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Pruning year effects on flying insect diversity and microclimate relationships in Jamus tea agroecosystem, East Java, Indonesia

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Abstract. *Suheriyanto D, Syahniar YY. 2026. Pruning year effects on flying insect diversity and microclimate relationships in Jamus tea agroecosystem, East Java, Indonesia. Asian J Agric 10 (1): g100134. https://doi.org/10.13057/asianjagric/g100134.* Flying insects provide essential ecosystem functions in tea agroecosystems, including pollination and pest regulation. This study examined how the post-pruning recovery cycle influences flying insect communities and microclimate in Jamus tea (*Camellia sinensis*) plantation. Insects were sampled and microclimate variables (temperature, humidity, light, wind speed) measured across blocks representing the first to fourth years after pruning (PY 1-4). Community metrics and Canonical Correspondence Analysis (CCA) were used to evaluate diversity and habitat associations. We identified 12 insect genera, namely *Diabrotica*, *Altica*, *Coccinella*, *Condylostylus*, *Musca*, *Syrphus*, *Sepedon*, *Taeniaptera*, *Gonocerus*, *Lasioglossum*, *Apanteles*, and *Amata*. Total abundance and genus richness increased with time since pruning, with the lowest diversity and highest dominance in PY 1. Although microclimate did not differ significantly among years, CCA revealed that community composition tracked two environmental gradients: one associated with higher light and wind exposure (linked to genera *Lasioglossum* and *Taeniaptera* in later years), and another with cooler, more humid conditions (associated with genera *Altica* and *Sepedon*). These findings demonstrate that pruning primarily structures insect communities by modifying physical habitat, rather than altering average plot-level microclimate.

Keywords: *Camellia sinensis*, Canonical Correspondence Analysis, ecosystem services, tea plantation, yellow pan trap

INTRODUCTION

Tea (*Camellia sinensis*) plantations are complex agroecosystems where sustainable productivity requires balancing intensive cultivation with ecological integrity (Le et al. 2023). The Jamus plantation, an important production site in Ngawi District, East Java, Indonesia, exemplifies this context; in 2023, its 405.3 hectares yielded 326.21 tons of tea (BPS-Statistics of Ngawi District 2024). Within this system, pruning is an essential agronomic practice primarily aimed at stimulating shoot growth to enhance productivity (Zhang et al. 2023). Its type and frequency considerable influence plant growth, yield, and quality (Hossen et al. 2021), with a well-documented productivity cycle where output is lowest in the first post-pruning year and increases through the fourth (Hatungimana et al. 2025). Beyond direct agronomic benefits, pruning acts as a cyclical disturbance that modifies canopy structure and light penetration (Reckziegel et al. 2022), thereby fundamentally reshaping the microhabitat for the diverse insect communities these plantations support.

Insect communities in tea plantations, including pests, natural enemies, and pollinators, play a crucial role in maintaining ecosystem function and supporting crop yield. These agroecosystems globally support high arthropod diversity, including approximately 808 pest species and over 1,100 natural enemy species (Ye et al. 2014). This biodiversity underpins essential services: pollinator diversity directly enhances ecosystem resilience and agricultural yields (Katumo et al. 2022; Dey and Laskar 2025), while predators and parasitoids provide vital biological control. However, these communities are vulnerable to management practices. Heavy reliance on chemical pesticides (Deka et al. 2021) leads to adverse outcomes, including heavy metal contamination (He et al. 2020), suppression of natural enemies (Li et al. 2019), and consumer health concerns driving demand for safer products (Hazarika et al. 2023). Consequently, organic management is promoted to mitigate pesticide residues and strengthen biological control mechanisms (Karalliyadda and Kazunari 2019; Török et al. 2021). Within this framework, cultural practices such as pruning may offer a complementary, yet underexplored, tool for modulating insect communities by deliberately altering the microclimate, a key driver of diurnal insect behavior (Juddin et al. 2023).

