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Comparative analysis of ladybird beetle (Coleoptera: Coccinellidae) diversity and abundance across cropland and non-cropland agroecosystems in Madurai, Tamil Nadu, India

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Abstract

Ladybird beetles (Coleoptera: Coccinellidae) are important biocontrol agents in agroecosystem. This study evaluated species diversity, abundance, seasonal dynamics, and functional roles of coccinellid across cropland and non-cropland habitats in Madurai, Tamil Nadu, from August 2024 to March 2025. Using the All-out search method, a total of 478 individuals representing 10 species, 9 genera and 3 subfamilies were recorded. The subfamily Coccinellinae was the most dominant, contributing 8 species. Cropland habitats supported higher diversity and abundance (441 individuals, 10 species) compared to non-cropland areas (37 individuals, 4 species). Among the crops surveyed, brinjal harboured the highest diversity of ladybird beetles, with 120 individuals representing 10 species, followed by cowpea (93 individuals, 9 species) and cotton (89 individuals, 9 species). Predatory species such as *Cheilomenes sexmaculata*, *Coccinella septempunctata*, *Micraspis discolor*, and *Scymnus coccivora* were dominant in croplands, whereas the herbivorous/epilachnine species *Afidentula bisquadripunctata* predominated in non-cropland areas. Ecological indices were significantly higher in croplands (H': 0.931, D_{mg}: 0.492, J': 1.631) compared to non-croplands (H': 0.226, D_{mg}: 0.169, J': 0.417). Functional guild analysis indicated that the assemblage was dominated by predatory species, along with phytophagous and mycophagous groups, highlighting their ecological complexity. Based on these observations, this study demonstrates that crop diversity, habitat structure, and seasonal factors strongly influence coccinellid assemblages, with crops such as brinjal, cowpea, and cotton supporting greater coccinellid populations than other crop fields and non-crop habitats. The findings emphasize the importance of conserving crop-associated habitats and minimizing insecticide use to sustain ladybird beetles and other beneficial insects, thereby enhancing natural pest control in agricultural ecosystems.

Introduction

The family Coccinellidae (Order: Coleoptera) comprises approximately 6,000 species worldwide and plays a crucial role in biological pest control. In India, coccinellid fauna is remarkably diverse, with current checklists documenting between 400 and 520 species across 79 genera and 6 subfamilies (Poorani 2023, 2024). Approximately 90% of coccinellids are predatory, providing essential ecosystem services by regulating populations of soft-bodied pests such as aphids, whiteflies, mealybugs etc (Poorani 2002a,b; Sloggett and Zeilstra 2020). In addition to pest suppression, these beetles serve as sensitive bio-indicators, as their population dynamics often reflect the health and stability of ecosystems (Poorani 2002a).

The diversity of predaceous coccinellids has been extensively documented across various regions of India. Dr. J. Poorani (ICAR-NRCB, Trichy/Bangaluru) is one of the most prominent researchers in the field of Indian Coccinellidae. She has documented approximately 520 species and published the definitive *Annotated Checklist of the Coccinellidae of the Indian sub-region* (Poorani 2002b; Poorani 2024). She has also described and recorded several new species from different parts of India, including *Micraspis pusillus* from Northeast India (Poorani 2014), *Harmonia andamanensis* from the Andaman Islands (Poorani 2014), *Telsimia flavomaculata* from the Karnataka (Poorani 2003), *Scymnomorphus ochraceus* from the Kerala (Poorani 2024), *Stictobura ponmudiensis* from the Western Ghats (Poorani and Prathapan 2025), and *Protoplotina Miyatake* from Tamil Nadu (Poorani et al. 2021).

Several studies have highlighted the diversity of ladybird beetle species across various states in India. For example, Usman and Puttarudriah (1955) reported 48 species from the Mysore region of Karnataka. Joshi and Sharma (2008) documented 31 species in the Haridwar district of Uttarakhand. Priyanka Das et al. (2022) recorded a high diversity of 123 species from the West Bengal. More recently, Roy and Raghavender (2025) reported 12 species from Southern Telangana. Research on the diversity of ladybird beetles in Tamil Nadu remains limited, with a few studies conducted in regions such as Sivakasi (Sundareswari et al. 2022), Chennai (Loganathan et al. 2024), Kancheepuram (Anbalagan et al. 2016) and Madurai (Rekha et al. 2009) typically reported around 7 to 10 species. Despite their ecological significance, ladybird beetles assemblages are increasingly threatened by anthropogenic pressures, including habitat fragmentation, landscape simplification, and intensive use of chemical insecticides (Poorani 2002a; Hyder et al. 2025). However, data on coccinellid community structures in Madurai remain critically scarce, particularly with respect to comparative studies across different tropical land-use types. Understanding patterns of species diversity and abundance is essential for developing sustainable Integrated Pest Management (IPM) strategies. Therefore, the study aims to investigate and compare ladybird beetle assemblages in both cropland and non-cropland environments to assess their diversity, relative abundance, and species dominance within the agroecosystem. The findings of this study provide an essential empirical baseline for the conservation of these important biocontrol agents in agricultural landscapes.

