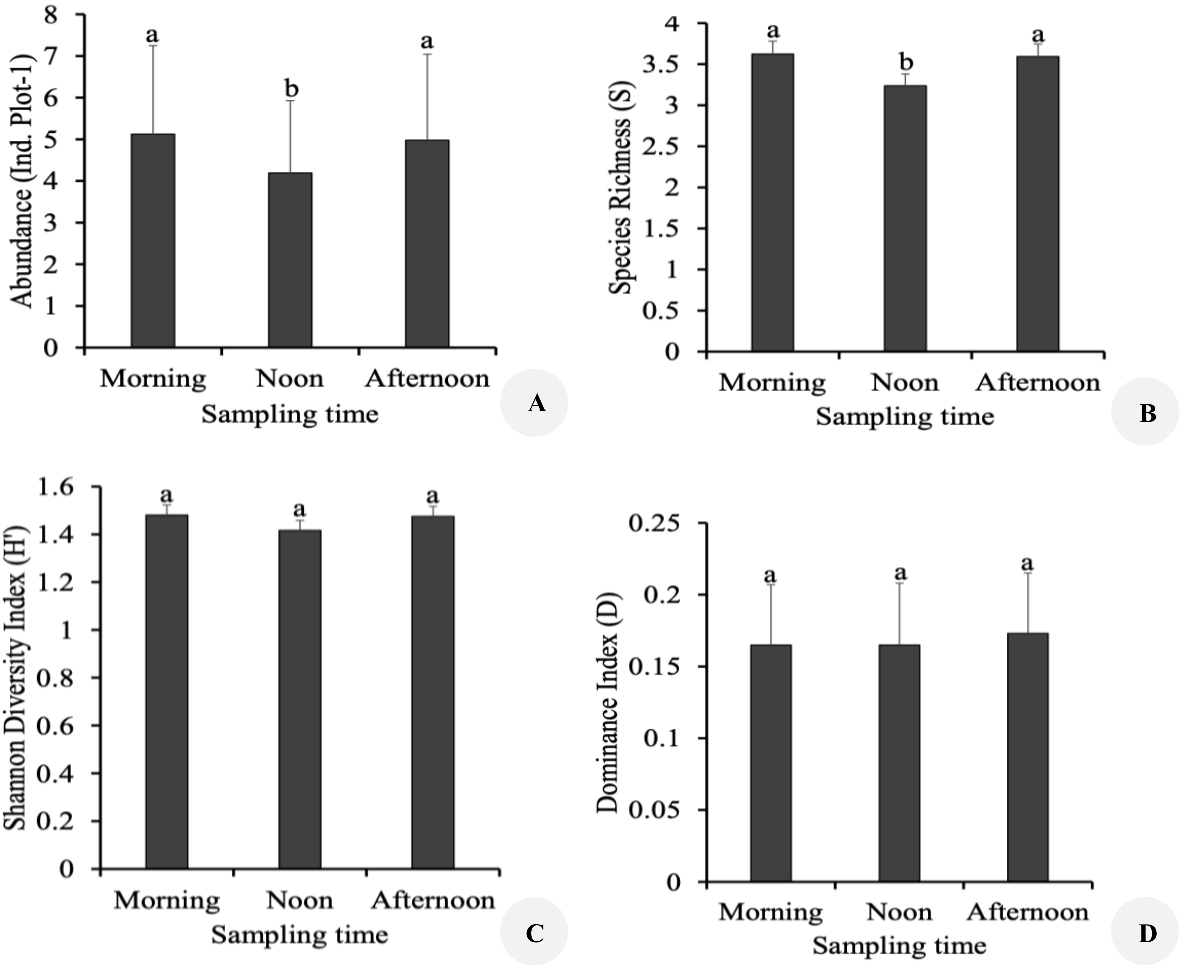

Figure 4. A. Grasshopper total abundance (mean±SE, n: 1044), B. Species richness (mean±SE, n: 1044), C. Species diversity (mean±SE, n: 940), D. Species dominance (mean±SE, n: 940) collected in morning, noon, and afternoon. Samples containing a single individual were excluded from analysis because the dominance value was not countable

The Organic Paddies (OP) location was characterized by the dominance of *Co. fasciatus* with a maximum indicator value (Indval: 100%, p: 0.0001), as well as the presence of *At. angusta* (Indval: 53.71%, p: 0.0001) and *Co. melaenus* (Indval: 66.67%, p: 0.0001) as supporting indicator species. Conversely, on conventional paddies (CP), the highest indicator values were shown by *O. hyla* (Indval: 35.88%, p: 0.0001), although the values were relatively lower than in other locations (Table 6). Meanwhile, in organic vegetable (OV) and conventional vegetable (CV) fields, the indicator values were in the low to moderate range, indicating a low degree of species affinity to the habitat.

