台灣農業研究 (J. Taiwan Agric. Res.) 75(2):231–247 (2026)
https://doi.org/10.6156/JTAR.202606_75(2).0005

Research Article

Predatory Lady Beetle Assemblages under Organic and Conventional Farming in Eastern Taiwan's Indigenous Agriculture

Yaw-Jen Dong[1], Pei-Chen Hsu[1,*], Chi-Feng Lee[2], Mei-Jung Tseng[3], and Hsien-Tzung Shih[4]

Abstract

Dong, Y. J., P. C. Hsu, C. F. Lee, M. J. Tseng, and H. T. Shih. 2026. Predatory lady beetle assemblages under organic and conventional farming in eastern Taiwan's indigenous agriculture. J. Taiwan Agric. Res. 75(2):231–247.

This study investigated the diversity and temporal stability of lady beetle communities under different farming practices in indigenous agricultural systems of Hualien, eastern Taiwan. From 2022 to 2024, surveys were conducted in organically and conventionally managed rice paddies and pomelo orchards using yellow sticky traps. A total of 29 species were recorded in rice fields and 31 in orchards. Organic management, particularly in perennial pomelo orchards, significantly enhanced lady beetle abundance, species richness, and population stability. In orchards, *Scymnus yangi* Yu et Pang, 1993, and *Sasajiscymnus tainanensis* (Ohta, 1929) were the most dominant species under organic management, while in rice fields, *Micraspis discolor* (Fabricius, 1798) showed higher abundance and stability in organic plots. These results suggest that organic practices can promote beneficial insect populations in indigenous farmlands, especially in orchard systems. The findings provide baseline data for the development of biological control strategies and may inform eco-label certification schemes that incorporate native predatory lady beetles as bioindicators in sustainable agriculture.

Key words: Indigenous farmlands, Organic farming, Conventional farming, Predatory lady beetles, Biodiversity, Stability.

INTRODUCTION

In eastern Taiwan, the relatively slow pace of industrial development has helped preserve low levels of environmental pollution, resulting in superior air quality, clean irrigation water, and healthy soil conditions. These favorable environmental factors provide a solid foundation for promoting environmentally friendly agricultural practices. A diverse population, rich cultural heritage, and picturesque rural landscapes also characterize the region. With both natural and cultural advantages, indigenous areas in eastern Taiwan have strong potential to develop organic and eco-friendly farming systems (Lin *et al.* 2024).

However, in practice, indigenous farmers often refrain from using chemical pesticides and fertilizers in accordance with organic farming principles, which increases their vulnerability to pest infestations. This frequently results in reduced yields and product quality, diminishing

Received: August 15, 2025; Accepted: January 28, 2026.
* Corresponding author, e-mail: bchen@tari.gov.tw
1 Associate Research Fellows, Applied Zoology Division, Taiwan Agricultural Research Institute, Taichung City, Taiwan, ROC.
2 Contract Research Fellow, Applied Zoology Division, Taiwan Agricultural Research Institute, Taichung City, Taiwan, ROC.
3 Project Assistant, Applied Zoology Division, Taiwan Agricultural Research Institute, Taichung City, Taiwan, ROC.
4 Research Fellow and Division Director, Applied Zoology Division, Taiwan Agricultural Research Institute, Taichung City, Taiwan, ROC.

farmers' willingness to maintain organic cultivation. Moreover, many tribal farmers lack sufficient technical knowledge of biological and physical pest control, and early warning or rapid response systems for pest outbreaks remain underdeveloped. These limitations have contributed to inconsistent pest management outcomes and represent a major barrier to advancing environmentally friendly agricultural practices in indigenous communities (Yen & Chen 2022).

In Taiwan's indigenous agricultural landscapes, the surrounding habitats are typically less intensively managed and more heterogeneous due to long-standing stewardship and customary land use practices. Such low-disturbance, high-heterogeneity settings support higher biodiversity than intensively farmed regions, with syntheses showing that biodiversity levels on indigenous-managed lands are comparable to- or exceed- those of protected areas (Garnett *et al.* 2018). Biodiversity responses to management are also strongly mediated by landscape heterogeneity, where complex, low-disturbance mosaics favor greater natural-enemy diversity and pest regulation (Batáry *et al.* 2011). In perennial orchard systems, organic management, embedded within heterogeneous landscapes, further enhances biological control compared to conventional systems (Porcel *et al.* 2018).

These relationships are also evident in Taiwan's indigenous farmlands. In the Rukai community of Wutai Village, for instance, traditional practices such as multi-cropping, crop rotation, and periodic fallowing are applied across various altitudes, representing long-term adaptations to mountainous environments. Such strategies maintain soil fertility and enhance biodiversity within indigenous systems (Yen & Chen 2014; Ba *et al.* 2023). The coexistence of low-disturbance habitats and traditional farming methods thus provides a unique setting for the persistence of natural enemies- key components of sustainable pest management.

Among these natural enemies, lady beetles (Family: Coccinellidae) are recognized as one of the most functionally important predator groups (Obrycki & Kring 1998; Symondson *et al.* 2002; Koch 2003). They are polyphagous predators that feed on a broad range of agricultural pests, and their abundance and diversity often reflect the quality of habitat management. As mobile generalist predators, lady beetles play a central role in sustaining natural pest regulation in diversified or low-disturbance farming systems, making them valuable indicators of the effectiveness of biodiversity-based pest control. The family Coccinellidae comprises approximately 6,000 species worldwide, grouped into three major functional categories- predatory, herbivorous, and mycophagous species (Seago *et al.* 2011; Patil & Gaikwad 2019). Among these, predatory species constitute the majority and are known for preying effectively on mites, aphids, thrips, scale insects, psyllids, planthoppers, leafhoppers, and the eggs or early instars of lepidopteran pests. Owing to this role, predatory lady beetles are integral to biological control strategies and remain key agents in integrated pest management (IPM) programs (Symondson *et al.* 2002; Giorgi *et al.* 2009; Megha *et al.* 2015; Kundoo & Khan 2017; Shanker *et al.* 2018; Pervez *et al.* 2020).

According to the Catalogue of Life in Taiwan, a total of 241 species of lady beetles, belonging to 63 genera, have been recorded in Taiwan (TaiCOL 2025). In a recent study of agricultural ecosystems, Dong *et al.* (2023) documented 68 species across 11 agricultural sites, representing 8 subfamilies, 11 tribes, and 32 genera- indicating considerable lady beetle diversity within farmlands.

Despite this diversity, research on lady beetle assemblages within Taiwan's indigenous agricultural systems remains scarce. To address this gap, the present study was conducted from 2022 to 2024 in two indigenous communities of Hualien County, eastern Taiwan. Lady beetle populations were systematically monitored under both organic and conventional management in the rice paddies of the Ceroh Tribe (Yuli Township) and the pomelo orchards of the Olalip Tribe (Ruisui Township). This study aims to establish baseline data on the species composition and abundance of lady beetles in tribal farmlands, providing essential references for promoting chemical-free agriculture and biological pest control among indigenous farmers, while supporting ecological intensification and the development of biodiversity-based eco-labeling strategies for indigenous agriculture.