While the broad influence of land management on insect populations is recognized (Staab et al. 2023) and pruning affects arthropod dynamics (Suheriyanto et al. 2017), a critical and specific knowledge gap remains. There is a distinct lack of empirical studies that directly correlate the defined temporal stages of post-pruning recovery with quantitative changes in the structure and diversity of functionally important flying insect communities within tea agroecosystems. Although regional surveys have documented moderate insect diversity in other tea-growing areas (Andisca et al. 2021; Putriyani et al. 2024), a systematic analysis of how this diversity responds to the cyclical pruning disturbance remains absent. The identified gap critically impedes the development of evidence-based pruning protocols capable of simultaneously optimizing two key objectives: agronomic productivity and biodiversity-driven ecosystem services.

This study addresses the identified gap by examining the relationships between pruning cycles, microclimatic factors, and flying insect diversity in the Jamus tea plantation. We hypothesize that the time elapsed since the last pruning event creates a deterministic gradient in both habitat structure and microclimate, driving predictable successional shifts in flying insect abundance and community composition. Specifically, we aim to compare flying insect diversity across tea blocks in different years of post-pruning regrowth (first to fourth year), to quantify concomitant changes in key microclimatic variables (e.g., temperature, humidity, light intensity, wind speed), and to analyze correlations between insect community metrics and these measured variables. By establishing these empirical relationships, our work provides actionable, science-based insights for refining sustainable plantation management to proactively harness ecological processes, ultimately enhancing both the crop productivity and the stability of biodiversity-based ecosystem services.

MATERIALS AND METHODS

Study area

This study was conducted at the Jamus tea plantation, managed by Perseroan Terbatas (PT) Candi Loka, in Ngawi District, East Java, Indonesia (Figure 1). To capture the complete agronomic recovery cycle and its associated habitat gradient, sampling was conducted in tea blocks representing the first through fourth years after pruning (Pruning Year 1/PY 1, Pruning Year 2/PY 2, Pruning Year 3/PY 3 and Pruning Year 4/PY 4). This progression encompasses three distinct management phases: the immediate Recovery Phase (PY 1), characterized by newly pruned plants (~45 cm height) with minimal canopy; the Peak Productivity Phase (PY 2 and PY 3), where the canopy re-establishes and closes at heights of ~80 cm and ~120 cm, respectively; and the late-cycle Maturation Phase (PY 4), where plants reach ~155 cm with a dense canopy that creates a distinct microclimate prior to the next pruning event. The specific coordinates for the central sampling point within each block are as follows: PY 1 (7°33'42"S, 111°10'53"E), PY 2 (7°33'38"S, 111°11'05"E), PY 3 (7°33'43"S, 111°11'07"E), and PY 4 (7°33'37"S, 111°10'50"E). All blocks were located within a contiguous area with comparable elevation (900 to 1,000 m above sea level).

Data collection

Flying insects were sampled across the four pruning year blocks (PY 1 to PY 4) using standard yellow pan traps, following established methods for sampling flying insects in agroecosystems (Vrdoljak and Samways 2012). Each trap consisted of a circular plastic pan measuring 30 cm in diameter and 8 cm in depth, with a capacity of approximately 2 liters. Traps were constructed from High-Density Polyethylene (HDPE) plastic in a standardized bright yellow color to maximize visual attraction for a broad spectrum of flying insects. This study employed a synchronic design: all four blocks were sampled concurrently during a single campaign to isolate the effect of pruning age from temporal variation. At each block, three parallel transects were established with 10 m spacing between them. Along each 90-m transect, ten yellow pan traps were placed at 10 m intervals and elevated to 150 cm above ground level. Traps were filled with approximately 0.5 liters of water mixed with five drops of liquid detergent to reduce surface tension and ensure insect capture. Traps were deployed for a standardized period of 24 hours (Acharya et al. 2021). Insect sampling in this study was conducted as a synchronous comparison, that is, a single sampling campaign in which all four cropping year blocks (PY1 to PY4) were sampled once simultaneously over a standardized 24-hour period.