Therefore, those species in OV and CV had no potential as an indicator. This pattern reinforces the analysis results that indicator species have clear habitat affinities and are sensitive to differences in environmental characteristics and land management systems (Siddig et al. 2016), demonstrating the potential for use as a biological indicator in assessing the quality of organic and conventional agricultural ecosystems. Overall, the distribution of IndVal scores across all locations shows significant variation in species-habitat affinity, reinforcing that community structure responds sensitively to differences in land management. High IndVal values, especially if statistically significant ($p<0.05$), suggest indicator species capable of distinguishing habitat types and potentially serving as reliable biological markers for agroecosystem assessment.

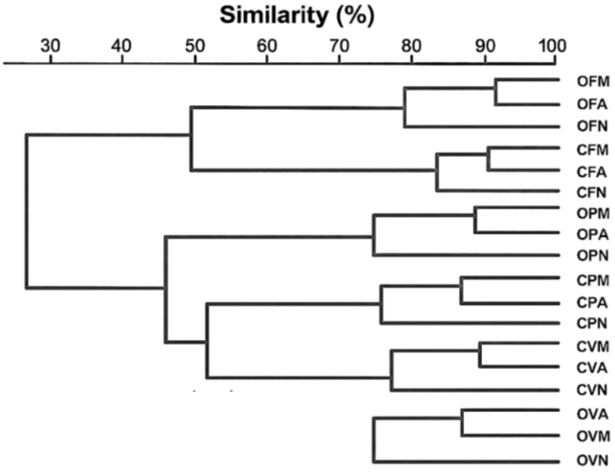

Figure 5. The UPGMA Bray-Curtis Similarity Matrix of grasshopper communities in six farm types (OV: Organic Vegetable, CV: Conventional Vegetable, OF: Organic Fruit, CF: Conventional Fruit, OP: Organic Paddy, CP: Conventional Paddy) in the morning (M), noon (N) and afternoon (A)