MATERIALS AND METHODS

Study sites and plot design

This study was conducted in two indigenous communities in Hualien County, eastern Taiwan, to investigate lady beetle populations. The survey sites included rice paddies in the Ceroh community of Chunri Village, Yuli Township, and pomelo orchards in the Olalip community of Hegang Village, Ruisui Township. In the Ceroh community, five organically managed rice fields were selected as sampling plots, located at the following coordinates: 23.447174°N, 121.393555°E; 23.446947°N, 121.393872°E; 23.449429°N, 121.397979°E; 23.455473°N, 121.402310°E; and 23.456656°N, 121.381532°E. In addition, five conventionally managed rice fields were surveyed at: 23.450590°N, 121.396706°E; 23.450955°N, 121.395676°E; 23.450296°N, 121.400425°E; 23.449523°N, 121.400985°E; and 23.458473°N, 121.382067°E. In the Olalip community, four organically managed pomelo orchards were selected at: 23.510089°N, 121.390830°E; 23.511996°N, 121.395446°E; 23.548905°N, 121.392892°E; and 23.548541°N, 121.396226°E. Another four conventionally managed pomelo orchards were surveyed at: 23.504307°N, 121.393696°E; 23.508642°N, 121.392785°E; 23.510239°N, 121.398667°E; and 23.514154°N, 121.394150°E.

All field sites had well-defined management histories prior to the initiation of this study. Among the five organic rice fields, only one held formal organic certification, while the remaining four had been managed under organic or eco-friendly practices without certification. All pomelo orchards were certified organic and had been managed under organic or eco-friendly practices for at least seven years. In contrast, the conventionally managed rice and pomelo orchards had been maintained under pesticide-based practices for more than seven years.

To clarify the spatial setting and experimental design, all selected plots were located within the same indigenous communities, thereby ensuring that organic and conventional fields were compared under the socio-ecological context of each community. In the Ceroh community, organically and conventionally managed rice fields were both surveyed, while in the Olalip community, paired comparisons were made between organically and conventionally managed pomelo orchards. Within each community, the individual fields or orchards were treated as independent replicates, and the organic-versus-conventional contrast was assessed at the community level rather than across distant sites.

In this study, "organically managed fields" refer to agricultural areas managed in accordance with the definition provided in Article 3, Chapter 1 of the Organic Agriculture Promotion Act of Taiwan: "Organic agriculture refers to agricultural practices- including crop cultivation, forestry, aquaculture, and livestock farming- that follow the principles of ecological balance and nutrient cycling, and in which synthetic chemical fertilizers, chemical pesticides, genetically modified organisms (GMOs), and their derivatives are not used during the production process." In practice, organically managed rice paddies and pomelo orchards in the surveyed regions were cultivated strictly in accordance with these regulations. Local farmers emphasized ecological balance and sustainability, refrained from using synthetic fertilizers or pesticides, and instead regularly used environmentally friendly plant protection materials and organic fertilizers throughout the cropping season to prevent or suppress pest and disease outbreaks.

By contrast, "conventionally managed fields" refer to areas where farmers use chemical fertilizers and pesticides for crop cultivation and pest control. In the surveyed rice paddies and pomelo orchards, conventional management followed fertilizer regimes recommended for rice and pomelo production, combined with farmers' routine practices. Chemical fertilizers were applied during crop growth, and pesticides were sprayed at scheduled intervals. When pest infestations became severe, the frequency of pesticide applications was increased to suppress pest and disease populations. These management regimes were representative of typical practices in the indigenous farming communities of eastern Taiwan.

Pesticide usage in rice paddies and pomelo orchards

Pesticide regimes for each management type were documented through interviews with farmers and field records. In conventionally managed rice paddies, pesticides were applied only once per crop cycle, typically around the fourth week after transplanting during the tillering stage. The single application included a mixture of insecticides and fungicides such as pyrethroids (cyhalothrin), organochlorines (endosulfan), and organophosphate fungicides (edifenphos and tricyclazole). No additional sprays were applied before or after the peak activity periods of lady beetles. In contrast, organically managed rice fields received no chemical pesticide applications throughout the study period.

In pomelo orchards, conventional management followed a substantially more intensive pesticide regime. From December to the following August, growers applied pesticides 1–2 times per month, depending on pest or disease pressure, with each spray involving 1–3 active ingredients. Common insecticides included organophosphates (malathion, chlorpyrifos), avermectins (abamectin), carbamates (carbaryl), pyrethroids (cyhalothrin, deltamethrin), neonicotinoids (imidacloprid, acetamiprid), and insect growth regulators (pyriproxyfen). Mite control relied on acaricides such as fenpyroximate, while disease management involved repeated applications of fungicides, including mancozeb, zineb, hymexazol, triflumizole, chlorothalonil, and difenoconazole. Organic pomelo orchards, by contrast, applied only environmentally friendly plant-derived materials- primarily narrow-range oil, neem oil, and potassium phosphite mixtures- at similar seasonal intervals.

These system-level differences in pesticide intensity provide essential contextual information for interpreting lady beetle responses under organic and conventional management. Conventional rice fields experienced only minimal chemical disturbance, whereas conventional pomelo orchards were exposed to pesticides for most of the year. This contrast in cumulative spray intensity helps explain why organic management produced much stronger community-level differences in pomelo orchards than in rice systems.

Survey methods

Lady beetle monitoring was conducted from 2022 to 2024 using yellow sticky papers, with surveys conducted at two-month intervals. The deployment and sampling protocols for yellow sticky traps in both rice paddies and pomelo orchards followed the standardized methods described by Dong *et al.* (2023). In the rice fields, five organically managed plots and five conventionally managed plots were selected for study. During each sampling event, four yellow sticky traps were installed in each plot, totaling 40 traps per sampling (5 plots × 2 management types × 4 traps). Similarly, in the pomelo orchards, four organic and four conventional plots were surveyed, with four traps installed per plot, resulting in a total of 32 traps per sampling event (4 plots × 2 management types × 4 traps). Trap placement within each plot followed a stratified random design to minimize microhabitat bias while maintaining consistency across sampling periods.

In rice paddies, traps were installed slightly above the canopy at each sampling event to account for plant growth over time, ensuring consistent exposure to flying insects across different crop stages. In pomelo orchards, traps were fixed at approximately chest height (~1.5 m above ground). Yellow sticky papers were replaced regularly, and all specimens adhering to the yellow sticky papers were collected and brought back to the laboratory for sorting and identification. Captured lady beetles were identified to the species level and recorded numbers for subsequent analysis. The mean abundance of each lady beetle species was calculated as the average number of individuals per trap per sampling event across each site × year combination (i.e., total individuals/number of traps/number of sampling months). This standardization allowed comparisons across plots and years with consistent trapping effort.

Statistical analysis

This study conducted statistical analyses to evaluate the community composition, diversity, and temporal stability of lady beetle populations under different farming practices. The following indices and methods were used:

Shannon diversity index (*H'*): This index measures species diversity and evenness within each sampling plot. Higher *H'* values indicate greater species richness and a more even distribution of individuals among species (Magurran 2004).

Berger-Parker dominance index (*d*): This index quantifies the proportion of individuals belonging to the most abundant species. Lower values of *d* suggest a more balanced community structure with less dominance by a single species (Berger & Parker 1970).

Coefficient of variation (CV**):** Used to assess interannual variability and temporal stability of lady beetle populations. It is calculated as the standard deviation divided by the mean (CV = *SD*/Mean), with lower CV values indicating greater population stability over time (Tilman 1999).

To compare differences between organic and conventional fields in terms of diversity indexes (*H'* and *d*) and total lady beetle abundance, non-parametric Mann-Whitney *U* tests were performed. The significance level was set at $P < 0.05$. All statistical analyses were conducted using R software (version 4.3.0; R Core Team, 2023). Significant differences between organic and conventional fields were indicated in tables using asterisks ($^{*}P < 0.05$, $^{**}P < 0.01$). Supplementary bar charts were generated to visualize differences in the abundance and diversity of dominant species.