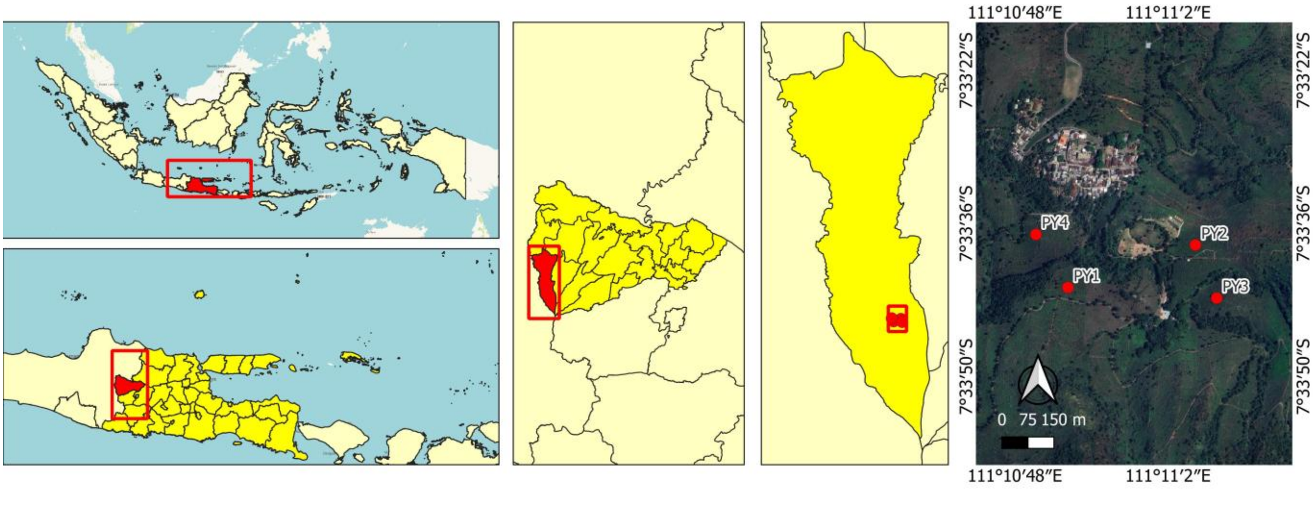

Figure 1. Research site at Jamus tea plantation, PT Candi Loka Ngawi District, East Java, Indonesia

Following collection, all captured insects were counted in the field. Representative specimens from all major taxa were preserved in 70% ethanol and transported to the laboratory for identification. In the laboratory, insects were identified to the genus level based on morphological characteristics using available taxonomic resources (BugGuide.net), then assigned to trophic groups (herbivore, pollinator, predator, parasitoid, or detritivore) based on ecological data from the same database. Genus level identification was selected to ensure consistent, replicable categorization across the sample set and to analyze community patterns at a functional resolution appropriate for agroecosystem comparisons.

Concurrent with insect sampling, key microclimatic variables were recorded at the center of each transect within every block. Measurements included air temperature, relative humidity, light intensity, and wind speed. All measurements were taken at a height of 150 cm to correspond with the trap elevation.

Data analysis

Data on flying insects assemblages were analyzed to determine community metrics: Dominance, the Shannon diversity index (H'), Evenness, and Richness. Differences in microclimate variables across the four pruning years (PY) were tested using one-way Analysis of Variance (ANOVA). The assumptions of normality and homogeneity of variances were verified prior to ANOVA. The Shapiro-Wilk test indicated that residuals were normally distributed for all microclimatic variables ($p>0.05$), and Levene's test confirmed homogeneity of variances across pruning years ($p>0.05$). Accordingly, one-way ANOVA was applied to untransformed data.