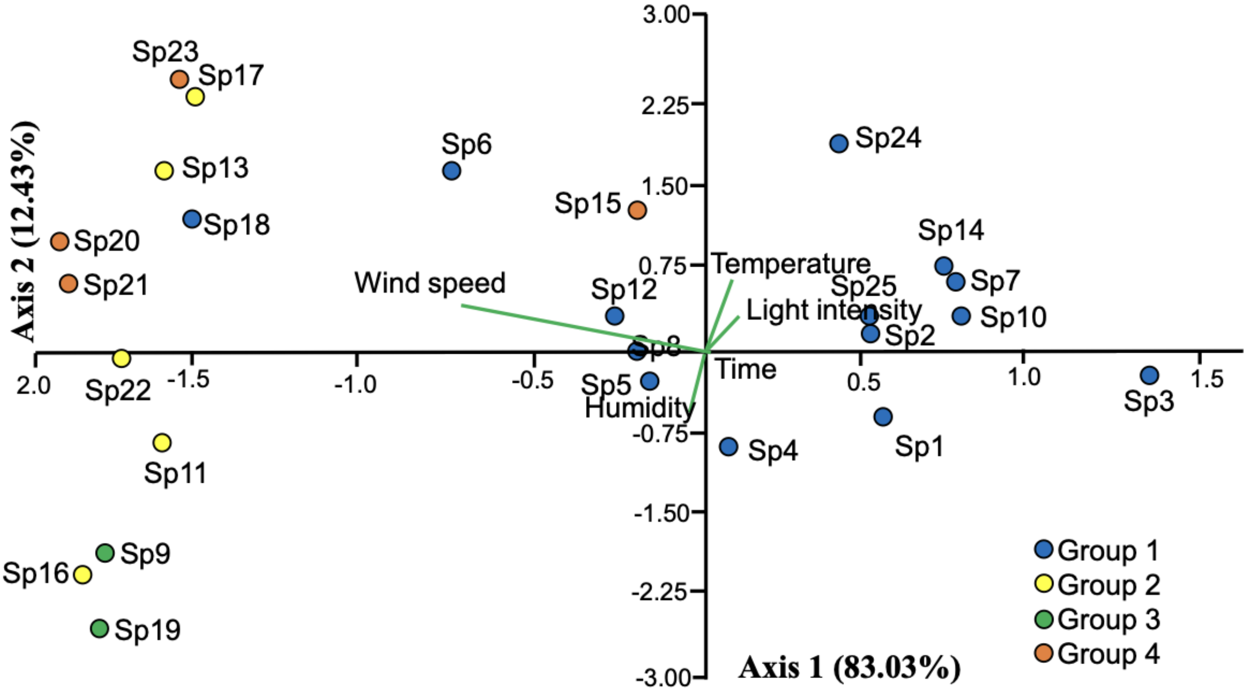

Figure 6. Ordination of species compositions responding to environmental factors. Arrows represented the degree of environmental variable (with twofold amplification). The species compositions were grouped using k-means clustering. It consisted of four groups, represented by blue circles (Group I), yellow circles (Group II), green circles (Group III), and orange circles (Group IV). Species code in the figure represent species name as follows Sp1 (*Atractomorpha lata*), Sp2 (*Paratettix curtipennis*), Sp3 (*Oxya hyla*), Sp4 (*Acrida turrita*), Sp5 (*Atractomorpha sinensis*), Sp6 (*Euparatettix* sp.), Sp7 (*Oxya japonica*), Sp8 (*Atractomorpha crenulata*), Sp9 (*Anaxipha* sp.), Sp10 (*Oxya chinensis*), Sp11 (*Atractomorpha angusta*), Sp12 (*Cesasundana lorniensis*), Sp13 (*Trilophidia annulata*), Sp14 (*Conocephalus fasciatus*), Sp15 (*Xenocatantops humilis*), Sp16 (*Phlaeoba infumata*), Sp17 (*Sedulia specularia*), Sp18 (*Thoradonta dentata*), Sp19 (*Apalacris varicornis*), Sp20 (*Caryanda spuria*), Sp21 (*Tagasta marginella*), Sp22 (*Elimaea subcarinata*), Sp23 (*Phlaeoba fumosa*), Sp24 (*Gesonula mundata*), Sp25 (*Conocephalus melaenus*)