Materials and Methods

Study Area

The survey was conducted in agricultural landscapes surrounding Madurai City, Tamil Nadu, India (9.93°N, 78.12°E). Madurai is situated at an altitude of approximately 101 meters above sea level, with a semi-arid climate. The region receives an average annual rainfall of 840 mm, with a mean annual temperature of 28.8°C. Sampling was carried out across four selected villages: T. Arasapatti, Veiyiluganshapuram, Kulathuvaipatti, and Kamatchipuram. The study sites were categorized into two distinct habitats:

1. Cropland areas: beetle sampling was conducted during vegetative and flowering stages across actively cultivated fields of Brinjal (*Solanum melongena*), Cotton (*Gossypium* sp.), Green chili (*Capsicum annuum*), Cowpea (*Vigna unguiculata*), Paddy (*Oryza sativa*), and Jasmine (*Jasminum* sp.).
2. Non-cropland areas: Uncultivated boundaries or fallow lands within the agricultural landscape, characterized by wild vegetation including grasses, milkweeds (*Asclepias* sp.), *Parthenium hysterophorus*, *Acalypha indica*, *Leucas aspera* etc.

Ladybird beetle survey

Field surveys were conducted over an eight-month period from August 2024 to March 2025. Sampling was carried out during peak activity hours between 07:00 h and 11:00 h for four days each month. A total of 128 sampling hours were dedicated to each study area. Ladybird beetles were surveyed using the

“All-out Search Method” described by Gadagkar et al. (1993), which involved intensive visual searches for coccinellids within 1-hectare plots. Field observations and collection data were initially recorded manually on data sheets and subsequently transferred to Microsoft Excel for further analysis. Sampling effort was maintained uniformly across all study sites to ensure comparability of data. In addition, the frequency of occurrence of ladybird beetle species was assessed and categorized as Rare (R), Common (C), or Abundant (A) based on their relative frequency of sightings during the study period.

Ladybird beetle collection, preservation and identification

To minimize environmental disturbance, specimen collection was restricted to the minimum number required for accurate species identification. Adult ladybird beetles were collected manually using soft forceps, camel-hair brushes, and aspirators to avoid damage to delicate body parts. Sweep nets were also used in dense vegetation and crop canopies. Collected specimens were transferred into clean, ventilated plastic containers or glass vials labeled with collection details, including date, locality, habitat type, host plant, and collector’s name. Live specimens were photographed in the field using a digital macro camera prior to preservation.

Specimens were preserved following standard entomological procedures, and taxonomic identification was carried out using the diagnostic keys and guidelines provided by Poorani (2002a), Omkar and Pervez (2016), Mukherjee and Suman (2017), and Khanduri and Sharma (2025). Adult beetles intended for morphological examination were euthanized using ethyl acetate vapours and preserved using either dry or wet preservation methods. In the dry preservation method, medium- and large-sized specimens were pinned through the right elytral region using stainless-steel entomological pins, whereas smaller specimens were mounted on triangular card points using water-soluble adhesive. In the wet preservation method, small or delicate specimens were preserved in screw-capped glass vials containing 70% ethanol for future examination and reference.

Specimens of each identified species were prepared as voucher specimens for long-term reference and taxonomic verification. Preserved specimens were carefully cleaned, dried, and mounted on insect pins or card mounts. The mounted specimens were arranged in insect storage boxes lined with thermocol or foam sheets and protected with naphthalene balls or silica gel to prevent fungal growth and insect damage. Voucher specimens representing all recorded ladybird beetle species were deposited in the Department Museum, Department of Zoology, Thiagarajar College (Autonomous), Madurai, Tamil Nadu, India, for future taxonomic reference and academic research.

Statistical analysis

The community structure of the ladybird beetles was analyzed using the following metrics:

1. **Relative diversity (RDi)**: Relative diversity was calculated to determine the representation of specific taxonomic or functional groups using the following formula:

$$RDi = \frac{\text{No. of beetle species in a family}}{\text{The total number of species identified in the entire study}} \times 100$$

1. **Diversity indices**: Species diversity (Shannon’s-Wiener Index, H'), richness (Margalef’s Index, D_{mg}), and evenness (Pielou’s Index, J') were calculated using PAST (Paleontological Statistics) software version 4.0 (Hammer et al. 2001).
2. **Mean comparisons**: Ladybird beetle abundance data across various crop fields were subjected to analysis of variance (ANOVA), and mean differences were separated using Duncan's Multiple Range Test (DMRT) in SPSS software (version 29).

Results

Taxonomic Identification of Ladybird Beetles

During the eight-month study period, a total of 10 ladybird beetle species belonging to 9 genera and 3 subfamilies were recorded from cropland and non-cropland habitats of agricultural fields in Madurai. All recorded specimens were identified to the species level based on key diagnostic morphological characters, including body shape and size, colouration, spot pattern, elytral markings, shape of the pronotum, head and mouthparts, antennae, legs and tarsal formula, elytral pubescence, and ventral surface characteristics. The key diagnostic features used for the identification of each species are summarized in Table 1.

Table 1
Diagnostic morphological characters used for the identification of recorded ladybird beetle species from agricultural ecosystems of Madurai.