The relationship between flying insect community composition and microclimate variables was assessed using Canonical Correspondence Analysis (CCA). Before running the CCA, multicollinearity among the four environmental predictors (temperature, humidity, light intensity, and wind speed) was assessed using Variance Inflation Factors (VIFs), with a threshold of $VIF<10$. The significance of the overall CCA model and of individual environmental axes was tested using permutation tests (999 permutations). CCA assumes a unimodal response of taxa to environmental gradients, an appropriate model for ecological community data across heterogeneous habitats.

All statistical analyses were performed using PAleontological STatistics (PAST) version 4.17. The Shannon diversity index was interpreted following Magurran (1988), with values <1.5 indicating low diversity, 1.5-3.5 indicating moderate diversity, and >3.5 indicating high diversity.

RESULTS AND DISCUSSION

Sampling across the four pruning-year blocks (PY1 to PY4) at the Jamus tea plantation yielded a total of 218 individual flying insects, representing 12 genera within 11 families and five orders: Coleoptera, Diptera, Hemiptera, Hymenoptera, and Lepidoptera (Table 1). Diptera was the most diverse order, represented by five genera and five families, followed by Coleoptera with three genera and two families. Total insect abundance increased progressively across the pruning-year gradient, from 41 individuals in PY 1 to 71 individuals in PY 4.

The distribution of individual genera varied markedly across pruning years (Table 1). The *Taeniaptera* (Diptera) was the most abundant single taxon, with 52 individuals collected. Its abundance was highest in the later pruning years (PY 3 and PY 4). Other genera exhibited distinct distribution peaks: the *Altica* (Coleoptera) was most abundant in PY 2 and PY 3, the *Apanteles* (Hymenoptera) was predominant in PY 1 and PY 2, and the *Lasioglossum* (Hymenoptera) was found exclusively in PY 3 and PY 4. In contrast, genera such as *Condylostylus* (Diptera) were present across multiple years with less pronounced variation.

Table 1. The flying insects trapped in the Jamus tea plantation

Order	Family	Genera	PY 1 (individual)	PY 2 (individual)	PY 3 (individual)	PY 4 (individual)	Total (individual)
Coleoptera	Chrysomelidae	*Diabrotica*	2	5	0	1	8
		Altica	0	8	12	0	20
	Coccinellidae	*Coccinella*	1	3	0	5	9
Diptera	Dolichopodidae	*Condylostylus*	11	2	9	12	34
	Muscidae	*Musca*	3	0	2	6	11
	Syrphidae	*Syrphus*	0	0	5	8	13
	Sciomyzidae	*Sepedon*	0	3	1	0	4
	Micropezidae	*Taeniaptera*	10	7	14	21	52
Hemiptera	Coreidae	*Gonocerus*	3	13	6	5	27
Hymenoptera	Halictidae	*Lasioglossum*	0	0	3	9	12
	Braconidae	*Apanteles*	11	9	2	0	22
Lepidoptera	Erebidae	*Amata*	0	1	1	4	6
Total			41	51	55	71	218

The abundance of insects within each trophic group varied across the pruning year. Herbivore abundance increased from 5 individuals in PY 1 to 27 individuals in PY 2, remained elevated in PY 3 (24 individuals), and then declined moderately in PY 4 (18 individuals). Pollinators were absent in PY 1 and PY 2, first appeared in PY 3 with 3 individuals, and increased to 9 individuals in PY 4. Predators were recorded across all years, with counts increasing from 22 individuals in PY 1 to 38 individuals in PY 4, following a slight decrease in PY 2. Parasitoid abundance was highest in the early pruning years (11 individuals in PY 1 and 9 in PY 2), then declined sharply to 2 individuals in PY 3 and disappeared entirely in PY 4. Detritivores occurred in low numbers throughout, with 3 individuals in PY 1, none in PY 2, 2 in PY 3, and 6 in PY 4. These patterns indicate a shift in the functional composition of the insect community as the canopy matures (Figure 2).