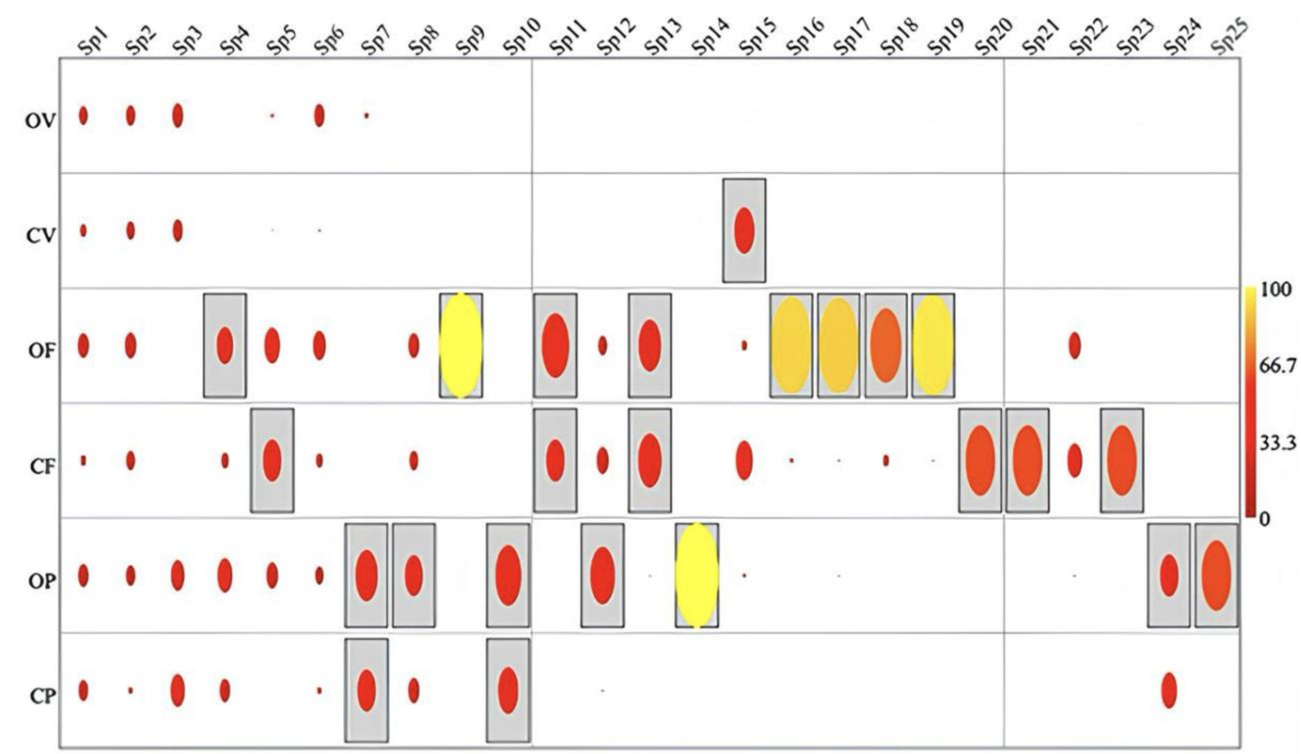

Figure 7. The list of species indicators among the farm types (OV: Organic Vegetable, CV: Conventional Vegetable, OF: Organic Fruit, CF: Conventional Fruit, OP: Organic Paddy, CP: Conventional Paddy). Sp1 (*Atractomorpha lata*), Sp2 (*Paratettix curtipennis*), Sp3 (*Oxya hyla*), Sp4 (*Acrida turrita*), Sp5 (*Atractomorpha sinensis*), Sp6 (*Euparatettix* sp.), Sp7 (*Oxya japonica*), Sp8 (*Atractomorpha crenulata*), Sp9 (*Anaxipha* sp.), Sp10 (*Oxya chinensis*), Sp11 (*Atractomorpha angusta*), Sp12 (*Cesasundana lorniensis*), Sp13 (*Trilophidia annulata*), Sp14 (*Conocephalus fasciatus*), Sp15 (*Xenocatantops humilis*), Sp16 (*Phlaeoba infumata*), Sp17 (*Sedulia specularia*), Sp18 (*Thoradonta dentata*), Sp19 (*Apalacris varicornis*), Sp20 (*Caryanda spuria*), Sp21 (*Tagasta marginella*), Sp22 (*Elimaea subcarinata*), Sp23 (*Phlaeoba fumosa*), Sp24 (*Gesonula mundata*), Sp25 (*Conocephalus melaenus*)

Table 5. Correlation between grasshopper group and environmental factors (univariate test)

Group	Correlation	Temperature	Humidity	Windspeed	Light intensity
Group I	Pearson Chi-square (χ^2)	-0.030	0.058	-0.033	0.054
	Sig. (2 tailed)	0.820	0.659	0.801	0.684
Group II	Pearson Chi-square (χ^2)	-0.137	0.001	0.389	-0.019
	Sig. (2 tailed)	0.298	0.996	0.002	0.886
Group III	Pearson Chi-square (χ^2)	-0.231	0.112	0.253	-0.081
	Sig. (2 tailed)	0.076	0.393	0.051	0.538
Group IV	Pearson Chi-square (χ^2)	-0.139	-0.014	0.141	-0.035
	Sig. (2 tailed)	0.291	0.915	0.284	0.793

Table 6. Indicator value species of grasshopper community in six farm types (OV: Organic Vegetable, CV: Conventional Vegetable, OF: Organic Fruit, CF: Conventional Fruit, OP: Organic Paddy, CP: Conventional Paddy) in the morning (M), noon (N) and afternoon (A)

Landuse	Potential indicator species		
	Species 1	Species 2	Species 3
OV	*Oxya hyla* (16.22%^{ns})	*Paratettix curtipennis* (14.78% ^{ns})	*Acrida turrita* (14.03% ^{ns})
CV	*Xenocatantops humilis* (25.58% ^{ns})	*Oxya hyla* (14.31% ^{ns})	*Paratettix curtipennis* (12,17% ^{ns})
OF	*Anaxipha* sp. (99%*)	*Phlaeoba infumata* (91.84%*)	*Sedulia specularia* (90.63%*)
CF	*Caryanda spuria* (66.67%*)	*Phlaeoba fumosa* (66.67%*)	*Trilophidia annulata* (50.34%*)
OP	*Conocephalus fasciatus* (100%*)	*Gesonula mundata* (66.67%*)	*Oxya chinensis* (59.64%*)
CP	*Oxya chinensis* (43.06%*)	*Oxya japonica* (38.81%*)	*Oxya hyla* (35.88%*)

Note: the star symbol (*) indicates the significance as an indicator species at $p<0.05$, ns: not significant

Discussion

This study revealed two major findings. First, grasshopper abundance, species richness, and diversity differed among land-use systems, with consistently higher values in organic than in conventional fields. Grasshopper abundance was significantly greater in organic systems, particularly in OF and OP sites, while the lowest abundance occurred in vegetable fields under both management types. These results confirm that organic farming practices generally support larger insect populations. Similar patterns have been reported in agroecosystems, where organic management increases insect abundance and visitation rates by maintaining natural ground cover and reducing pesticide exposure (Grabovska et al. 2020; Purwantiningsih et al. 2025). Species richness followed a comparable trend, with organic fruit systems supporting the highest number of species, whereas conventional sites showed lower richness and more simplified community structures. Such reductions in conventional systems are widely attributed to habitat homogenization and routine chemical inputs that selectively suppress sensitive taxa. Previous studies have demonstrated similar outcomes, where organic farming significantly increased beetle diversity and overall arthropod richness compared to conventional management (Popov et al. 2018; Chouangthavy et al. 2021). The diversity index further reinforced this pattern. Organic systems, particularly OF and OP, exhibited significantly higher Shannon diversity values, indicating not only more species but also more even community structures. In contrast, conventional systems tended to be dominated by a few tolerant species, reflecting strong selection pressures from pesticide use and intensive cultivation. This pattern aligns with earlier findings showing consistently higher insect diversity indices in organic agroecosystems due to reduced chemical disturbance and greater habitat complexity (Leksono 2017; Grabovska et al. 2021). In contrast to those in conventional systems, especially CV and CP sites, higher species dominance was observed, indicating communities dominated by disturbance-tolerant species. High dominance reflects trophic simplification and ecological imbalance, whereas lower dominance in organic systems suggests more stable and evenly distributed communities. Similar findings indicate that insect assemblages in conventional agriculture are often dominated by pesticide-resistant species, whereas organic systems maintain more balanced community compositions (Gómez-Guzmán et al. 2017; Grabovska et al. 2020). The results of this study demonstrate the important role of organic farming systems, but that is not the sole determining factor. Differences in elevation, surrounding landscape composition and configuration can influence grasshopper composition. In vegetable farms, there was no significant difference between organic and conventional fields. This may be due to two factors: the small number of grasshoppers and the dominance of certain species.

