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Diversity and Abundance of Insect Pollinators Associated with Bitter Gourd (*Momordica charantia* L.) and Their Role in Sustainable Pollination Services

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ABSTRACT

Bitter gourd (Momordica charantia L.), an economically important cucurbit crop cultivated widely across tropical and subtropical regions, relies predominantly on insect-mediated cross-pollination for successful fruit set and yield. Understanding the diversity and activity of floral visitors is essential for developing pollinator-friendly crop management strategies. The present study was conducted during 2023–2024 through weekly field surveys in bitter gourd-growing ecosystems of Tiruchirappalli district, Tamil Nadu, India, to document the diversity, abundance, and temporal distribution of insect pollinators. Pollinator observations were recorded at regular intervals between 06:00 and 18:00 h using direct field observations, sweep netting, aspirators, and pan traps throughout the flowering period. A total of 51 insect species belonging to four major orders Hymenoptera, Lepidoptera, Diptera, and Coleoptera—were recorded visiting bitter gourd flowers for nectar and pollen collection, predation, and feeding. Hymenoptera constituted the dominant group with 19 species, followed by Lepidoptera (15 species), Diptera (7 species), and Coleoptera (6 species). Among the pollinators, Tetragonula iridipennis was the most abundant species, followed by Apis florea, Halictus sp., and Apis cerana indica, whereas Syrphus ribesii represented the dominant dipteran pollinator. Among butterflies, Pachliopta hector was the most frequently observed species, followed by Danaus chrysippus, Tirumala limniace, and Delias eucharis. Pollinator richness was highest during 08:00–10:00 h with 26 species and declined progressively towards evening, reaching a minimum of seven species during 16:00–18:00 h. Diversity analysis revealed the greatest species diversity and evenness during 10:00–12:00 h, with Shannon–Wiener and Simpson's diversity indices of 2.52 and 9.18, respectively, indicating a well-balanced pollinator community during peak flowering hours. The predominance of native bee species highlights their crucial role in ensuring effective pollination and improving crop productivity. The study emphasizes the ecological significance of conserving pollinator diversity through reduced pesticide application during peak foraging periods and the adoption of pollinator-friendly agricultural practices. These findings provide valuable baseline information for biodiversity conservation and sustainable bitter gourd production by promoting ecosystem services essential for long-term agricultural productivity.

Keywords: *Momordica charantia, insect pollinators, floral visitors, pollination ecology, Hymenoptera, biodiversity, Shannon diversity index, sustainable agriculture.*

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Introduction

Pollination is a fundamental ecological process that ensures the sexual reproduction of flowering plants and contributes significantly to biodiversity conservation, ecosystem resilience, and global food security. In agricultural ecosystems, animal-mediated pollination enhances fruit set, seed production, crop quality, and overall yield. Approximately 75% of global food crop species benefit from animal pollination, while nearly 35% of worldwide agricultural production depends directly on pollinator services [1].

Recent global assessments further emphasize that pollinators contribute an estimated US$235–577 billion annually to global crop production, highlighting their immense ecological and economic value [2,3]. Pollination by insects remains one of the most sustainable and environmentally friendly ecosystem services for improving productivity in cross-pollinated crops while reducing dependence on external agricultural inputs [4,5]. In agroecosystems, pollination substantially enhances crop productivity, fruit quality, and seed set.

It has been estimated that 75% of cultivated crops benefit from animal pollinators, and roughly 35% of global food production depends directly on pollination services [6]). Insect pollination is therefore widely regarded as a cost-effective and environmentally sustainable approach for improving yields in cross-pollinated crops [4].

The family Cucurbitaceae comprises more than 1,000 species distributed across approximately 100 genera and includes several economically important vegetable crops such as ridge gourd (*Luffa acutangula* L. Roxb.), cucumber (*Cucumis sativus*), pumpkin (*Cucurbita* spp.), bottle gourd (*Lagenaria siceraria*), sponge gourd (*Luffa cylindrica*), bitter gourd (*Momordica charantia*), and chayote (*Sechium edule*). These crops are extensively cultivated throughout tropical and subtropical regions and play an important role in nutritional security and rural livelihoods owing to their high content of carbohydrates, dietary fibre, vitamins, antioxidants, and essential minerals [7,8].