The diversity of flying insects in the Jamus tea plantation is variedly marked across the pruning cycle (Table 2). Among all pruning periods, PY1 exhibited the lowest values for the number of genera, number of individuals, Shannon diversity index, Evenness, and Richness, while showing the highest dominance value. In contrast, PY3 supported the highest taxonomic diversity, with the greatest number of genera (10) and the highest species richness (2.25). The number of individuals increased consistently across pruning periods, rising from 41 individuals in PY1 to the highest abundance in PY4 (71 individuals). The Shannon diversity index values ranged from 1.67 to 1.98, indicating a moderate level of flying insect diversity in the Jamus tea plantation (Magurran 1988).

Microclimatic variables measured are summarized in Table 3. The variations in microclimatic variables (temperature, humidity, light intensity, and wind speed) across different pruning periods (PY 1-PY 4). The range of microclimate recorded in the Jamus tea plantation during the study was as follows: temperature, 26.7°C to 28.4°C; relative humidity, 57% to 68 %; light intensity, 2,218 to 2,690 lux; and wind speed, 4.03 to 5.4 m/s. In this study, pruning of tea plants did not have a significant impact on abiotic factors. The Analysis of Variance results for all microclimatic variables indicated no significant differences among all pruning years. The p values for temperature, humidity, light intensity, and wind speed were 0.84, 0.38, 0.86, and 0.60, respectively.

The Canonical Correspondence Analysis (CCA) produced a robust ordination of the insect community data constrained by environmental variables. Axis 1 had an eigenvalue of 0.297 and explained 55.85% of the total variance (inertia) in the species-environment relationship. Axis 2 had an eigenvalue of 0.155, explaining a further 29.18% of the variance. Together, the first two axes accounted for 85.03% of the explained inertia, indicating they capture the dominant ecological gradients structuring the flying insect community (Table 4). Axis 1 primarily represents a gradient of physical exposure and canopy maturity, strongly associated with increasing wind speed and light intensity. PY 3 and 4 (positive scores) are separated from the earlier years (negative scores) along this axis. Genera with high positive scores along Axis 1, including *Lasioglossum* (1.70), *Syrphus* (1.43), *Amata* (1.05), *Musca* (1.02), and *Taeniaptera* (0.44), were positively associated with environments characterized by greater wind exposure and higher light availability. Axis 2 represents a gradient of atmospheric conditions, strongly and positively correlated with humidity and negatively with temperature. Genera with high positive scores along Axis 2, such as *Altica* (2.08), *Sepedon* (1.55), *Syrphus* (0.93), *Gonocerus* (0.60), and *Amata* (0.53), showed a strong association with more humid environmental conditions.

Consequently, the distribution of insect genera in the ordination space reflects their habitat preferences. For instance, genera with high positive scores on Axis 1 (e.g., *Lasioglossum*, *Syrphus*) are associated with the conditions of later pruning years (higher wind exposure, brighter light within the mature canopy structure). Genera with high scores on Axis 2 (e.g., *Altica*, *Sepedon*) are linked to cooler, more humid conditions.

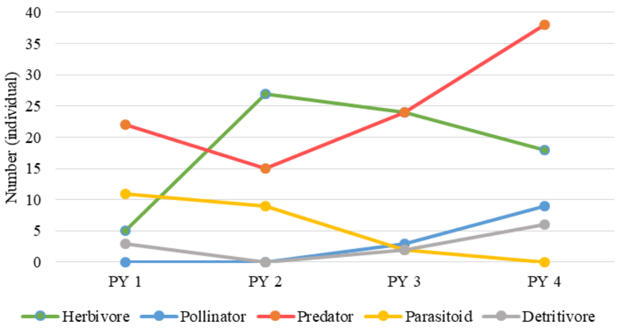

Figure 2. Abundance of insects by trophic groups across four pruning years

Table 2. The effect of pruning on flying insect diversity

	PY 1	PY 2	PY 3	PY 4
Number of genera	7	9	10	9
Number of individuals	41	51	55	71
Dominance	0.22	0.16	0.17	0.17
Shannon index	1.67	1.98	1.98	1.97
Evenness	0.67	0.77	0.63	0.78
Richness	1.62	2.04	2.25	1.88