RESULTS

Paddy fields (Table 1). A total of 29 lady beetle species were recorded in paddy fields during 2022–2024, forming a predator-dominated assemblage. The community was mainly composed of predatory taxa, among which *Micraspis discolor* (Fabricius, 1798) was the most abundant (14.2 ± 1.49 individuals trap^{-1} event^{-1}), representing about 55% of all captures. *Propylea japonica* (Thunberg, 1781) (2.68 ± 0.38; 10%) and *Cheilomenes sexmaculata* (Fabricius, 1781) (2.07 ± 0.50; 8%) were the next most common species, followed by *Scymnus hoffmanni* Weise, 1879 (1.84 ± 0.43; 7%) and *Lemnia biplagiata* (Swartz, 1808) (0.32 ± 0.07; 1%). Together, these five predatory species accounted for roughly 81% of the total individuals, indicating a highly uneven dominance structure. In addition, one fungivorous species (*Illeis koebelei* Timberlake, 1943) and three herbivorous species- *Hensepilachna vigintioctopunctata* (Fabricius, 1775), *Epilachna maxima* (Weise, 1898), and *E. hendecaspilota* (Mader, 1927)- were recorded but occurred at very low abundances (< 0.1 individuals trap^{-1} event^{-1}). Overall, the paddy-field lady beetle community was strongly dominated by predatory species, with only a minor presence of herbivorous and fungivorous taxa.

Pomelo orchards (Table 2). A total of 31 lady beetle species were recorded in pomelo orchards during 2022–2024, forming a predator-dominated assemblage. The community was mainly composed of predatory taxa, with the five most abundant species being *Sc. yangi* Yu et Pang, 1993, *Sasajiscymnus tainanensis* (Ohta, 1929), *Sticholotis formosana* Weise, 1923, *Cryptogonus orbiculus* (Gyllenhal, 1808), and *Axinoscymnus nigripennis* Kamiya, 1965, which together accounted for over 70% of total captures. Among these, *Sc. yangi* (1.18 ± 0.32 individuals trap^{-1} event^{-1}) and *Sa. tainanensis*

Table 1. Lady beetle species and their mean abundance in paddy fields from 2022 to 2024 (ranked by abundance).

Scientific name	Mean abundance (mean ± *SE*)[z]
Micraspis discolor (Fabricius, 1798)[y]	14.2 ± 1.49
Propylea japonica (Thunberg, 1781)[y]	2.68 ± 0.38
Cheilomenes sexmaculata (Fabricius, 1781)	2.07 ± 0.50
Scymnus hoffmanni Weise, 1879[y]	1.84 ± 0.43
Lemnia biplagiata (Swartz, 1808)	0.32 ± 0.07
Harmonia octomaculata (Fabricius, 1781)	0.21 ± 0.04
Cryptogonus orbiculus (Gyllenhal, 1808)[y]	0.14 ± 0.04
Sasajiscymnus tainanensis (Ohta, 1929)[y]	0.13 ± 0.03
Sc. yangi Yu et Pang, 1993[y]	0.06 ± 0.02
Hensepilachna vigintioctopunctata (Fabricius, 1775)[y]	0.06 ± 0.02
Platynaspidius maculosus (Weise, 1910)[y]	0.05 ± 0.02
Coccinella transversalis Fabricius, 1781	0.04 ± 0.02
L. saucia (Mulsant, 1850)	0.03 ± 0.02
Sticholotis formosana Weise, 1923[y]	0.02 ± 0.01
Stethorus aptus Kapur, 1948[y]	0.02 ± 0.01
Sc. posticalis Sicard, 1912[y]	0.02 ± 0.02
Jauravia limbata Motschulsky, 1858[y]	0.02 ± 0.02
Sc. quadrillum Motschulsky, 1858	0.02 ± 0.01
Nephus tagiapatus (Kamiya, 1961)	0.01 ± 0.01
Olla v-nigrum (Mulsant, 1866)	0.01 ± 0.01
Coelophora inaequalis (Fabricius, 1775)[y]	0.01 ± 0.01
Cr. montrouzieri Mulsant, 1853	0.01 ± 0.01
Epilachna maxima (Weise, 1898)	0.01 ± 0.01
Amida tricolor formosana Kurisaki, 1920[y]	0.01 ± 0.01
Illeis koebelei Timberlake, 1943[y]	0.01 ± 0.01
Oenopia sauzeti Mulsant, 1866	0.01 ± 0.01
Oe. formosana (Miyatake, 1965)[y]	0.01 ± 0.01
E. hendecaspilota (Mader, 1927)	0.01 ± 0.01
Sa. fuscus (Yang, 1971)	0.01 ± 0.01

[z] This table presents the average number of lady beetles (Coccinellidae) captured in organic and conventional paddy fields from 2022 to 2024. Mean abundance = average number per trap per sampling event (see Methods for details).
[y] Indicates species occurring in both paddy fields and pomelo orchards.

(1.02 ± 0.18) were the two predominant species. In addition to the predatory taxa, one fungivorous species (*I. koebelei*) and two herbivorous species- *H. vigintioctopunctata* and *E. chinensis* (Weise, 1912)- were also recorded, though all occurred only occasionally at very low abundance (< 0.05 individuals trap^{-1} event^{-1}). The pomelo-orchard community exhibited a more pronounced predator-dominated pattern, with only occasional records of herbivorous and fungivorous species.

Across the two agricultural environments, 17 lady beetle species were shared between rice paddies and pomelo orchards: *M. discolor*, *P. japonica*, *Ch. sexmaculata*, *Sc. hoffmanni*, *Sc. yangi*, *Sc. posticalis* Sicard, 1912, *Sti. formosana*, *Stechorus aptus* Kapur, 1948, *Sa. tainanensis*, *Cr. orbiculus*, *I. koebelei*, *Amida tricolor formosana* Kurisaki, 1920, *Jauravia limbata* Motschulsky, 1858, *Platynaspidius maculosus* (Weise, 1910), *Coelophora inaequalis* (Fabricius,

Table 2. Lady beetle species and their mean abundance in pomelo orchards from 2022 to 2024 (ranked by abundance).

Scientific name	Mean abundance (mean ± *SE*)[z]
Scymnus yangi Yu et Pang, 1993[y]	1.18 ± 0.32
Sasajiscymnus tainanensis (Ohta, 1929)[y]	1.02 ± 0.18
Sticholotis formosana Weise, 1923[y]	0.51 ± 0.13
Cryptogonus orbiculus (Gyllenhal, 1808)[y]	0.33 ± 0.08
Axinoscymnus nigripennis Kamiya, 1965	0.22 ± 0.09
Sa. orbiculatus (Yang, 1971)	0.21 ± 0.09
Sc. centralis Kamiya, 1965	0.19 ± 0.07
Stethorus aptus Kapur, 1948[y]	0.19 ± 0.08
Cheilomenes sexmaculata (Fabricius, 1781)[y]	0.15 ± 0.05
Sa. parenthesis (Weise, 1923)	0.10 ± 0.03
Rodolia okinawensis Miyatake, 1959	0.08 ± 0.04
Propylea japonica (Thunberg, 1781)[y]	0.07 ± 0.03
Illeis koebelei Timberlake, 1943[y]	0.06 ± 0.02
Hensepilachna vigintioctopunctata (Fabricius, 1775)[y]	0.05 ± 0.02
Sc. hoffmanni Weise, 1879[y]	0.04 ± 0.03
St. loi Sasaji, 1968	0.03 ± 0.03
Micraspis discolor (Fabricius, 1798)[y]	0.03 ± 0.02
R. cardinalis (Mulsant, 1850)	0.03 ± 0.01
Platynaspidius quinquepunctatus Miyatake, 1961	0.02 ± 0.01
Amida tricolor formosana Kurisaki, 1920[y]	0.02 ± 0.01
Jauravia limbata Motschulsky, 1858[y]	0.02 ± 0.02
Nesolotis shirozui Sasaji, 1967	0.01 ± 0.01
Coelophora inaequalis (Fabricius, 1775)[y]	0.01 ± 0.01
Pl. maculosus (Weise, 1910)[y]	0.01 ± 0.01
Sc. posticalis Sicard, 1912[y]	0.01 ± 0.01
Oenopia formosana (Miyatake, 1965)[y]	0.01 ± 0.01
Sa. quinquepunctatus (Weise, 1923)	0.01 ± 0.01
St. hirashimai Sasaji, 1967	0.01 ± 0.01
Aspidimerus esakii Sasaji, 1968	0.01 ± 0.01
Cr. kurosawai Sasaji, 1968	0.01 ± 0.01
Epilachna chinensis (Weise, 1912)	0.01 ± 0.01

[z] Mean abundance = average number per trap per sampling event (see Methods for details).
[y] Indicates species occurring in both paddy fields and pomelo orchards.