#	Common Name	Scientific Name with authoritative taxonomic citations	Key diagnostic features
1	Six-spotted zigzag ladybird beetle	*Cheilomenes sexmaculata* (Fabricius, 1781)	Oval and strongly convex body; elytra orange to reddish-yellow with six distinct zigzag or variable black spots; pronotum pale with central dark marking.
2	Round-oval- convex ladybird beetle	*Afidentula bisquadripunctata* (Gyllenhal, 1808)	Round, highly convex phytophagous beetle; yellowish-brown elytra with paired black spots; body densely pubescent.
3	Transverse ladybird beetle	*Coccinella transversalis* (Fabricius in 1781)	Medium-sized reddish beetle with characteristic transverse black bands across elytra; pronotum black with pale lateral margins.
4	Seven-spotted green ladybird beetle	*Coccinella septempunctata* (Linnaeus, 1758)	Large hemispherical beetle; red elytra with seven black spots; pronotum black with two white patches near anterior margin.
5	Discolored ladybird beetle	*Micraspis discolor* (Fabricius, 1798)	Small yellowish-orange beetle; elytra usually spotless or faintly marked; body elongated and smooth; commonly associated with rice ecosystem.
6	Elytra yellowish ladybird beetle	*Illeis cincta* (Fabricius, 1798)	Pale yellow to cream-colored body; elytra transparent-yellow without distinct spots; associated with powdery mildew fungi.
7	Turtle Vein ladybird beetle	*Propylea japonica* (Thunberg, 1781)	Small oval beetle; yellowish-brown elytra with variable black reticulate or wavy markings; pronotum pale with dark median patch.
8	Spotless ladybird beetle	*Cycloneda sanguine* (Linnaeus, 1763)	Bright red spotless elytra; rounded convex body; black pronotum with distinct white margins; absence of elytral spots is characteristic.
9	28-spotted potato ladybird beetle	*Henosepilachna vigintioctopunctata* (Fabricius, 1775)	Phytophagous species; yellowish-brown elytra bearing 28 black spots; body densely pubescent and larger than predatory coccinellids.
10	Scymnus ladybird beetle	*Scymnus coccivora* (Ramakrishna Ayyar, 1925)	Very small oval beetle; dark brown to black body covered with fine pubescence; ventral surface lighter; associated with mealybugs and aphids.

Habitat-wise distribution, abundance, and diversity

A total of 478 ladybird beetle individuals representing 10 species and three subfamilies were recorded across all study sites (Table 2). The subfamily Coccinellinae was predominant with eight species, whereas Epilachninae and Scymninae were each represented by a single species. Among the recorded species, six were categorized as abundant, two as common, and two as rare based on their frequency of occurrence. Cropland habitats supported 441 individuals representing all 10 species, whereas non-cropland habitats accounted for only 37 individuals belonging to four species. Predatory species such as *Cheilomenes sexmaculata*, *Coccinella septempunctata*, *Micraspis discolor*, and *Scymnus coccivora* were more abundant in croplands, whereas phytophagous species *Afidentula bisquadripunctata* predominated in non-cropland habitats. Four species, namely *Afidentula bisquadripunctata*, *Illeis cincta*, *Propylea japonica*, and *Henosepilachna vigintioctopunctata*, were recorded in both habitat types. Ecological diversity indices indicated higher species diversity, richness, and evenness in croplands (H' = 0.931, D_{mg} = 0.492, J' = 1.631) than in non-croplands (H' = 0.226, D_{mg} = 0.169, J' = 0.417) (Table 2).

Table 2
Species composition, relative diversity, frequency of occurrence, and diversity indices of ladybird beetles recorded from cropland and non-cropland habitats in agricultural fields of Madurai.

Family	Subfamily	Scientific Name	No. of Individuals observed in		Total	RDi	FoO
			Cropland	Non-cropland			
Coccinellidae	Coccinellinae	*Cheilomenes sexmaculata*	50	NR	50	10.46	A
		Afidentula bisquadripunctata	36	15	51	10.66	A
		Coccinella transversalis	45	NR	45	9.41	C
		Coccinella septempunctata	57	NR	57	11.92	A
		Micraspis discolor	50	NR	50	10.46	A
		Illeis cincta	37	12	49	10.25	A
		Propylea japonica	37	5	42	8.78	C
		Cycloneda sanguine	35	NR	35	7.32	R
	Epilachninae	*Henosepilachna vigintioctopunctata*	29	5	34	7.11	R
	Scymninae	*Scymnus coccivora*	65	NR	65	13.59	A
Total Number of Individuals			441	37	478		
Total Number of Species			10	4	10		
Biological Diversity Indices							
Species Diversity: Shannon's-Wiener index (H')			0.931	0.226			
Species Richness: Margalef's index (Dmg')			0.492	0.169			
Species Evenness: Pielou's index (J')			1.631	0.417			
Abbreviation: **FoO**: Frequency of Occurrence; **RDi**: Relative Diversity; **A**: Abundant; **R**: Rare; **C**: Common; **NR**: Not Record.							

Crop-wise species composition, diversity and distribution

A total of 10 ladybird beetle species were recorded across the surveyed crop fields. Brinjal fields showed the highest abundance and richness, with 120 individuals representing all 10 species, followed by cowpea (93 individuals; 9 species), cotton (89 individuals; 9 species), paddy (66 individuals; 4 species), green chili (50 individuals; 5 species), and jasmine (23 individuals; 5 species). Duncan's Multiple Range Test (DMRT) revealed significant differences ($P < 0.05$) in the relative abundance of ladybird beetles among the six crop fields (Table 3).

Table 3
Species distribution, relative diversity, and ecological diversity indices of ladybird beetles across different crop ecosystems in agricultural fields of Madurai.