Among cucurbits, ridge gourd is predominantly monoecious and cross-pollinated, bearing separate staminate and pistillate flowers on the same plant. Consequently, successful fruit set depends almost entirely on efficient insect-mediated pollen transfer [9] Wind pollination contributes minimally because cucurbit pollen grains are relatively large, sticky, and heavy, making entomophily the principal mechanism of fertilization [10] Pollination efficiency directly influences fruit quality, seed development, fruit shape, and marketable yield in cucurbit crops [11,12]

The floral biology of ridge gourd further emphasizes the importance of insect pollinators. Flowers generally open during the late afternoon or evening, remain receptive for only a short duration, and exhibit maximum pollen viability immediately after anthesis before declining rapidly [13,10] This narrow period of floral receptivity limits opportunities for pollination by managed honey bees and increases the significance of native bees, solitary bees, stingless bees, nocturnal moths, and crepuscular pollinators. Native pollinators often provide more effective pollination because of their synchronized foraging behaviour and frequent flower visitation [14,15].

Worldwide, insect pollinator populations are experiencing alarming declines due to habitat fragmentation, excessive pesticide use, climate change, invasive species, and emerging pathogens, posing a serious threat to crop production and ecosystem functioning [16,17,18] These concerns have renewed interest in documenting pollinator diversity and developing pollinator-friendly agricultural practices that conserve beneficial insects while maintaining crop productivity. Although several studies have documented pollinator diversity in cucurbit crops, comprehensive information on the diversity, abundance, and temporal activity of insect pollinators associated with ridge gourd remains limited, particularly under Indian agroecosystems. Characterizing pollinator communities is essential for understanding plant–pollinator interactions, improving pollination efficiency, and formulating evidence-based conservation strategies. Therefore, the present investigation was undertaken to document the diversity and abundance of insect pollinators visiting ridge gourd flowers, identify dominant pollinator groups, and generate baseline information for developing pollinator-friendly crop management practices that support sustainable vegetable production. Flowers typically open in the late afternoon or evening and remain receptive for a brief period, usually lasting a single night.

Pollen viability peaks immediately after anthesis and declines rapidly thereafter [10, 19]. Successful fruit set in cucurbits depends on efficient pollen transfer. Most cucurbit species are monoecious, bearing separate male and female flowers on the same plant, which necessitates biotic pollen transfer for fertilization [20]. Wind dispersal is generally ineffective because cucurbit pollen grains are relatively large, heavy, and adhesive. Therefore, insect visitors are critical for achieving optimum fruit set, seed development, and marketable yield in cucurbit crops.

Material and Methods

The field investigation was conducted during the 2023–2025 cropping season at the Vegetable Research Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth (PDKV), Maharaj bag Road, Nagpur, Maharashtra, India. The experimental farm is situated at approximately 21°08′57″ N latitude and 79°04′45″ E longitude, at an altitude **of** approximately 310 m above mean sea level (MSL)**.** Nagpur experiences a tropical wet-and-dry climate, characterized by hot summers, a monsoon season extending from June to September, and mild winters, making it suitable for the cultivation of cucurbitaceous vegetable crops.

The experiment was conducted in a 500 m² experimental plot laid out in a Randomized Block Design (RBD). Ridge gourd was cultivated following the recommended package of agronomic practices prescribed by Dr. Panjabrao Deshmukh Krishi Vidyapeeth, with a plant-to-plant spacing of 0.75 m and appropriate row spacing to facilitate crop growth and pollinator observations. Standard irrigation, nutrient management, intercultural operations, and plant protection measures were followed throughout the cropping season. No insecticidal sprays were applied during the flowering period to avoid interference with the natural pollinator assemblage.

Investigations on the diversity and abundance of insect pollinators were carried out throughout the flowering period of the crop. Pollinator sampling was performed at weekly intervals from 10% flowering until 90% flowering to document seasonal changes in pollinator communities. Insect visitors were sampled using a combination of water pan traps, sweep netting, and hand aspirators to ensure comprehensive collection of both flying and flower-visiting insects. Sampling was conducted during peak flowering hours under favourable weather conditions to maximize pollinator observations.