1775), *Oenopia formosana* (Miyatake, 1965), and *H. vigintioctopunctata*. In contrast, several species were recorded exclusively in one habitat type, such as *A. nigripennis* and *Nesolotis shirozui* Sasaji, 1967 in pomelo orchards, and *L. biplagiata* and *Harmonia octomaculata* (Fabricius, 1781) in rice fields. The occurrence of both shared and habitat-specific species indicates distinct species assemblages between annual (paddy) and perennial (orchard) systems.

Dominant species in rice fields (Table 3). Organic management in rice fields significantly altered the composition of the lady beetle community. *M. discolor* showed a 2.2-fold higher abundance in organic (OC) rice fields compared with conventional (CC) fields (19.50 ± 2.54 vs. 8.90 ± 1.36 individuals trap^{-1} event^{-1}), corresponding to a 119% increase relative to CC fields. This single species accounted for approximately 75% of the total lady beetle abundance in organic rice systems, indicating a strongly dominance-driven community structure. In contrast, *Ch. sexmaculata* showed slightly higher abundance in conventional fields (2.88 ± 0.96 vs. 1.27 ± 0.23), though this difference was not statistically significant (P = 0.213).

Dominant species in pomelo (Table 4). In pomelo orchards, all five major predatory species-*Sc. yangi*, *Sa. tainanensis*, *Sti. formosana*, *Cr. orbiculus*, and *A. nigripennis*- were significantly more abundant in organically managed (OC) than in conventionally managed (CC) orchards (5 of 5 species; 100% significant; all P < 0.001). Among these, *Sc. yangi* and *Sa. tainanensis* were the most dominant, with mean abundances of 2.32 ± 0.62 and 1.76 ± 0.32 individuals trap^{-1} event^{-1} in OC orchards, respectively, compared with < 0.3 in CC orchards. The co-dominance of these two species and the consistent presence of other predators indicate a more even and stable assemblage structure under organic management. In contrast, CC orchards exhibited a highly uneven community composition, characterized by the near absence of these dominant predators.

Event-level (In this analysis, each "event" corresponds to one standardized sampling occasion (every two months), representing temporal variation across crop stages and across years.) Comparisons between organic (OC) and conventional (CC) management (Table 5) revealed clear differences in community stability and diversity. Across all sites, OC fields exhibited higher Shannon diversity (H': = 0.763 ± 0.042 vs. 0.490 ± 0.042; U = 16,974.5, P <

Table 3. Analysis of dominant lady beetle species under organic (OC) and conventional (CC) management in rice fields.

Scientific name	Mean abundance (mean ± SE) OC	CC	U statistic	P-value[z]
Micraspis discolor (Fabricius, 1798)	19.50 ± 2.54**	8.90 ± 1.36	5,471.5	< 0.0001
Propylea japonica (Thunberg, 1781)	2.48 ± 0.34	2.89 ± 0.68	4,257.0	0.5431
Cheilomenes sexmaculata (Fabricius, 1781)	1.27 ± 0.23	2.88 ± 0.96	3,649.5	0.2134
Scymnus hoffmanni Weise, 1879	1.72 ± 0.64	1.96 ± 0.56	3,775.0	0.3554
Lemnia biplagiata (Swartz, 1808)	0.27 ± 0.09	0.37 ± 0.10	3,863.5	0.4118

[z] Mann-Whitney U test was used to compare the mean number of lady beetles between organic and conventional treatments. Mean abundance = average number per trap per sampling event (see Methods for details).
*Significance codes: *P < 0.05, **P < 0.01. Values with different superscript letters differ significantly between management types.

Table 4. Analysis of dominant lady beetle species under organic (OC) and conventional (CC) management in pomelo orchards.

Scientific name	Mean abundance (mean ± SE) OC	CC	U statistic	P-value[z]
Scymnus yangi Yu et Pang, 1993	2.32 ± 0.62**	0.04 ± 0.02	3,628.50	< 0.0001
Sasajiscymnus tainanensis (Ohta, 1929)	1.76 ± 0.32**	0.28 ± 0.12	3,755.50	< 0.0001
Sticholotis formosana Weise, 1923	1.00 ± 0.26**	0.01 ± 0.01	3,858.50	< 0.0001
Cryptogonus orbiculus (Gyllenhal, 1808)	0.64 ± 0.14**	0.03 ± 0.02	3,396.00	< 0.0001
Axinoscymnus nigripennis Kamiya, 1965	0.44 ± 0.17**	0.00 ± 0.00	3,024.00	0.0003

[z] Mann-Whitney U test was used to compare the mean number of lady beetles between organic and conventional treatments. Mean abundance = average number per trap per sampling event (see Methods for details).
*Significance codes: *P < 0.05, **P < 0.01. Values with different superscripts differ significantly across management types.

Table 5. Comparison of coefficients of variation (CV) and Mann-Whitney *U* test results for three stability indicators of lady beetle populations between organic (OC) and conventional (CC) management.

	Mean Shannon (*SE*)				CV (*SE*)	
Stability indicator/sampling category	OC	CC	*U* statistic	*P*-value[z] (Cohen's *d*)	OC	CC
Shannon diversity index, (*H'*)						
Overall	0.763** (0.042)	0.490 (0.042)	16,974.5	< 0.0001 (0.51)	0.697 (0.054)	1.089 (0.111)
Rice fields	0.665* (0.049)	0.814 (0.051)	3,358.5	0.0475 (-0.32)	0.704 (0.074)	0.591 (0.057)
Pomelo orchards	0.886** (0.069)	0.085 (0.028)	4,455.5	< 0.0001 (1.79)	0.657 (0.075)	2.799 (0.952)
Total lady beetle abundance (*N*)						
Overall	18.250** (1.850)	10.300 (1.430)	17,850.5	< 0.0001 (0.38)	1.287 (0.148)	1.770 (0.265)
Rice fields	26.010* (2.930)	17.930 (2.280)	4,920.0	0.0126 (0.40)	1.069 (0.144)	1.204 (0.177)
Pomelo orchards	8.560** (1.240)	0.750 (0.180)	4,691.5	< 0.0001 (1.14)	1.232 (0.206)	2.084 (0.541)
Berger-Parker dominance index (*d*)						
Overall	12.930** (1.550)	6.680 (0.980)	17,701.5	< 0.0001 (0.29)	1.526 (0.202)	1.869 (0.293)
Rice fields	19.860* (2.520)	11.540 (1.590)	5,131.0	0.0020 (0.44)	1.204 (0.177)	1.304 (0.204)
Pomelo orchards	4.260** (0.630)	0.600 (0.150)	4,579.0	< 0.0001 (0.94)	1.246 (0.210)	2.115 (0.556)

[z] Mann-Whitney *U* test was used to compare the mean number of lady beetles between organic and conventional treatments. Effect sizes (Cohen's *d*) were calculated as the difference between means divided by the pooled standard deviation to complement *P*-values (Cohen 1988). Values of d ≈ 0.2, 0.5, and 0.8 correspond to small, medium, and large effects, respectively. Positive values of Cohen's *d* indicate higher means in organic (OC) fields, whereas negative values indicate higher means in conventional (CC) fields.