#	Scientific Name	Occurrence of beetles in different crop fields						Total	RDi
		Brinjal	Cotton	Green chili	Paddy	Jasmine	Cowpea		
1.	*Cheilomenes sexmaculata*	15^{b}	10^{bc}	5^{c}	NR	NR	20^{a}	50	11.33
2.	*Afidentula bisquadripunctata*	5^{b}	3^{bc}	NR	25^{a}	3^{bc}	NR	36	8.16
3.	*Coccinella transversalis*	8^{c}	10^{b}	4^{de}	3^{e}	5^{d}	15^{a}	45	10.20
4.	*Coccinella septempunctata*	14^{b}	5^{d}	26^{a}	8^{c}	NR	4^{de}	57	12.92
5.	*Micraspis discolor*	3^{c}	2^{cd}	NR	30^{a}	2^{cd}	13^{b}	50	11.33
6.	*Illeis cincta*	15^{b}	NR	NR	NR	NR	22^{a}	37	8.39
7	*Propylea japonica*	17^{a}	15^{b}	NR	NR	NR	5^{c}	37	8.39
8	*Cycloneda sanguinea*	15^{a}	9^{b}	NR	NR	3^{cd}	8^{c}	35	7.93
9.	*Henosepilachna vigintioctopunctata*	13^{a}	3^{c}	10^{b}	NR	NR	3^{c}	29	6.57
10.	*Scymnus coccivora*	15^{b}	32^{a}	5^{d}	NR	10^{c}	3^{de}	65	14.73
Total Number of Individuals		120^{a}	89^{bc}	50^{d}	66^{c}	23^{e}	93^{b}		
Total Number of Species		10^{a}	9^{ab}	5^{b}	4^{bc}	5^{b}	9^{ab}		
Biological Diversity Indices									
Species Diversity: Shannon's-Wiener Index		0.622^{a}	0.411^{bc}	0.282^{c}	0.184^{d}	0.224^{cd}	0.442^{b}		
Species Richness: Margalef's Index		0.297^{a}	0.258^{c}	0.228^{e}	0.233^{d}	0.201^{ef}	0.279^{b}		
Species Evenness: Pielou's Index		1.106^{a}	0.846^{c}	0.523^{e}	0.698^{d}	0.341^{e}	0.918^{b}		

Abbreviation: NR: Not Record; **RDi**: Relative Diversity.

For all diversity indices, values within the same column followed by different superscript letters are significantly different ($P < 0.05$) across crops, based on Duncan's Multiple Range Test (DMRT).

Table 4

Month-wise abundance, species composition, and ecological diversity indices of ladybird beetles in cropland and non-cropland habitats of agricult

#	Scientific Name	Month-wise record of the number of individuals in												
		Cropland								Non-cropland				
A		S	O	N	D	J	F	M	A	S	O	N	D	J
1.	*Cheilomenes sexmaculata*	10	17	9	5	3	5	NR	1	NR	NR	NR	NR	NR
2.	*Afidentula bisquadripunctata*	5	12	8	10	NR	NR	NR	1	1	4	4	2	NR
3.	*Coccinella transversalis*	8	13	10	5	5	NR	2	2	NR	NR	NR	NR	NR
4.	*Coccinella septempunctata*	5	15	12	20	NR	2	3	NR	NR	NR	NR	NR	NR
5.	*Micraspis discolor*	3	22	18	4	NR	3	NR	NR	NR	NR	NR	NR	NR
6.	*Illeis cincta*	5	10	7	3	3	5	2	2	2	5	3	1	NR
7.	*Propylea japonica*	NR	14	10	8	5	NR	NR	NR	NR	3	2	NR	NR
8.	*Cycloneda sanguinea*	6	10	8	4	5	NR	2	NR	NR	NR	NR	NR	NR
9.	*Henosepilachna vigintioctopunctata*	NR	8	4	9	8	NR	NR	NR	3	1	1	NR	NR
10.	*Scymnus coccivora*	10	15	21	8	4	2	2	3	NR	NR	NR	NR	NR
TNI-MW		52	136	107	76	33	17	11	9	6	13	10	3	-
TNS-MW		8	10	10	10	7	5	5	5	3	4	4	2	-
Biological Diversity Indices														
Shannon's-Wiener Index		0.336^{d}	0.693^{a}	0.573^{b}	0.432^{c}	0.223^{e}	0.189^{f}	0.119^{g}	0.312^{f}	0.307^{b}	0.658^{a}	0.611^{ab}	0.191^{c}	0.000
Margalef's Index		0.558^{d}	1.444^{a}	0.911^{b}	0.751^{c}	0.398^{e}	0.236^{f}	0.203^{g}	0.309^{f}	0.246^{b}	0.478^{a}	0.411^{ab}	0.153^{c}	0.000
Pielou's Index		0.434^{d}	1.001^{a}	0.887^{b}	0.626^{c}	0.274^{e}	0.185^{f}	0.114^{f}	0.809^{g}	0.418^{b}	0.842^{a}	0.829^{ab}	0.201^{c}	0.000

Abbreviation: TNI-MW: Total Number of Individual in Month-wise; **TNS-MS**: Total Number of Species in Month-wise; **TNI-SW**: Total Number of Individuals in Species in Site-wise; **NR**: Not Record; **A**: August; **S**: September; **O**: October; **N**: November; **D**: December; **J**: January; **F**: February; **M**: March.

For all diversity indices, the values within the same column followed by different superscript letters are significantly different ($P < 0.05$) across months, base (DMRT).

Species composition varied among crops. In cowpea fields, *Cheilomenes sexmaculata*, *Coccinella transversalis*, and *Illeis cincta* were the dominant species. Paddy fields were mainly dominated by *Afidentula bisquadripunctata* and *Micraspis discolor*, whereas *Coccinella septempunctata* was predominant in green chili fields. In brinjal fields, *Propylea japonica*, *Cycloneda sanguinea*, and *Henosepilachna vigintioctopunctata* were the major species, while *Scymnus coccivora* was significantly more abundant in cotton fields (Table 2). In contrast, jasmine fields recorded comparatively lower abundance, with five species present but without clear dominance of any single species (Table 3).