Table 3. The effect of pruning on microclimate

Microclimatic variables	PY 1	PY 2	PY 3	PY 4	p value
Temperature (°C)	28.4	26.9	26.7	28.1	0.84
Humidity (%)	57	61	68	60	0.38
Light intensity (lux)	2,646	2,218	2,378	2,690	0.86
Wind speed (m/s)	4.4	4.03	4.6	5.4	0.60

Table 4. Canonical Correspondence Analysis (CCA) scores for pruning year blocks (PY), insect genera, and microclimatic variables

	Axis 1	Axis 2
Eigenvalue	0.297	0.155
% of inertia	55.85	29.18
PY 1	-0.23	-0.74
PY 2	-0.80	0.18
PY 3	0.07	0.42
PY 4	0.66	-0.02
Condylostylus	0.43	-0.82
Musca	1.02	-0.91
Syrphus	1.43	0.93
Sepedon	-1.95	1.56
Taeniaptera	0.44	-0.10
Lasioglossum	1.70	0.54
Apanteles	-1.46	-1.66
Diabrotica	-1.59	-0.48
Altica	-0.93	2.08
Coccinella	0.24	-0.23
Gonocerus	-0.92	0.60
Amata	1.05	0.53
Temperature	0.40	-0.88
Light Intensity	0.74	-0.65
Humidity	0.11	0.86
Wind Speed	0.98	0.03

Discussion

This study demonstrates that the cyclical practice of pruning is a key driver of ecological succession in tea agroecosystems, shaping both the microclimate and the assembly of flying insect communities. Our findings confirm the hypothesis that time since pruning creates a deterministic habitat gradient, with significant shifts in insect abundance, diversity, and functional composition across a four-year cycle. These results underscore that pruning, in addition to its agronomic function, has ecological implications by shaping habitat structure and influencing the composition of insect communities that support key ecosystem services such as pest regulation and pollination.

The observed insect assemblage, dominated by Diptera, reflects a community typical of complex agroecosystems. Diptera is consistently one of the most diverse insect orders in agricultural landscapes due to its broad ecological niches and varied life-history strategies (Courtney et al. 2017). Our finding of high dipteran diversity and abundance aligns with their recognized role in ecosystem functions such as decomposition and nutrient cycling (Nizam et al. 2022). The variation in genus abundance across pruning years supports our central hypothesis that time since pruning creates a deterministic habitat gradient. This gradient is characterized by contrasting environmental conditions: the open, high-light environment of PY 1 favors one subset of the insect community, while the dense, shaded canopy of later years (PY 3 and PY 4) favors distinctly different taxa. Notably, the *Taeniaptera* exhibited pronounced dominance in PY 3 and PY 4, a finding that is ecologically important as it confirms the association of this detritivorous genus with the moist, structurally complex microhabitats characteristic of mature canopies. Species in this genus are known for their broad distribution and adaptability to various agricultural habitats (Harterreiten-Souza et al. 2016).

The relationship between pruning cycles and insect communities observed in our study aligns with established patterns in tea agroecosystems. Other studies confirm that pruning plays a significant role in abundance, peaking in the third year after pruning (Hidayat et al. 2019). This pattern is often associated with the development of increased habitat complexity. For example, the higher insect diversity documented in shaded tea systems compared to monocultures underscores how the structural complexity of shade trees promotes more stable and complex food webs. This principle extends to vegetation management within fields, where diverse plant compositions have been shown to increase natural enemy populations, thereby enhancing the biological control of herbivorous pests (Meng et al. 2021). Furthermore, the integration of cover crops provides a range of ecological services, including increasing natural enemy abundance, disrupting pest colonization, and preventing outbreaks that collectively contribute to sustainable pest management strategies (Pokharel et al. 2023).