[*] Significance codes: $^{*}P < 0.05$, $^{**}P < 0.01$. Values with different superscripts differ significantly across management types.

0.0001, Cohen's $d = 0.51$ – medium effect) and greater total abundance (18.25 ± 1.85 vs. 10.30 ± 1.43; $U = 17{,}850.5$, $P < 0.0001$, $d = 0.38$ – small-to-medium effect). In rice fields, diversity was slightly higher in CC plots (H': = 0.814 ± 0.051 vs. 0.665 ± 0.049; $U = 3{,}358.5$, $P = 0.0475$, $d = -0.32$ – small negative effect), suggesting limited sensitivity of the rice assemblage to organic management. In contrast, pomelo orchards showed a pronounced positive response, with OC fields having markedly greater Shannon diversity (H': = 0.886 ± 0.069 vs. 0.085 ± 0.028; $U = 4{,}455.5$, $P < 0.0001$, $d = 1.79$ – large effect) and abundance (8.56 ± 1.24 vs. 0.75 ± 0.18; $d = 1.14$). To improve interpretability, significant contrasts between organic and conventional management shown in Tables 3–5 were also visualized in supplementary bar charts (Supplementary Figs. 1 and 2).

Coefficients of variation (CV) corroborated these patterns: OC fields, particularly in pomelo orchards, exhibited lower temporal variability (Overall: 0.697 vs. 1.089; Pomelo: 0.657 vs. 2.799), indicating greater population stability under organic management. Overall, both statistical significance and effect-size strength confirm that organic management enhances coccinellid diversity and stability, especially in perennial orchard systems.

DISCUSSION

Species composition and cross-system patterns

This study revealed a diverse assemblage of lady beetles across both rice and pomelo systems within the indigenous agricultural landscapes of Hualien. Seventeen species were shared between the two systems, including generalist predators such as *Ch. sexmaculata* (Fabricius, 1781) and *M. discolor* (Fabricius, 1798), reflecting broad ecological tolerance and cross-habitat persistence among predatory taxa. Consistent with the data in Tables 1 and 2, these traditional farmlands supported a predominantly predatory coccinellid community, underscoring the ecological integrity maintained under low-intensity, community-based management.

Comparative evidence from tropical Asia shows partially overlapping species composition with that of Taiwan's indigenous agroecosystems. In India's organic vegetable farms, *Coccinella transversalis* Fabricius, 1781, *Ch. sexmaculata*, *H. octomaculata* (Fabricius, 1781), and *M. discolor* dominate under low-input management (Rajan *et al.* 2019), suggesting that tropical Asian systems share a core guild of generalist predators adapted to reduced-chemical environments. In contrast, temperate and Neotropical regions exhibit distinct predator assemblages- *Coccinella septempunctata* Linnaeus, 1758, *Tytthaspis sedecimpunctata* Linnaeus, 1758, and *Scymnus* spp. in Ukraine (Grabovska *et al.* 2021) and *Rodolia cardinalis* (Mulsant, 1850) in Brazilian citrus orchards (de Paula Malheiros *et al.* 2025). The exclusive occurrence of *R. cardinalis* in our pomelo orchards reinforces its citrus specialization. Together, these regional contrasts illustrate how both shared and habitat-specific predators shape the broader ecological mosaic of indigenous farmlands.

Ecological differentiation and resilience

The coexistence of shared and habitat-specific lady beetles reflects distinct ecological filters between annual and perennial systems. Shared taxa such as *Ch. sexmaculata* and *M. discolor* demonstrate cross-habitat persistence, while orchard- or paddy-restricted species likely represent localized adaptation or prey specialization. This differentiation aligns with studies showing that diversified or perennial habitats promote predator persistence and ecological stability (Symondson *et al.* 2002; Crowder *et al.* 2010; Tscharntke *et al.* 2012; Porcel *et al.* 2018). Collectively, generalists ensure continuity across habitats, whereas specialists sustain localized stability- together enhancing the resilience of indigenous farming landscapes.

Global parallels and habitat complexity

Similar biodiversity patterns have been widely reported in organic systems worldwide, where reduced pesticide use and diversified vegetation promote higher predator abundance and community stability (Porcel *et al.* 2018; Grabovska *et al.* 2021; de Paula Malheiros *et al.* 2025). Studies from Asia and other subtropical regions, which enhance natural pest regulation (Chouangthavy *et al.* 2021; Chouangthavy & Fourcade 2024). These parallels suggest that the indigenous farmlands of eastern Taiwan functionally resemble mature organic systems in other tropical regions, despite their smaller scale and community-based management.

This pattern accords with the "habitat complexity-stability" relationship in landscape ecology. Perennial orchards- with their greater structural complexity and year-round continuity- provide more favorable habitats for natural enemies than short-cycle rice fields (Tscharntke *et al.* 2012; Rada *et al.* 2023). Structural and temporal heterogeneity within these indigenous farmlands thus enhances predator stability and reinforces ecological resilience under low-input management.

Biogeographic distinctiveness and endemic diversity

The limited overlap with temperate or Neotropical systems underscores the biogeographic uniqueness of Taiwan's indigenous farmlands. Situated at the subtropical–tropical transition, these landscapes host both Oriental and island-endemic predator lineages such as *Sc. yangi* Yu et Pang, 1993, *Sa. tainanensis* (Ohta, 1929), and *A. nigripennis* Kamiya, 1965- taxa seldom recorded elsewhere. Their coexistence with cosmopolitan species, such as *Ch. sexmaculata* and *M. discolor*, forms a mosaic community that integrates local adaptation and broad ecological tolerance. This pattern reflects the heterogeneous, low-intensity management characteristic of indigenous farming (Yen & Chen 2014; Ba *et al.* 2023), positioning these systems as valuable references for understanding predator persistence and trophic stability in traditional agroecosystems.

Functional mechanisms and stability patterns

The functional mechanisms underlying these assemblages have been elucidated through stable-isotope and diet-based studies in Taiwanese rice systems. Hsu *et al.* (2021) demonstrated that generalist predators shift trophic niches seasonally, consuming more herbivorous prey in conventional fields where pest densities are higher. Landscape complexity further enhances predator abundance and prey availability (Ali *et al.* 2020; Saqib *et al.* 2022). These findings indicate that heterogeneous, low-disturbance landscapes typical of indigenous areas facilitate predator persistence and flexible foraging that track pest pulses, thereby enhancing biodiversity-based pest regulation.

Within this trophic framework, *M. discolor* consistently emerged as a keystone predator maintaining pest suppression under fluctuating prey conditions (Shanker *et al.* 2013; Poorani *et al.* 2023; Chouangthavy & Fourcade 2024). Beyond *M. discolor*, other predatory coccinellids also responded positively to organic management, contributing complementary roles in stability and resilience (Letourneau *et al.* 2011; Porcel *et al.* 2018; Grabovska *et al.* 2021; Rada *et al.* 2023). In perennial pomelo orchards, *Sc. yangi*, *Sa. tainanensis*, and *A. nigripennis* were closely associated with pesticide-free, structurally complex habitats, serving as reliable indicators of reduced-chemical environments. Together, these results demonstrate that resilience in indigenous agroecosystems is achieved through dual stability mechanisms- dominance-driven in annual rice systems and diversity-driven in perennial orchards.