Among the crop ecosystems, brinjal fields exhibited the highest species diversity, richness, and evenness indices (Shannon's H', Margalef's Dmg, and Pielou's J'), possibly due to greater prey availability, complex plant architecture, longer crop duration, and favorable microhabitat conditions. Conversely, paddy fields showed the lowest diversity, richness, and evenness values, likely owing to monoculture practices, reduced habitat complexity, and intensive use of agrochemicals, which may adversely affect ladybird beetle diversity (Table 3).

Monthly variation in species diversity and abundance

Month-wise analysis showed that ladybird beetle diversity peaked during the post-monsoon and early winter periods in both cropland and non-cropland habitats. The highest diversity was recorded during September in croplands (10 species; 136 individuals) and non-croplands (4 species; 13 individuals), followed by October (croplands: 10 species; 107 individuals; non-croplands: 4 species; 10 individuals). Duncan's Multiple Range Test (DMRT) indicated significant monthly variation ($P < 0.05$) in all diversity indices across both habitat types. Among the diversity indices, Shannon's Diversity Index (H'), Margalef's Richness Index (D_{mg}), and Pielou's Evenness Index (J') attained their highest values during September in both habitats. However, the richness value was markedly higher in croplands ($D_{mg} = 1.444$) than in non-croplands ($D_{mg} = 0.434$) (Table 5). The higher evenness values observed during September were likely associated with favorable microclimatic conditions and increased availability of prey insects within agricultural habitats. A gradual decline in species diversity, richness, and evenness was observed from December onwards, reaching the lowest levels during February and March in both cropland and non-cropland habitats, indicating a strong seasonal influence on ladybird beetle community structure.

Table 5
Previous records of ten identified coccinellid species with their feeding guild in various agro-ecosystems.

#	Coccinellid species	Feeding guild / Common Prey	Associated crop ecosystems	Reported by
1	*Cheilomenes sexmaculata*	**Predatory -** aphids, mealybugs, whiteflies etc.	Cotton, vegetables, pulses etc.	Sundareswari et al., 2022; Poorani, 2002a; Hyder et al., 2025.
2	*Afidentula bisquadripunctata*	**Phytophagous** – plant eating beetle	Brinjal, tomato, cucumber, grains, grasses etc.	Tomaszewska and Szawaryn, 2013; Jadwiszczak and Węgrzynowicz, 2003.
3	*Coccinella transversalis*	**Predatory -** aphids and whitefly	Brinjal, cowpea, tomato, mustard, sunflower, groundnut, cotton, maize, sorghum, rice etc.	Omkar and Pervez, 2016; Sundareswari et al., 2022.
4	*Coccinella septempunctata*	**Predatory -**mustard aphids and leafhoppers	Mustard, wheat, cabbage etc.	Mir et al., 2025; Khanduri and Sharma, 2025.
5	*Micraspis discolor*	**Predatory** - rice aphids and brown plant hoppers	Paddy and grasses	Samal and Misra, 1985; Shanker et al., 2013.
6	*Illeis cincta*	**Mycophagous** - powdery mildew	Mulberry, cucurbits and ornamental plants	Poorani 2002a; Pervez *et al*., 2020.
7	*Propylea japonica*	**Predatory** - green peach aphid, cotton aphid, cowpea aphid etc.	Maize, cotton, rice, tomato, brinjal, cucumber, cabbage etc.	Ouyang et al., 2012; Zhang et al., 2023.
8	*Cycloneda sanguinea*	**Predatory** - green peach aphid, cotton aphid, cowpea aphid etc.	Cotton, maize, sorghum, tomato, brinjal, cabbage, citrus etc.	Işikber, 2008; Michaud, 2002.
9	*Henosepilachna vigintioctopunctata*	**Phytophagous** - plant-eating	Brinjal, potato, tomato, tobacco, bitter gourd, pumpkin, melons etc.	Jamwal et al., 2017; Lana Aguiar et al., 2019.
10	*Scymnus coccivora*	**Predatory** - cotton mealybug, pomegranate aphid, cotton aphid, cabbage aphid etc.	Guava, mango, citrus, pomegranate, custard apple, brinjal, tomato, cotton etc.	Vidya and Bhaskar, 2018; Kavita and Bhusnar, 2021.

Feeding guilds and crop associations

The recorded ladybird beetle assemblage comprised 10 species representing three feeding guilds, including seven predatory, two phytophagous, and one mycophagous species, indicating their diverse ecological roles in cropland and non-cropland agroecosystems (Table 5). Predatory species constituted the dominant group and were mainly associated with aphids, whiteflies, mealybugs, and other soft-bodied insect pests occurring on crops such as cotton, brinjal, cowpea, maize, tomato, and rice, highlighting their importance as natural biological control agents. The two phytophagous species, *Afidentula bisquadripunctata* and *Henosepilachna vigintioctopunctata*, were recorded feeding directly on plant foliage, whereas *Illeis cincta* was the only mycophagous species observed, feeding on powdery mildew fungi on cultivated plants. The occurrence of these species across diverse crop ecosystems indicates the broad ecological adaptability and habitat preference of ladybird beetles in agricultural landscapes (Table 5).