CCA ordination revealed that microclimatic factors influenced grasshopper distribution, with wind speed as one environmental factor associated with part of the compositional variation. Wind plays an important ecological role for insects by affecting dispersal ability, flight behavior, thermoregulation, and foraging efficiency. Moderate wind can facilitate passive dispersal of small insects such as fruit flies, but high wind speeds often reduce flight activity, limit feeding time, and increase energetic costs (Susanto et al. 2022). For grasshoppers specifically, strong winds can hinder jumping-flight trajectories, disrupt acoustic communication used for mating, and increase desiccation risk due to enhanced evaporative water loss (Prinster et al. 2020). Consequently, windier habitats may act as ecological filters, favoring robust, ground-active, or disturbance-tolerant species while excluding more specialized taxa. This mechanism likely explains the observed shifts in community composition along wind gradients in this study. Temperature, humidity, and solar radiation also contributed to community differentiation, consistent with previous research showing that microclimatic conditions are primary drivers of Orthoptera distribution patterns across landscapes (Zografou et al. 2017; Li et al. 2024). The result indicates the importance of microclimate (wind speed) in shaping the composition of grasshopper assemblages.

The second major finding relates to species-specific habitat associations. Several species showed a strong affinity for specific habitats and could serve as indicators of particular farm types. For example, *Anaxipha* sp. and *Co. fasciatus* were strongly associated with organic fruit and rice systems, respectively, indicating high habitat specificity and fidelity. Such species are typically associated with dense vegetation and stable microhabitats, reflecting the greater structural complexity and lower chemical stress in organic systems. In contrast, conventional systems were dominated by generalist and disturbance-tolerant species, such as *O. chinensis* and *O. hyla*, which are widely reported as dominant taxa in intensively managed rice agroecosystems (Leksono et al. 2022; Leksono et al. 2024). Members of Acrididae are known for their broad environmental tolerance and ability to thrive under fluctuating microclimatic conditions and anthropogenic disturbance (Guo et al. 2024; Hussain et al. 2024). Other species, such as *X. humilis,* exhibit generalist ecological strategies influenced by seasonal climatic variability, further supporting their association with simplified habitats. Indicator species analysis confirms that grasshopper communities respond sensitively to land-use intensity and habitat quality. However, further study is needed to deepen the analysis of the association between potential species and habitat, including plant, herbivore interactions and grasshopper life-table analysis. Another study reported that some grasshoppers may have potential as bioindicators, such as *Catantops ochthephilus* in an area of indigenous forest; *Aiolopus meruensis*, *Coryphosima stenoptera*, *Oedaleus carvalhoi*, and *Orthochtha* sp.2 in grass height; *Tylotropidius didymus*, *Faureia milanjica*, *Mesopsis laticornis*, and *Pnorisa* sp. in a burn habitat (last a year); and *Acrida* sp.1 and *Cannula gracilis* were strong indicators for an individual site (Bazelet and Samways 2011). Species exhibiting high specificity and fidelity effectively reflect ecological conditions and levels of disturbance, making them valuable bioindicators of agroecosystem sustainability (Siddig et al. 2016). This responsiveness is largely driven by microclimate and management practices that shape resource availability and habitat suitability (Zografou et al. 2017).

More broadly, biodiversity within agroecosystems plays a crucial role in supporting ecosystem services such as nutrient cycling, pollination, and biological pest control. Agricultural intensification often compensates for biodiversity loss through synthetic inputs, which may increase short-term productivity but threaten long-term sustainability (Liu et al. 2022; Mehran et al. 2025). Grasshoppers are particularly sensitive to land-use change and climatic conditions, with habitat loss representing a major threat to population persistence (Fartmann et al. 2012; Löffler et al. 2019). However, their physiological and biochemical adaptations, including structural resilience and developmental plasticity, enable certain species to tolerate environmental stress and persist in disturbed systems (Brahimi et al. 2020; Psarianos et al. 2024).