Community stability

Quantitative stability indices (Table 5) revealed that organic management generally enhanced lady beetle stability, particularly in orchard systems. In contrast, rice fields exhibited lower diversity under organic management due to the dominance of *M. discolor*. While such dominance reduces evenness, it ensures strong pest control- a trade-off widely observed in tropical agroecosystems (Shanker *et al.* 2013; Grabovska *et al.* 2021; Rada *et al.* 2023).

Previous studies have shown that predatory lady beetles adjust their diets according to prey availability and crop phenology. Hsu *et al.* (2025) reported that predator foraging behavior in rice fields shifts substantially across growth stages, with broader prey use in organic systems due to higher habitat heterogeneity and alternative prey sources. Such seasonal and habitat-mediated flexibility likely also operates in our indigenous agricultural systems.

Seasonal peaks in herbivore availability during the flowering-maturation stages likely shape the foraging dynamics of predatory lady beetles in both rice and orchard systems. Meanwhile, surrounding semi-natural habitats within indigenous agricultural landscapes provide alternative prey and microhabitats that buffer population fluctuations and promote trophic resilience. These landscape-level features may explain why organic orchard systems showed high temporal stability, whereas organic rice fields were more strongly affected by single-species dominance.

Dominant predator function and trophic stability

Across management regimes, *M. discolor* demonstrated consistent functional stability, preying heavily on rice herbivores throughout ripening (Hsu *et al.* 2025). This persistent prey specialization underlines its role as a dominant "pest specialist" capable of sustaining top-down control even when community diversity is reduced. Such dominance-based stability mechanisms are well documented in other low-input systems (Chouangthavy *et al.* 2021; Grabovska *et al.* 2021). Collectively, these findings emphasize that community-level trophic flexibility and the persistence of efficient predator species together ensure reliable pest suppression in indigenous and organic rice ecosystems.

In addition, all survey sites were located within indigenous agricultural landscapes of eastern Taiwan, where forest cover, landscape heterogeneity, and traditional low-input farming practices contribute to substantially lower anthropogenic disturbance compared with Taiwan's highly intensified western plains (Chen *et al.* 2021). Such regional contrasts are ecologically meaningful. International syntheses show that biodiversity responses to organic management are strongly context-dependent: organic systems yield larger gains in structurally complex, low-disturbance landscapes than in simplified high-intensity regions (Tuck *et al.* 2014). Likewise, landscape-level disturbance filters strongly influence natural-enemy diversity and trophic stability across agricultural ecosystems (Tscharntke *et al.* 2005). Our findings align with this landscape-context framework. The strong predator stability observed in organic orchards and the dominance-driven patterns in organic rice fields likely reflect interactions between farming practice and the unique low-disturbance setting of indigenous territories.

Ecological intensification and landscape moderation frameworks

The observed dynamics closely correspond to the "ecological intensification" and "landscape moderation" frameworks (Crowder *et al.* 2010; Tscharntke *et al.* 2012). The former proposes that enhanced on-farm biodiversity can substitute for chemical inputs to sustain yields and stability, while the latter predicts that organic benefits are strongest in heterogeneous landscapes and weaker in simplified ones (Bengtsson *et al.* 2005; Batáry *et al.* 2011). Perennial pomelo orchards exemplify ecological intensification through long-term organic management and vegetation complexity, whereas short-cycle rice systems align with the landscape moderation hypothesis, showing weaker diversity responses. Together, these frameworks explain how biodiversity outcomes are jointly shaped by local management and surrounding landscape context.

Indicator species and certification perspectives

Several predatory coccinellids- *Sc. yangi*, *Sa. tainanensis*, *Sti. formosana* Weise, 1923, *Cr. orbiculus* (Gyllenhal, 1808), *A. nigripennis*, and *M. discolor*- show strong affinity to organic systems, suggesting their potential as bioindicators of ecological integrity. Rather than relying on a single species, a multi-species indicator framework would provide a more accurate reflection of functional resilience. Similar models elsewhere show that organic and low-input farms sustain higher predator diversity and more stable community dynamics (Porcel *et al.* 2018; Grabovska *et al.* 2021; Rada *et al.* 2023). Inspired by Finland's "Ladybird Label," a locally adapted certification system could highlight native beetles- *A. nigripennis* for orchards and *M. discolor* for rice- to communicate biodiversity outcomes and strengthen consumer trust. Integrating scientific and cultural symbols would reinforce both ecological branding and the socio-economic sustainability of indigenous organic agriculture.

Future research and management implications

Variability in rice fields indicates that the benefits of organic management are context-dependent, influenced by crop type, local environment, and surrounding landscape configuration (Bengtsson *et al.* 2005; Batáry *et al.* 2011). Future studies should integrate long-term monitoring, functional trait analyses, and landscape-scale approaches to clarify these interactions. Such integrative research will strengthen evidence-based strategies that guide organic transitions and promote biodiversity-friendly management in Taiwan's indigenous agricultural landscapes.

CONCLUSIONS

This study provides the first multi-year documentation of lady beetle assemblages within indigenous farming systems of eastern Taiwan, recording 29 species in rice paddies and 31 in pomelo orchards from 2022 to 2024. Organic management generally supported higher species richness, abundance, and population stability-particularly in perennial orchard systems. In organically managed pomelo orchards, several dominant species, including *Sc. yangi* Yu et Pang, 1993, and *A. nigripennis* Kamiya, 1965, showed significantly higher or exclusive occurrence, underscoring the ecological benefits of reduced-chemical practices. In rice paddies, *M. discolor* (Fabricius, 1798) emerged as a consistently dominant and stable predator, emphasizing its role as a key biocontrol agent in low-pesticide rice ecosystems.

The integration of diversity and stability indicators demonstrates the value of lady beetles as bioindicators for agroecological assessment. Moreover, these findings provide a robust baseline for developing eco-labeling or certification strategies grounded in native biodiversity, thereby enhancing both the visibility and economic viability of organic produce from indigenous communities.

However, the effects of organic farming were not uniform across crop types. The slightly lower diversity observed in organically managed rice fields suggests that local landscape context, habitat structure, and ecological infrastructure modulate biodiversity outcomes. Future research should therefore integrate landscape-scale, trait-based approaches to elucidate predator–prey dynamics more and support evidence-based policy design for sustainable, biodiversity-friendly agriculture in Taiwan's indigenous regions.

ACKNOWLEDGMENTS

This study was financially supported by the Ministry of Agriculture, Taiwan, under the Scientific Research Projects 114-AgriSci-9.2.3-Bio-01 and 114-AgriSci-4.4.2-Agri-02. The authors sincerely thank the Ministry for its generous support.