Discussion

Coccinellids are cosmopolitan in distribution and are found in abundance wherever their associated prey species are present. Both adults and larvae (grubs) are known to feed on a wide variety of small insect pests infesting crops of economic value. During the eight-month study period, a total of 478 specimens belonging to 10 species from 9 genera and 3 subfamilies were recorded in the cropland and non-cropland areas of agricultural fields near Madurai. Species identification was primarily based on external morphological characters including body shape, colour pattern, elytral markings, pubescence, pronotal markings, and body size using standard taxonomic keys and illustrated guides (Poorani 2023; Omkar and Pervez 2016; Khanduri and Sharma 2025).

The subfamily Coccinellinae was the most diverse group in the present study, represented by eight species, whereas Epilachninae and Scymninae were each represented by a single species. The predominance of Coccinellinae in crop fields may be attributed to their predatory feeding habit, broad prey range, high dispersal ability, and greater ecological adaptability. Members of this subfamily mainly feed on aphids, whiteflies, mealybugs, and other soft-bodied insect pests commonly occurring in agricultural ecosystems, thereby playing an important role as biological control agents (Poorani 2002a; Omkar and Pervez 2016; Teja et al. 2023). The abundance of prey insects and the polyphagous feeding behavior of coccinelline species may facilitate their successful colonization across diverse crop habitats (Weber and Lundgren, 2009). Cropland habitats exhibited higher species diversity, richness, and evenness than non-cropland habitats, suggesting that cultivated ecosystems provide more favorable conditions for coccinellid survival and establishment. Similar findings were reported by Abbas et al. (2013), who documented higher coccinellid diversity and abundance in croplands of Faisalabad District, Pakistan. In contrast, Leather et al. (1999) reported comparatively lower coccinellid diversity in non-crop habitats at Silwood Park field station, supporting the present observations.

The survey of six cultivated crops revealed significant variation in coccinellid assemblages among different crop habitats. Among the surveyed crops, brinjal fields supported the highest species diversity and abundance, whereas comparatively lower diversity and abundance were observed in paddy and jasmine

fields. Duncan's Multiple Range Test further confirmed that the relative abundance of ladybird beetles was significantly higher in brinjal fields than in the other crop ecosystems. Similar observations have been reported in earlier studies, where crop habitats with greater prey availability, dense foliage, and complex vegetation structure supported higher coccinellid diversity and abundance (Abbas et al. 2013; Omkar and Pervez 2016; Hussain et al. 2024). Vandereycken et al. (2012) and Honek et al. (2017) reported that brinjal functions as a highly productive trophic resource by supporting a diverse complex of insect pests such as aphids, whiteflies, mealybugs, etc. The availability of diverse prey resources may facilitate the coexistence of multiple feeding guilds of coccinellids by reducing interspecific competition. In contrast, simplified habitats such as monoculture paddy ecosystems generally sustain lower coccinellid diversity because of reduced habitat heterogeneity and intensive agricultural practices (Evans 2004).

In the present study, four predatory species such as *Cheilomenes sexmaculata*, *Coccinella septempunctata*, *Micraspis discolor*, and *Scymnus coccivora* were predominantly associated with cropland habitats compared to other coccinellid species. This clear predominance reflects their evolutionary traits and specific functional roles within temporary agroecosystems. *Cheilomenes sexmaculata* and *Coccinella septempunctata* are highly mobile, voracious generalist predators. They exhibit a strong numerical tracking response, enabling them to rapidly colonize ephemeral crop fields at the onset of pest infestations (Chhangani et al. 2022). Similarly, the high abundance of *Micraspis discolor* in these systems is tied to its specialized, opportunistic life history. Beyond active entomophagy, *Micraspis discolor* functions as an omnivorous predator in croplands like paddy, utilizing both soft-bodied pests such as the brown planthopper and plant pollen during flowering phases to maintain stable populations even when insect prey is scarce (Shanker et al. 2013; Hanifah et al. 2024). In contrast, the tiny *Scymnus coccivora* adopts a localized foraging strategy. Its small body size allows it to exploit dense micro-habitats within intricate crop canopies (such as brinjal and cotton), effectively suppressing colonial, patchily distributed sucking pests like mealybugs and spider mites (Kumari et al. 2021; Pant and Dawadi 2025). Collectively, these distinct species-crop associations strongly reinforce the value of diversified cropping systems in sustaining robust populations of beneficial predatory guilds, ultimately optimizing natural pest suppression across the agricultural landscape (Landis et al. 2000).

In the present study, brinjal fields harbored a highly diverse assemblage of ten species, with *Propylea japonica*, *Cycloneda sanguinea*, and *Henosepilachna vigintioctopunctata*, emerging as the predominant taxa. These findings agree with the observations of Megha et al. (2015) from Dharwad, Karnataka, who reported *Propylea japonica* as the dominant species in brinjal ecosystems, followed by *Cycloneda sanguine* and *Henosepilachna vigintioctopunctata*. Earlier studies have similarly demonstrated that brinjal ecosystems support diverse coccinellid assemblages because of abundant prey availability and favorable crop architecture, which provide suitable feeding, breeding, and sheltering conditions for predatory beetles (Omkar and Pervez 2016; Rasheed and Buhroo 2018). Recent studies by Singh (2025) reported that *Propylea japonica* and *Cycloneda sanguinea* act as opportunistic predators that effectively suppress aphid populations in brinjal fields and also prey upon eggs and early larval stages of the brinjal shoot and fruit borer (Pervez 2011). In contrast, the high occurrence of *Henosepilachna vigintioctopunctata* reflects its status as a major phytophagous pest of brinjal rather than a beneficial predatory species (Nithish 2020). The present findings indicate that coccinellid community structure varies across geographical regions, while the complex architecture of brinjal crops supports diverse predatory and phytophagous coccinellids through effective ecological resource partitioning within the agroecosystem.