In conclusion, this study shows that the structure of grasshopper communities in agroecosystems is strongly influenced by farm type, sampling time and wind speed. Overall, 5,636 individuals belonging to 25 species were recorded across six farm types. Farm type significantly affected all community parameters (abundance, species richness, dominance and diversity), while sampling time influenced only abundance and species richness, with no significant interaction effects. Among the environmental factors, wind speed had a significant correlation with grasshopper groups, indicating that it is one of the environmental factors associated with part of the compositional variation. Several species were found to have potential as group or individual indicator species such as *Anaxipha* sp., *Phlaeoba infumata*, and *Sedulia specularia* in OF; *Caryanda spuria* and *Tagasta marginella*, *Phlaeoba fumosa* in CF; *Conocephalus fasciatus*, *Atractomorpha angusta* and *Conocephalus melaenus* in OP; and *Oxya hyla* in CP. No indicator species were identified in vegetable farms.

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REFERENCES

Abrori M, Leksono AS, Gama ZP. 2021. The abundance and diversity of grasshopper (Orthoptera) in Batu City, East Java. Biotropika 9 (1): 19-26. https://doi.org/10.21776/ub.biotropika.2021.009.01.03.

BPS [Badan Pusat Statistik]. 2026. Average Air Temperature (°C). BPS, Batu City. https://batukota.bps.go.id/id/statistics-table/2/ OTkjMg::/rata-rata-suhu-udara--0c-.html.

Brahimi D, Mesli L, Rahmouni A, Zeggai FZ, Khaldoun B, Chebout R, Belbachir M. 2020. Why Orthoptera fauna resist of pesticide? First experimental data of resistance phenomena. Data Brief 30: 105659. https://doi.org/10.1016/j.dib.2020.105659.

Chouangthavy B, Sanguansub S, Das A. 2021. Sustainable organic farming supports diversity of coleopteran beetles as a good indicator taxon: A case study from Central Lao PDR. Org Agric 11 (4): 615-624. https://doi.org/10.1007/s13165-021-00367-x.

Conti M, Dalpasso A, Nodari AM, Cantera I, Barzaghi B, Brambilla M, Ferrari A, Ficetola GF, Giachello S, Lo Parrino E, Messina V, Polidori C, Pozzi M, Redaelli S, Zerboni A, Losapio G, Falaschi M. 2026. Effects of local management and landscape factors on taxonomic and functional diversity of multiple taxa in managed grasslands. Agric Ecosyst Environ 400: 110257-110270. https://doi.org/10.1016/j.agee.2026.110257.

Dufrêne M, Legendre P. 1997. Species assemblages and indicator species: The need for a flexible asymmetrical approach. Ecological Monographs 67: 345-366. https://doi.org/10.1890/0012-9615(1997)067[0345:SAAIST]2.0.CO;2.

Farooq MO, Razaq M, Shah FM. 2022. Plant diversity promotes species richness and community stability of arthropods in organic farming. Arthropod-Plant Interact 16 (6): 593-606. https://doi.org/10.1007/s11829-022-09920-1.

Fartmann T, Krämer B, Stelzner F, Poniatowski D. 2012. Orthoptera as ecological indicators for succession in steppe grassland. Ecol Indic 20: 337-344. https://doi.org/10.1016/j.ecolind.2012.03.002.

Fess TL, Benedito VA. 2018. Organic versus conventional cropping sustainability: A comparative system analysis. Sustainability 10 (1): 272. https://doi.org/10.3390/su10010272.

Galloway AD, Seymour CL, Gaigher R, Pryke JS. 2021. Organic farming promotes arthropod predators, but this depends on neighbouring patches of natural vegetation. Agric Ecosyst Environ 310: 1-9. https://doi.org/10.1016/j.agee.2020.107295.

Gamage A, Gangahagedara R, Gamage J, Jayasinghe N, Kodikara N, Suraweera P, Merah O. 2023. Role of organic farming for achieving sustainability in agriculture. Farm Syst 1 (1): 100005-100019. https://doi.org/10.1016/j.farsys.2023.100005.

Geng Y, Zhao L, Huang W, Dong Y, Ma H, Guo A, Ren Y, Xing N, Huang Y, Sun R, Wang J. 2022. A landscape-based habitat suitability model (LHS model) for oriental migratory locust area extraction at large scales: A case study along the middle and lower reaches of the Yellow River. Remote Sensing 14 (5): 1058. https://doi.org/10.3390/rs14051058.

Gómez-Guzmán JA, García-Marín FJ, Sáinz-Pérez M, González-Ruiz R. 2017. Behavioural resistance in insects: Its potential use as bio indicator of organic agriculture. IOP Conf Ser Earth Environ Sci 95 (4): 042038. https://doi.org/10.1088/1755-1315/95/4/042038.