The high diversity of natural enemies within tea plantations forms a critical foundation for biological pest control (Ye et al. 2014). In our study, the functional groups of herbivores and predators were present across all sampling sites, but their temporal dynamics differed in relation to the pruning cycle. Herbivorous insects reached their peak abundance in PY 2 and PY 3, a period of vigorous plant regrowth that may offer optimal nutritional resources. Despite this potential increase in prey availability, predator abundance remained high at all sites except PY 2. This pattern suggests that the predator community, which plays a crucial role in regulating herbivore populations and preventing pest outbreaks (El-Wakeil and Gaafar 2020), is generally resilient to pruning disturbance. The concurrent presence of significant predator abundance during peaks in herbivore numbers indicates a potential for effective top-down control, potentially mitigating the negative impacts herbivores can have on plant growth and yield (Myers and Sarfraz 2017).

The moderate insect diversity observed in this study aligns with reports from other tea agroecosystems, though its interpretation varies with management context, from an indicator of ecosystem stability to a signal for vigilant pest monitoring (Andisca et al. 2021; Putriyani et al. 2024). Our findings clarify this context by revealing that diversity is not static but follows a predictable successional trajectory driven by the pruning cycle. The observed increase in genus richness and total abundance from PY 1 to PY 3, coupled with a decrease in dominance, reflects how habitat complexity directly shapes the community. This pattern mirrors dynamics in other managed perennial systems like forest coppicing, where distinct insect assemblages correspond to different regrowth stages (Weiss et al. 2020). Such succession underpins the development of diverse functional groups as the insect assemblage shifts in response to changing vegetation structure. Consequently, maintaining structural heterogeneity is key to supporting biodiversity and stabilizing ecological communities (Rothacher et al. 2025).

The exclusive presence of pollinators during later pruning stages (PY 3 and PY 4) suggests that the mature, dense canopy provides important resources, such as a favorable microclimate, wind protection, and flowering understory, which are crucial for these taxa. Pollinators are known to respond positively to increasing habitat complexity, increasing their abundance and richness at multiple spatial scales, although the effects vary by taxa and plant species (Bentrup et al. 2019). In contrast, predator and parasitoid communities, which are important for biological control, showed a more resilient relationship to the pruning cycle. Predator abundance remained consistently high throughout most years, while parasitoid abundance increased steadily from PY 1 to PY 4. Our finding that older, structurally complex tea canopies support greater predator abundance aligns with recent work in urban agroecosystems, where higher vegetation cover was positively associated with predator richness and abundance, particularly among spiders (Lucatero et al. 2024).

While microclimate is fundamentally influenced by habitat structure, affecting insect distribution across major landscape types such as forests and agricultural fields (Herdananta et al. 2025), our plot-level analysis within a single plantation revealed no statistically significant differences in temperature, humidity, light intensity, or wind speed across the four pruning years (PY 1-PY 4). This suggests that the cyclical pruning intervention did not generate substantially divergent mean microclimatic conditions within the timeframe of this study. This finding is consistent with research in managed forest ecosystems, where canopy structure strongly regulates microclimate, yet statistically detectable shifts often require recovery periods extending beyond a few years (Kovács et al. 2020).

Later pruning years (PY 3 and PY 4) are associated with increased wind speed and light intensity, which create a more aerated and illuminated understory environment that influences insect assemblages by modifying microclimatic conditions and resource availability. Studies show that insects respond behaviorally to changes in light intensity, with swarming midges (*Chironomus riparius*) increasing activity under brighter conditions, indicating that light can directly affect insect movement and aggregation patterns (Sinhuber et al. 2019). Similarly, *Drosophila melanogaster* displays intensity-dependent behavioral responses, with low-intensity UV light evoking positive phototaxis and high-intensity UV light triggering avoidance behavior (Baik et al. 2019). Moths (*Galleria mellonella*) show dose-dependent responses to light intensity, with increased walking and jumping frequencies at higher light levels (Jägerbrand et al. 2023). Wind speed also plays a role in shaping insect communities; for example, flying insect abundance varies with wind conditions, and wind directionality can influence the spatial organization of invertebrate metacommunities by affecting dispersal patterns (Saha et al. 2023).