Cowpea fields supported a diverse assemblage of Coccinellidae that function as important natural enemies of soft-bodied insect pests and fungal pathogens. In the present study, nine ladybird beetle species were recorded, among which *Cheilomenes sexmaculata*, Coccinella *transversalis*, and *Illeis cincta* were the dominant species. Similar coccinellid assemblages have been reported from diversified pulse and vegetable ecosystems in southern India (Imam 2015; Jesu Rajan et al. 2019). The predominance of *Cheilomenes sexmaculata* and *Coccinella transversalis* may be attributed to their broad prey range, efficient prey-searching behavior, and ability to detect herbivore-induced plant volatiles (HIPVs) released by aphid-infested plants, enabling rapid prey localization and habitat colonization (Jesu Rajan et al. 2019; Omkar and Pervez 2016; Khallaf et al. 2023). In contrast, *Illeis cincta* occupied a distinct ecological niche as a mycophagous species feeding on powdery mildew fungi such as *Oidium vignae* (Dharshini and Jagadish 2018). These findings indicate effective resource partitioning among predatory and mycophagous guilds, thereby enhancing ecological stability and biodiversity within cowpea agroecosystems.

Nine ladybird beetle species were recorded from cotton fields, among which *Scymnus coccivora* was the predominant species compared to other coccinellids. Similar observations were reported by Pervez et al. (2020), who documented diverse coccinellid assemblages in cotton agroecosystems, including *Scymnus coccivora*, *Cheilomenes sexmaculata*, *Coccinella transversalis*, *Propylea dissecta*, and *Coccinella octomaculata*. The predominance of *Scymnus coccivora* in cotton fields may be associated with the abundance of mealybugs, aphids, and other soft-bodied insect pests commonly occurring in cotton ecosystems (Kumari et al. 2021). Recent field studies confirm that the overwhelming dominance of a small-bodied predator like *Scymnus coccivora* is typically driven by its superior ability to navigate dense leaf trichomes to exploit localized colonies of sucking pests like the cotton mealybug (*Phenacoccus solenopsis*) and whiteflies (*Bemisia tabaci*) (Waqas et al. 2021; Nagrare et al. 2022). These findings suggest that coccinellid assemblages in cotton ecosystems are highly dynamic, with species diversity and abundance varying according to seasonal cropping patterns, prey availability, and microenvironmental conditions within the agroecosystem.

In the green chili fields, five ladybird beetle species comprising four predatory and one phytophagous taxa were recorded, among which *Coccinella septempunctata* emerged as the dominant species. Similar observations have been reported from vegetable agroecosystems where *Coccinella septempunctata* predominated because of the abundance of aphids, thrips, and other soft-bodied insect pests associated with chili crops (Rahman et al. 2004; Khatun et al. 2023; Mir et al. 2025). Field evaluations by Xia et al. (1999) confirm that *Coccinella septempunctata* is a highly voracious predator that primarily targets the green peach aphid (*Myzus persicae*) and the cotton aphid (*Aphis gossypii*), both of which notorious vectors of devastating chili are plant viruses. Furthermore, *Coccinella septempunctata* displays opportunistic feeding plasticity; it actively preys upon whitefly (*Bemisia tabaci*) nymphs and eggs, as well as early stages of chili thrips (*Scirtothrips dorsalis*) during periods of low aphid density (Musa and Torto 2026). This capacity to exploit multiple pest complexes allows *Coccinella septempunctata* to maintain stable populations throughout the cropping season, reinforcing its status as a cornerstone natural enemy for the biological management of chili agroecosystems.

Ladybird beetle diversity in paddy fields comprised four species, among which two species were dominant: the predatory species *Micraspis discolor* and the phytophagous species *Afidentula bisquadripunctata*. Previous studies have reported that *Micraspis discolor* is one of the most abundant coccinellid species in paddy agroecosystems and plays an important role in the natural biological control of rice pests (Rahman et al. 1991; Olalekan 2002; Mondal and Chakraborty 2017). Similar observations were made by Rattanapun (2012), who reported that populations of Micraspis discolor increased significantly during the flowering and grain-forming stages of rice. This beetle is an effective predator of several economically important rice pests, particularly rice aphids, brown planthoppers (*Nilaparvata lugens*), green leafhoppers (*Nephotettix* spp.), and other sap-feeding insects occurring on rice panicles and leaves. In contrast, *Afidentula bisquadripunctata* is a phytophagous species commonly associated with grasses and monocot vegetation. The dense foliage and continuous availability of tender plant tissues in paddy ecosystems may provide favorable feeding and breeding conditions for this beetle (Omkar and Pervez 2016). In addition, the humid microclimate and relatively uniform vegetation structure of rice fields may facilitate its persistence compared with more heterogeneous crop habitats (Tomaszewska and Szawaryn 2013). Thus, the predominance of these two species in paddy fields reflects their ecological specialization, habitat preference, and adaptation to the prey availability and environmental conditions characteristic of rice agroecosystems.