Grabovska T, Lavrov V, Grabovskyi M. 2021. Insects diversity in soybean crops under organic and conventional farming. 6th ISOFAR Conference, Rennes, France, 8-10 September 2021.

Grabovska T, Lavrov V, Grabovskyi M, Mazur T, Polishchuk Z, Rozputnii O, Bogatyr L. 2020. Effect of organic farming on insect diversity. Ukr J Ecol 10 (4): 96-101. https://doi.org/10.15421/2020_174.

Guo W, Ma C, Kang L. 2024. Community change and population outbreak of grasshoppers driven by climate change. Curr Opin Insect Sci 61: 101154-101162. https://doi.org/10.1016/j.cois.2023.101154.

Huang F, Wang C, Liu M, Chen Q, Han X, Wang L, Xi Y, Zhang J. 2022. Effects of organic planting on arthropod diversity in farmland: A meta-analysis. Biodiver Sci 30 (1): 21243. https://doi.org/10.17520/biods.2021243.

Hussain M, Kazam SN, Noreen A, Shah SH, Zeb U, Iftikhar A. 2024. Diversity and distributional patterns of grasshoppers in croplands of District Gujrat, Punjab, Pakistan. Biologia 70 (2): 38-46. https://doi.org/10.17582/journal.Biologia/2024/70.2.38.46.

Johnson DL. 2008. Grasshopper Identification and Control Methods to Protect Crops and The Environment. Pulse Canada and Saskatchewan Agriculture and Food, Canada.

Khatimah A, Leksono AS, Yanuwiadi B. 2022. Diversity of grasshopper on agricultural land and savana in Dompu Regency, Indonesia. Biotropika 10 (3): 203-210. https://doi.org/10.21776/ub.biotropika.2022.010.03.06.

Kistner-Thomas E, Kumar S, Larry J, Woller DA. 2021. Modeling rangeland grasshopper (Orthoptera: Acrididae) population density using a landscape-level predictive mapping approach. J Econ Entomol 114 (4): 1557-1567. https://doi.org/10.1093/jee/toab119.

Leksono AS, Yanuwiadi B, Afandhi A, Farhan M, Zairina A. 2020. The abundance and diversity of grasshopper communities in relation to elevation and land use in Malang, Indonesia. Biodiversitas 21 (12): 5614-5620. https://doi.org/10.13057/biodiv/d211231.

Leksono AS, Yanuwiadi B, Gama ZP, Kurniawan N, Abrori M, Grahadi R, Zairina A. 2024. Preliminary inventory of grasshopper diversity in several sites in Central and East Java. AIP Conf Proc 3132 (1): 0201314. https://doi.org/10.1063/5.0201314.

Leksono AS, Yanuwiadi B, Khotimah A, Zairina A. 2022. Grasshopper diversity in several agricultural areas and savannas in Dompu, Sumbawa Island, Indonesia. Biodiversitas 23 (1): 75-80. https://doi.org/10.13057/biodiv/d230109.

Leksono AS. 2017. The effect of organic farming systems on species diversity. AIP Conf Proc 1908 (1): 030001-5. https://doi.org/10.1063/1.5019553.

Li XD, Xin L, Rong WT, Liu XY, Deng WA, Qin YC, Li XL. 2021. Effect of heavy metals pollution on the composition and diversity of the intestinal microbial community of a pygmy grasshopper (*Eucriotettix oculatus*). Ecotoxicol Environ Saf 223: 112582. https://doi.org/10.1016/j.ecoenv.2021.112582.

Li Y, Liu Q, Zhang X, Mao B, Yang G, Shi F, Bi J, Ma Z, Tang G. 2024. Effects of environmental factors on the diversity of grasshopper communities along altitude gradients in Xizang, China. Insects 15 (9): 671-691. https://doi.org/10.3390/insects15090671.

Lichtenberg EM, Kennedy CM, Kremen C, Batáry P, Berendse F, Bommarco R. 2017. A global synthesis of the effects of diversified farming systems on arthropod diversity within fields and across agricultural landscapes. Glob Chang Biol 23 (11): 4946-4957. https://doi.org/10.1111/gcb.13714.

Liu Q, Sun X, Wu W, Liu Z, Fang G, Yang P. 2022. Agroecosystem services: A review of concepts, indicators, assessment methods and future research perspectives. Ecol Indic 142: 109218. https://doi.org/10.1016/j.ecolind.2022.109218.

Löffler F, Poniatowski D, Fartmann T. 2019. Orthoptera community shifts in response to land-use and climate change: Lessons from a long-term study across different grassland habitats. Biol Conserv 236: 315-323. https://doi.org/10.1016/j.biocon.2019.05.018.