REFERENCES

Ali, M. P., M. M. M. Kabir, S. S. Haque, S. Afrin, N. Ahmed, B. Pittendrigh, and X. Qin. 2020. Surrounding landscape influences the abundance of insect predators in rice field. BMC Zool. 5:8. doi:10.1186/s40850-020-00059-1

Ba, Q. X., H. Z. Wang, and M. H. Wang. 2023. Agrobiodiversity, social institutions, and indigenous farming practices: A case study of the Rukai in Wutai, Taiwan. Hum. Ecol. 51:1127–1140. doi:10.1007/s10745-023-00463-4

Batáry, P., A. Báldi, D. Kleijn, and T. Tscharntke. 2011. Landscape-moderated biodiversity effects of agri-environmental management: A meta-analysis. Proc. Biol. Sci. B 278:1894–1902. doi:10.1098/rspb.2010.1923

Bengtsson, J., J. Ahnström, and A. C. Weibull. 2005. The effects of organic agriculture on biodiversity and abundance: A meta-analysis. J. Appl. Ecol. 42:261–269. doi:10.1111/j.1365-2664.2005.01005.x

Berger, W. H. and F. L. Parker. 1970. Diversity of planktonic foraminifera in deep-sea sediments. Science 168:1345–1347. doi:10.1126/science.168.3937.1345

Catalogue of Life in Taiwan (TaiCOL). 2025. Coccinellidae. https://taicol.tw/zh-hant/taxon/t0005668 (visit on 11/9/2025) (in Chinese)

Chen, K. L., W. H. Kong, C. C. Chen, and J. L. Liou. 2021. Evaluating benefits of eco-agriculture: The cases of farms along Taiwan's East Coast in Yilan and Hualien. Sustainability 13:10889. doi:10.3390/su131910889

Chouangthavy, B. and Y. Fourcade. 2024. Organic farming drives higher diversity of beetles, with more predators and less pests. Research Square. doi:10.21203/rs.3.rs-4586391/v1

Chouangthavy, B., S. Sanguansub, and A. Das. 2021. Sustainable organic farming supports diversity of Coleopteran beetles as a good indicator taxon: A case study from central Lao PDR. Org. Agric. 11:615–624. doi:10.1007/s13165-021-00367-x

Cohen, J. 1988. Statistical Power Analysis for the Behavioral Sciences. 2nd ed. Routledge. New York, NY. 567 pp. doi:10.4324/9780203771587

Crowder, D. W., T. D. Northfield, M. R. Strand, and W. E. Snyder. 2010. Organic agriculture promotes evenness and natural pest control. Nature 466:109–112. doi:10.1038/nature09183

de Paula Malheiros, K., M. V. de Oliveira Santana, C. H. Marchiori, and É. M. de Melo. 2025. The importance of ladybugs (Coleoptera: Coccinellidae) for agriculture and biodiversity in Brazil. Middle East Res. J. Microbiol. Biotechnol. 5:15–25. doi:10.36348/merjmb.2025.v05i01.003

Dong, Y. J., W. H. Yang, P. C. Hsu, C. F. Lee, M. J. Tseng, J. Y. Chang, … H. T. Shih. 2023. Differences in lady beetle species composition between conventional and organic farming environments in Taiwan. J. Taiwan Agric. Res. 72:343–358. (in Chinese with English abstract) doi:10.6156/JTAR.202312_72(4).0005

Garnett, S. T., N. D. Burgess, J. E. Fa, Á. Fernández-Llamazares, Z. Molnár, C. J. Robinson, … I. Leiper. 2018. A spatial overview of the global importance of indigenous lands for conservation. Nat. Sustain. 1:369–374. doi:10.1038/s41893-018-0100-6

Giorgi, J. A., N. J. Vandenberg, J. V. McHugh, J. A. Forrester, S. A. Ślipiński, K. B. Miller, … M. F. Whiting. 2009. The evolution of food preferences in Coccinellidae. Biol. Control 51:215–231. doi:10.1016/j.biocontrol.2009.05.019

Grabovska, T., M. Jelínek, and V. Shevchenko. 2021. Effect of organic farming on the ladybird beetle diversity (Coleoptera: Coccinellidae). Agrobiologiâ 1:188–197. doi:10.33245/2310-9270-2021-163-1-188-197

Hsu G. C., J. A. Ou, and C. K. Ho. 2021. Pest consumption by generalist arthropod predators increases with crop stage in both organic and conventional farms. Ecosphere 12:e03625. doi:10.1002/ecs2.3625

Hsu, G. C., J. A. Ou, M. H. Ni, Z. H. Lin, and C. K. Ho. 2025. Generalist predators function as pest specialists: Examining diet composition of spiders and ladybeetles across rice crop stages. J. Appl. Ecol. 62:1889–1901. doi:10.1111/1365-2664.70066

Koch, R. L. 2003. The multicolored Asian lady beetle, *Harmonia axyridis*: A review of its biology, uses in biological control, and non-target impacts. J. Insect Sci. 3:32. doi:10.1093/jis/3.1.32

Kundoo, A. A. and A. A. Khan. 2017. Coccinellids as biological control agents of soft bodied insects: A review. J. Entomol. Zool. Stud. 5:1362–1373.

Letourneau, D. K., I. Armbrecht, B. S. Rivera, J. M. Lerma, E. J. Carmona, M. C. Daza, … A. R. Trujillo. 2011. Does plant diversity benefit agroecosystems? A synthetic review. Ecol. Appl. 21:9–21. doi:10.1890/09-2026.1

Lin, C. M., C. L. Chen, C. M. Tseng, and H. J. Liu. 2024. Discussion on the key success factors of organic operators- A case study of the aboriginal farmers in Hualien area. Bull. Hualien DARES. 42:55–67. (in Chinese with English abstract)

Magurran, A. E. 2004. Measuring Biological Diversity. Blackwell Science. Oxford, UK. 256 pp.

Megha, R. R., A. S. Vastrad, B. C. Kamanna, and N. S. Kulkarni. 2015. Species complex of coccinellids in different crops at Dharwad region. J. Exp. Zool. India 18:931–935.

Obrycki, J. J. and T. J. Kring. 1998. Predaceous Coccinellidae in biological control. Annu. Rev. Entomol. 43:295–321. doi:10.1146/annurev.ento.43.1.295

Patil, P. B. and S. M. Gaikwad. 2019. Diversity and association of ladybird beetles with the agricultural crops. J. Emerg. Technol. Innov. Res. 6:457–459.

Pervez, A., Omkar, and M. M. Harsur. 2020. Coccinellids on crops: Nature's gift for farmers. p.429–460. *in*: Innovative Pest Management Approaches for the 21st Century: Harnessing Automated Unmanned Technologies. (Chakravarthy, A. K. ed.) Springer. Singapore. 519 pp. doi:10.1007/978-981-15-0794-6_21

Poorani, J., R. G. Booth, C. Anuradha, R. G. Gracy, R. Thanigairaj, and R. S. Swathi. 2023. Identity of the 'true' *Micraspis discolor* (Fabricius) (Coleoptera, Coccinellidae) with illustrated diagnostic notes on other *Micraspis* spp. in Indian paddy fields. Zootaxa 5271:446–476. doi:10.11646/zootaxa.5271.3.2

Porcel, M., G. K. S. Andersson, J. Pålsson, and M. Tasin. 2018. Organic management in apple orchards: Higher impacts on biological control than on pollination. J. Appl. Ecol. 55:2779–2789. doi:10.1111/1365-2664.13247

Rada, P., P. Bogusch, P. Pech, J. Pavlíček, J. Rom, and J. Horák. 2023. Active management of urban fruit orchard meadows is important for insect diversity. Ecol. Eng. 186:106833. doi:10.1016/j.ecoleng.2022.106833

Rajan, J. S., S. E. Latha, K. S. Madhuri, R. Vijayaraghavendra, and C. H. S. Rao. 2019. Predatory coccinellids diversity in organic vegetable farming systems: Conservation and mass production. J. Entomol. Zool. Stud. 7:1148–1151.