Genera including *Lasioglossum*, *Syrphus*, *Amata*, *Musca*, and *Taeniaptera* showed a positive association with the greater wind exposure and higher light availability characteristic of later pruning stages. These abiotic conditions directly shape insect behavior and resource utilization. At the canopy height where sampling occurred (150 cm), light availability in later pruning stages remains relatively high despite overall canopy maturation, as sensors were positioned within the upper canopy rather than beneath it. Within this structurally complex environment, patches of greater light penetration may enhance the visibility and accessibility of floral resources, potentially improving foraging efficiency for pollinators such as *Lasioglossum* and *Syrphus* that were positively associated with higher light intensity in the CCA. Elevated wind exposure, meanwhile, can influence movement and dispersal; certain insects can actively orient their flight relative to wind direction, facilitating navigation even when wind speeds exceed their own flight capacity (Sarig and Ribak 2021).

Genera such as *Altica*, *Sepedon*, *Syrphus*, *Gonocerus*, and *Amata* show a strong association with the cooler temperatures and higher humidity levels that characterize specific microclimates within the plantation. These conditions provide critical physiological benefits: lower temperatures mitigate thermal stress, while higher humidity supports water balance by reducing desiccation risk (Sinclair et al. 2024). Similar patterns have been observed across multiple bee species, with differential sensitivities to thermal and desiccation stress influencing their distribution and resilience to climate change (Burdine and McCluney 2019; Gonzalez et al. 2024). Although high humidity generally promotes survival by limiting water loss, extreme temperature-humidity combinations can induce oxidative stress and disrupt metabolic functions, as observed in honeybees (Li et al. 2019).

This study demonstrates that the pruning cycle in tea plantations is a significant driver of flying insect diversity and community composition, while plot-level microclimate, measured at a single point in time, showed no statistically significant variation across pruning years. Specifically, a longer period since pruning was associated with greater total insect abundance and distinct shifts in functional groups. Most notably, pollinators were exclusively present in later pruning stages (PY 3 and PY 4), whereas predators remained abundant and parasitoids increased over time. These findings suggest that tea plantation management can enhance agroecosystem balance and resilience by strategically leveraging the habitat gradient created by pruning. The consistent presence of natural enemies across the cycle indicates an inherent potential for biological pest control. The temporal bottleneck for pollinators, however, highlights a key management consideration: large-scale synchronized pruning may periodically limit this ecosystem service.

As an evergreen perennial crop, tea provides a relatively stable habitat that supports diverse insect communities. By intentionally managing this habitat through practices such as asynchronous pruning schedules, plantation managers can promote a more stable and continuous supply of ecosystem services. This approach aligns with the broader principle that increasing within-crop habitat complexity promotes biodiversity (Barrios et al. 2018) and supports effective natural enemy communities (Chen et al. 2019), thereby contributing to sustainable pest management and the conservation of biodiversity within agricultural landscapes (Liu et al. 2024).

In conclusion, our study acknowledges several methodological considerations that frame the interpretation of its findings. Spatially, microclimate measurements at the plot scale capture average conditions but may not reflect fine-scale heterogeneity relevant to insects, such as edge effects or ground-level microhabitats. The synchronic design effectively isolates pruning effects from temporal variation but cannot account for seasonal, interannual, or fine-scale spatial environmental differences that may influence insect communities. While block selection minimized major environmental heterogeneity, residual variation in microhabitat conditions cannot be excluded. Longitudinal studies with replicated sites would help address these limitations. Taxonomically, genus-level identification combined with yellow pan traps provides a standardized, functional overview but may underrepresent nocturnal, trap-averse, or cryptic taxa, while potentially masking species-specific responses within genera. Future research incorporating continuous microclimate monitoring, multi-season sampling, and species-level identification would be valuable for elucidating the finer-scale and longer-term dynamics of insect communities in these managed successional habitats.

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