Mehran M, Ikram M, Ghoneim AM, Ghafar S, Ashraf M, Rehman H, Ahmad IA, Haider S, Shah MN, Ehsan A, Minhas A, Ghaffor K, Zahid M. 2025. Biodiversity within agroecosystems and its benefits to soil. In: Shaaban M (eds). Soils and Sustainable Agriculture. Springer, Cham.

Ostandie N, Giffard B, Bonnard O, Joubard B, Richart-Cervera S, Thiéry D, Rusch A. 2021. Multi-community effects of organic and conventional farming practices in vineyards. Sci Rep 11 (1): 11979. https://doi.org/10.1038/s41598-021-91095-5.

Popov V, Kostadinova E, Rancheva E, Yancheva C. 2018. Causal relationship between biodiversity of insect population and agro management in organic and conventional apple orchard. Org Agric 8 (4): 355-370. https://doi.org/10.1007/s13165-017-0202-x.

Prinster AJ, Resasco J, Nufio CR. 2020. Weather variation affects the dispersal of grasshoppers beyond their elevational ranges. Ecol Evol 10 (24): 14411-14422. https://doi.org/10.1002/ece3.7045.

Psarianos M, Fricke A, Altuntaş H, Baldermann S, Schreiner M, Schlüter OK. 2024. Potential of House Crickets *Acheta domesticus* L. (Orthoptera: Gryllidae) as a novel food source for integration in a Co-cultivation system. Future Foods 9: 100332. https://doi.org/10.1016/j.fufo.2024.100332.

Purwantiningsih B, Leksono AS, Yanuwiyadi B, Penata GZP. 2025. Abundance and diversity of insect visitors to ground cover plants in organic orchard with bee hives (*Apis mellifera*) in Batu, Indonesia. Acta Univ Agric Silvic Mendel Brun 72 (56): 153-164. https://doi.org/10.11118/actaun.2024.010.

Samways MJ, Lecoq M, Deacon C. 2026. Orthoptera biodiversity for environmental assessment and agroecological advancement. Agronomy 16 (1): 57. https://doi.org/10.3390/agronomy16010057.

Schrama M, de Haan JJ, Kroonen M, Verstegen H, van der Putten WH. 2018. Crop yield gap and stability in organic and conventional farming systems. Agric Ecosyst Environ 256: 123-130. https://doi.org/10.1016/j.agee.2017.12.023.

Siddig AAH, Ellison AM, Ochs A, Villar-Leeman C, Lau MK. 2016. How do ecologists select and use indicator species to monitor ecological change? Insights from 14 years of publication in ecological indicators. Ecol Indic 60: 223-230. https://doi.org/10.1016/j.ecolind.2015.06.036.

Song H, Mariño-Pérez R, Woller DA, Cigliano MM. 2018. Evolution, diversification, and biogeography of grasshoppers (Orthoptera: Acrididae). Insect Syst Diver 2 (4): 1-25. https://doi.org/10.1093/isd/ixy008.

Susanto A, Permana AD, Subahar TS, Soesilohadi RCH, Leksono AS, Fernandes AAR. 2022. Population dynamics and projections of fruit flies *Bactrocera dorsalis* and *B. carambolae* in Indonesian Mango Plantation. Agric Nat Res 56 (1): 169-179. https://doi.org/10.34044/j.anres.2021.56.1.16.

Sutherland WJ. 2006. Ecological Census Techniques Second Edition. Cambridge University Press, Cambridge.

Tan MK. 2012. Orthoptera in the Bukit Timah and Central Catchment Nature Reserves (Part 1): Suborder Caelifera. Raffles Museum of Biodiversity Research, National University Singapore, Singapore.

Tan MK. 2017. Orthoptera in the Bukit Timah and Central Catchment Nature Reserves (Part 2): Suborder Ensifera. Raffles Museum of Biodiversity Research, National University Singapore, Singapore.

Veran S, Simpson SJ, Sword GA, Deveson E, Piry S, Hines JE, Berthier K. 2015. Modeling spatiotemporal dynamics of outbreaking species: Influence of environment and migration in a locust. Ecology 96 (3): 737-748. https://doi.org/10.1890/14-0183.1.

Wang Z, Xu D, Liao W, Xu Y, Zhuo Z. 2023. Predicting the current and future distributions of *Frankliniella occidentalis* (Pergande) based on the MaxEnt species distribution model. Insects 14 (5): 458-470. https://doi.org/10.3390/insects14050458.

Zografou D, Adamidis G, Komnenov M, Kati V, Sotirakopoulos P, Pitta E, Chatzaki M. 2017. Diversity of spiders and Orthopterans respond to intra-seasonal and spatial environmental changes. J Insect Conserv 21: 531-543. https://doi.org/10.1007/s10841-017-9993-z.