Saqib, H. S. A., L. Sun, G. Pozsgai, P. Liang, M. You, G. M. Gurr, and S. You. 2022. DNA metabarcoding of gut contents reveals key habitat and seasonal drivers of trophic networks involving generalist predators in agricultural landscapes. Pest Manag. Sci. 78:5390–5401. doi:10.1002/ps.7161

Seago, A. E., J. A. Giorgi, J. Li, and A. Ślipiński. 2011. Phylogeny, classification and evolution of ladybird beetles (Coleoptera: Coccinellidae) based on simultaneous analysis of molecular and morphological data. Mol. Phylogenet. Evol. 60:137–151. doi:10.1016/j.ympev.2011.03.015

Shanker, C., L. Chintagunta, S. Muthusamy, S. Vailla, A. Srinivasan, and G. Katti. 2018. Flora surrounding rice fields as a source of alternative prey for coccinellids feeding on the pests of rice. Eur. J. Entomol. 115:364–371. doi:10.14411/eje.2018.036

Shanker, C., M. Mohan, M. Sampathkumar, C. Lydia, and G. Gatti. 2013. Functional significance of *Micraspis discolor* (F.) (Coccinellidae: Coleoptera) in rice ecosystem. J. Appl. Entomol. 137:601–609. doi:10.1111/jen.12035

Symondson, W. O. C., K. D. Sunderland, and M. H. Greenstone. 2002. Can generalist predators be effective biocontrol agents? Annu. Rev. Entomol. 47:561–594. doi:10.1146/annurev.ento.47.091201.145240

Tilman, D. 1999. The ecological consequences of changes in biodiversity: A search for general principles. Ecology 80:1455–1474. doi:10.1890/0012-9658(1999)080[1455:TECOCI]2.0.CO;2

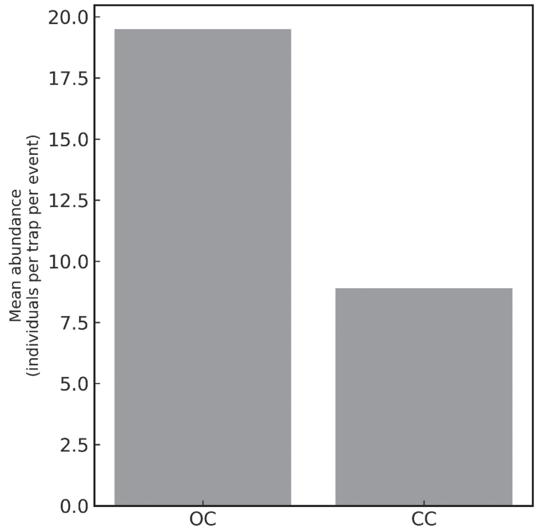
Tscharntke, T., A. M. Klein, A. Kruess, I. Steffan-DewenterI, and C. Thies. 2005. Landscape perspectives on agricultural intensification and biodiversity- Ecosystem service management. Ecol. Lett. 8:857–874. doi:10.1111/j.1461-0248.2005.00782.x

Tscharntke, T., J. M. Tylianakis, T. A. Rand, R. K. Didham, L. Fahrig, P. Batáry, … C. Westphal. 2012. Landscape moderation of biodiversity patterns and processes- Eight hypotheses. Biol. Rev. 87:661–685. doi:10.1111/j.1469-185X.2011.00216.x

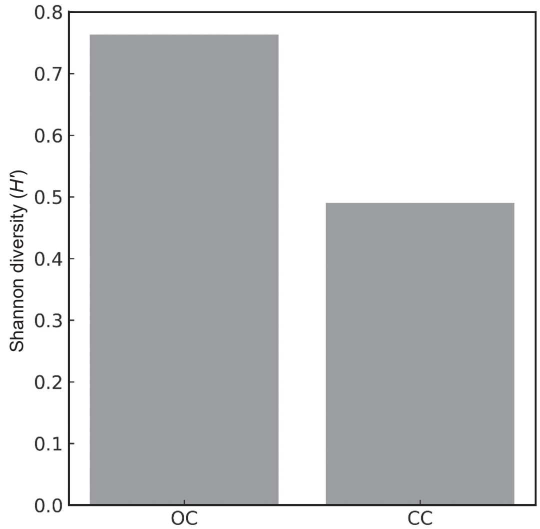
Tuck, S. L., C. Winqvist, F. Mota, J. Ahnström, L. A. Turnbull, and J. Bengtsson. 2014. Land-use intensity and the effects of organic farming on biodiversity: A hierarchical meta-analysis. J. Appl. Ecol. 51:746–755. doi:10.1111/1365-2664.12219

Yen, A. C. and Y. A. Chen. 2014. Sustainable agriculture and indigenous community development: Some experiences in Taiwan. Intl. J. Soc. Sustain. Econ. Soc. Cult. Context 93:85–105. doi:10.18848/2325-1115/CGP/v09i03/55240

Yen, A. C. and Y. A. Chen. 2022. The dilemmas and opportunities for indigenous people in promoting natural farming: A case study of the Tayal Ethnic Group in Jianshi, Taiwan. Taiwan J. Anthrop. 20(2):23–78. (in Chinese with English abstract)



Supplementary Fig. 1. Mean abundance of *Micraspis discolor* (Fabricius, 1798) in organic (OC) and conventional (CC) rice fields during 2022–2024. Bars show the mean number of individuals per trap per sampling event. Values correspond to statistical comparisons presented in Table 3.



Supplementary Fig. 2. Shannon diversity index (H') of lady beetle communities in organic (OC) and conventional (CC) agricultural fields during 2022–2024. Bars represent mean diversity values per sampling event. Statistical results are reported in Table 5.

東臺灣原住民農業系統中有機與慣行農法對天敵瓢蟲群聚組成與穩定性的影響

董耀仁[1] 許北辰[1,*] 李奇峯[2] 曾美容[3] 石憲宗[4]

摘要

董耀仁、許北辰、李奇峯、曾美容、石憲宗。2026。東臺灣原住民農業系統中有機與慣行農法對天敵瓢蟲群聚組成與穩定性的影響。台灣農業研究 75(2):231–247。

本研究旨在盤點花蓮地區原住民農耕系統中之瓢蟲資源，並評估不同農法對其群聚組成與年際穩定性的影響。2022–2024 年間，於玉里鎮織羅部落之有機 (organic; OC) 與慣行 (conventional; CC) 水稻田，以及瑞穗鄉屋拉力部落之文旦果園進行田野調查，採用黃色黏蟲紙進行瓢蟲標本收集。結果於水稻田共記錄 29 種瓢蟲，以橙瓢蟲 (*Micraspis discolor* (Fabricius, 1798)) 為優勢種；果園則記錄 31 種，以內囊小瓢蟲 (*Scymnus yangi* Yu et Pang, 1993) 與臺南方瓢蟲 (*Sasajiscymnus tainanensis* (Ohta, 1929)) 為優勢種。研究採用 Shannon 多樣性指數 (H') 衡量群聚多樣性、Berger-Parker 優勢度指數 (d) 評估優勢物種比例，以及變異係數 (coefficient of variation; CV) 評估族群穩定性，並以 Mann-Whitney U 檢定比較不同農法間指標之差異 (顯著水準 $P < 0.05$)。結果顯示，在文旦果園中，有機農法顯著提升瓢蟲族群之總數量、多樣性及穩定性；而在水稻田中，有機田區之多樣性未呈現穩定優勢，可能與地區環境條件或周邊土地利用差異有關，仍需進一步探討。整體而言，有機管理在多年生果園系統中有助於提升瓢蟲族群之穩定性與多樣性；但於一年生作物系統 (如水稻) 中的效果則可能因地制宜而異。本研究為首度系統性調查花蓮原鄉農地瓢蟲群聚組成，提供生物防治策略與東部永續農業政策擬定之基礎資料。

關鍵詞：原住民農田、有機農法、慣行農法、天敵瓢蟲、多樣性與穩定性。

投稿日期：2025 年 8 月 15 日；接受日期：2026 年 1 月 28 日。
[*] 通訊作者：bchen@tari.gov.tw
[1] 農業部農業試驗所應用動物組副研究員。臺灣 臺中市。
[2] 農業部農業試驗所應用動物組聘用研究員。臺灣 臺中市。
[3] 農業部農業試驗所應用動物組計畫助理。臺灣 臺中市。
[4] 農業部農業試驗所應用動物組研究員兼組長。臺灣 臺中市。