Collected insect specimens were preserved following standard entomological procedures. Hard-bodied insects were pinned and preserved as dry specimens, whereas soft-bodied insects were preserved in 70% ethanol for subsequent examination. The specimens were identified to the lowest possible taxonomic level (species or genus) using standard taxonomic keys and available identification manuals. The diversity, abundance, and relative composition of pollinator species visiting ridge gourd flowers were subsequently analysed to assess the pollinator community associated with the crop.

The relative abundance of species was calculated using the formula given below.

Relative abundance (%) = Ni ÷ NA × 100 [21]

Where,

Ni = Total number of individual pollinator species

NA = Total number of pollinator species

Shannon-Wiener Diversity Index

It was used to quantify community diversity, incorporating both the number of individuals and the number of taxa [22]

The formula used for calculation-

$H = -\Sigma\, Pi \ln Pi$

Where,

$Pi = S / N$

S = number of species

N = total number of individuals

ln = logarithm to base e

Simpson index

The Simpson index, which accounts for both species richness and the relative abundance of each species, was calculated as 1 – D [23]

The formula used for calculation -

$D = \Sigma ni\,(ni - 1) / N(N-1)$

where,

ni = Total number of individuals of a particular species

N = Total number of individuals of all species

Statistical analysis: The abundance and diversity of insect pollinators collected from four cucurbitaceous vegetables were computed by the following indices using the software PAST (Paleontological Statistics Tool) version 3.25.

Results and Discussion

Bitter gourd (*Momordica charantia* L.) is a monoecious and predominantly cross-pollinated cucurbit crop that depends largely on insect pollinators for effective pollen transfer, fertilization, fruit set, and seed production. During the present investigation, a total of 51 insect pollinator species belonging to four orders, namely Hymenoptera, Lepidoptera, Diptera, and Coleoptera, were recorded visiting bitter gourd flowers throughout the flowering period. Hymenoptera represented the dominant order with 19 species, followed by Lepidoptera (15 species), Diptera (7 species), and Coleoptera (6 species). The majority of floral visitors were observed collecting nectar and pollen, while a few predatory and scavenging insects were also encountered on the flowers.

Among the hymenopteran pollinators, *Tetragonula iridipennis* was the most abundant species, followed by *Apis florea*, *Halictus* sp., and *Apis cerana indica*, indicating that native stingless bees and honey bees constituted the major pollinator guild associated with bitter gourd. Among dipteran visitors, *Syrphus ribesii* was the dominant species, whereas *Pachliopta hector*, followed by *Danaus chrysippus*, *Tirumala limniace*, and *Delias eucharis*, represented the most frequently observed lepidopteran pollinators.

Pollinator activity varied considerably throughout the day. The highest species richness (26 species) was recorded during 08:00–10:00 h, while the lowest richness (7 species) occurred during 16:00–18:00 h, indicating that the morning hours constitute the peak foraging period.

Diversity indices further supported this pattern, with Shannon–Wiener diversity index (H′ = 2.52) and Simpson's diversity index (9.18) attaining their maximum values during 10:00–12:00 h**.** Shannon's evenness ranged from 0.44 to 0.86, whereas Simpson's evenness varied between 0.28 and 0.54, indicating a relatively uniform distribution of pollinator species during peak flowering hours. The predominance of native bees highlights their ecological significance in facilitating effective pollination and maximizing fruit production in bitter gourd.

The present findings are consistent with earlier reports on cucurbit pollination. [24 documented a rich diversity of hymenopteran pollinators in cucurbit crops, with native bees constituting the dominant pollinator group. Similarly, [25] reported *Apis dorsata*, *Apis florea*, *Xylocopa* spp., syrphid flies, and muscid flies as important pollinators of cucurbits under Indian field conditions. The dominance of Tetragonula iridipennis observed in the present study agrees with the findings of [26] who identified stingless bees as highly efficient pollinators because of their frequent flower visitation and synchronized foraging behaviour in cucurbit vegetables.