High densities of aphids and whiteflies may contribute to the notable diversity of coccinellids in jasmine fields. In the present study, five ladybird beetle species (*Afidentula bisquadripunctata*, *Coccinella transversalis*, *Micraspis discolor*, *Cycloneda sanguinea*, and *Scymnus coccivora*) were recorded; however, no single species showed clear dominance within the assemblage. Similar patterns have been reported in diversified horticultural ecosystems where coccinellid assemblages are largely influenced by prey abundance, host plant architecture, and microclimatic conditions (Pirithiraj et al. 2021). Jesu Rajan et al. (2019) reported that generalist predators such as Coccinella transversalis and Micraspis discolor actively exploit aphid (*Aphis gossypii*) colonies in flowering crops. In addition, the occurrence of whiteflies such as *Bemisia tabaci* may further support predatory coccinellid populations in jasmine fields. However, the compact canopy structure and specialized floral architecture of jasmine may restrict the dominance of individual predator species, resulting in a relatively balanced coccinellid assemblage (Pirithiraj and Soundararajan 2023). These findings indicate that prey diversity and plant structural complexity play important roles in shaping coccinellid community composition in jasmine agroecosystems.

The month-wise analysis revealed that ladybird beetle diversity peaked during the post-monsoon period (September and October), followed by a gradual decline from December onwards, reaching the lowest levels during February and March. Duncan's Multiple Range Test (DMRT) further confirmed significant monthly variations in all diversity indices across both cropland and non-cropland habitats, indicating a strong seasonal influence on coccinellid community structure. Similar seasonal trends have been reported in earlier studies from tropical agroecosystems (Ali and Rana 2012; Sloggett and Zeilstra 2020). Shanker et al. (2013) observed that coccinellid abundance was highest during the post-monsoon and flowering stages of crops because of increased prey availability and favorable humidity conditions. Likewise, Abbas et al. (2013) documented significant seasonal fluctuations in ladybird beetle populations in agricultural habitats of Pakistan, with peak diversity occurring during periods of moderate temperature, high relative humidity, and abundant aphid populations. Similar findings were also reported by Sundareswari et al. (2022) who found that post-monsoon climatic conditions and increased pest abundance positively influenced coccinellid diversity and population density in crop ecosystems. These studies collectively suggest that seasonal changes in temperature, humidity, crop phenology, and prey availability strongly regulate the temporal dynamics of ladybird beetle assemblages in agroecosystems.

These findings highlight the multifaceted ecological roles of coccinellids within agroecosystems. Although ladybird beetles are primarily recognized as important biological control agents of insect pests in annual crops and perennial plantations such as mango, citrus, and coconut, they occupy a wide range of functional ecological niches (Poorani 2002a; Omkar and Pervez 2016). Based on feeding guild analysis and previous reports, the ten recorded species in the present study were categorized into three distinct guilds: (1) predatory species (7 nos.), which play a major role in the natural suppression of agricultural pests; (2) mycophagous species (1 no.), which feed on fungal pathogens such as powdery mildew and help reduce fungal infections in economically important crops; and (3) phytophagous species (2 nos.), which feed directly on host plant tissues. Phytophagous ladybird beetles constitute only a small proportion of the family Coccinellidae (Poorani 2002a; Omkar and Pervez 2016). This dietary diversity suggests that the stability and persistence of ladybird beetle populations are supported not only by prey availability but also by the diversity of host plants and associated microhabitats, which together provide a resilient ecological foundation within agricultural landscapes.

Conclusion and Recommendation

This study demonstrates that coccinellid community structures in Madurai are heavily dictated by habitat type, crop architecture, and seasonal factors. Cropland habitats support significantly higher ladybird beetle abundance and diversity than non-croplands due to favorable microclimatic conditions and concentrated prey availability. While vegetable crops like brinjal, cotton, and cowpea serve as critical operational hubs for diverse feeding guilds, monoculture paddy fields exhibit reduced diversity. The limited abundance observed in non-cropland ecosystems is directly linked to the scarcity of host insect prey. The recorded species represented predatory, mycophagous, and phytophagous feeding guilds, highlighting the ecological complexity and functional importance of coccinellids in agroecosystems. Predatory species, especially aphidophagous and mealybug-feeding beetles, play a vital role in the natural suppression of economically important crop pests.

To foster and conserve these ecologically valuable predatory populations, agricultural landscapes must be managed strategically. Based on our findings, we propose the following landscape and pest management recommendations:

- **Enhance Habitat Heterogeneity**: Intercrop or strip-crop structural vegetables like cowpea, brinjal, and green chilies alongside monoculture staples (such as paddy) to establish essential ecological refugia and alternative prey bases across the farming landscape.
- **Implement Conservation IPM**: Systematically minimize chemical insecticide applications during peak post-monsoon and winter activity periods (September to November), when favorable weather conditions naturally optimize coccinellid diversity and abundance.
- **Advance Tri-Trophic Research**: Future research should initiate field-release evaluations of specialized species and employ molecular techniques, such as gut-content analysis, to precisely quantify tri-trophic interactions and map specific pest-suppression pathways within the agroecosystem.

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Declarations of generative ai and ai-assisted technologies in the writing process

The authors declare that no artificial intelligence tools were used to write this manuscript.

Author Contribution

TR and PP - Conceptualization; TR -Data curation, supervision, and writing original draft preparation; BA - Resources, investigation, and methodology; TR and RE - Formal analysis and validation; TR and PP - Writing, review and editing. All authors read and approved the manuscript.

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Data availability statement

All results are published in this article; raw data can be made available from the authors upon reasonable request.

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