Recent investigations have emphasized that wild and native bees contribute significantly to crop pollination, often surpassing managed honey bees in pollination efficiency, particularly in tropical agroecosystems [27, 28] The abundance of halictid bees recorded in the present study also corroborates the observations of [29] who highlighted the importance of bee diversity in ensuring stable pollination services across agricultural landscapes. Furthermore, syrphid flies and butterflies, although less abundant than bees, provide supplementary pollination, especially under conditions where bee activity is reduced due to climatic factors [30].

The temporal variation in pollinator visitation observed during the present investigation corresponds closely with the flowering biology of bitter gourd, where maximum nectar secretion and pollen availability occur during the early morning hours, thereby attracting a greater diversity of insect visitors. Similar diurnal patterns have been reported in bitter gourd and other cucurbit crops by [31,32] who observed peak bee activity between 08:00 and 11:00 h. Reduced visitation during the afternoon may be attributed to elevated temperature, declining nectar rewards, and reduced pollen availability.

The present investigation further highlights the importance of conserving native pollinator communities through pollinator-friendly agricultural practices. Excessive pesticide application during peak flowering periods can significantly reduce bee populations and consequently affect fruit set and crop productivity. Recent studies recommend restricting pesticide applications during morning foraging hours, maintaining flowering field margins, and preserving natural habitats to sustain pollinator diversity and ecosystem services [33,34,35].The results of the present study provide valuable baseline information on the diversity, abundance, and temporal dynamics of insect pollinators associated with bitter gourd and reinforce the importance of integrating pollinator conservation into sustainable cucurbit production systems.

Table 1: List of insect pollinators from Bitter gourd (Momordica charantia L.)

S. No.	Order	family	Common name	Scientific name	No. of individuals
1.	Hymenoptera	Apidae	Stingless bee	*Tetragonula* sp.	50
			Indian little bee	*Apis florea* Fabricus	15
			Rock bee	*Apis dorsata* Fabricius	20
			Carpenter bee	*Xylocopa* sp.	5
			Pubescent carpenter bee	*Xylocopa* (Koptortosoma) *pubescens*	2
			Blue banded bee	*Amegilla* sp.	35
			Digger bees	*Amegilla violacea* (Lepeletier)	10
			Small carpenter bee	*Ceratina binghami* Cockerell	8
				Sub total	**145**
		Halictidae	Alkali bee	*Nomia* sp.	80
				Sub total	**80**
		Megachilidae	Woodborer bee	*Lithurgus* sp.	10
				Sub total	**10**
		Formicidae	Common black ant	*Camponotus compressus* Fab.	65
			Acrobat ant	*Crematogaster* sp.	55
			Tropical fire ants	*Solenopsis* sp.	25
				Sub total	**145**
				Total of families	**380**
2.	Lepidoptera	Nymphalidae	Plain tiger	*Danaus chrysippus* Linn.	4
				Sub total	**4**
		Pieridae	Common grass yellow	*Eurema hecabe* Linn.	6
			Crimson tip	*Colotis danae* Fabricius	2
			Pioneer white	*Belenois aurota*	2
		Hesperiidae		**Sub total**	**10**
			Paint brush swift	*Baoris* sp.	5
				Sub total	**5**
				Total of families	**19**
3.	Diptera	Syrphidae	Common hover fly	*Ischidon scutellaris* Fabricius	8
			Hover fly	*Eristalinus quinquestriatus* Fabricius	10
				Sub total	**18**
		Calliphoridae	Blow fly	*Chrysoma* sp.	5
				Sub total	**5**
		Muscidae	House fly	*Musca* sp.	6
				Sub total	**6**
				Total of families	**29**
				Overall Total	**428**

Relative Abundance of Insect pollinators on Bitter gourd (*Momordica charantia* L.)

Ridge gourd flowers are receptive for only a single day and undergo senescence shortly after anthesis, making pollination dependent on floral visitors due to a limited period of flower receptivity. The relative abundance of insect pollinators recorded on ridge gourd flowers is presented in (Table.2). Among the documented insect orders, Hymenoptera was reported as dominant with relative abundance 88.78%, followed by Diptera (6.78%) and Lepidoptera (4.44%) (Figure 1). This highlights the important role of hymenopterans in ridge gourd pollination. In contrast, Apidae (33.88%), Formicidae (33.87%), and Halictidae (18.69%) were documented as the most abundant families. At the same time, the remaining families contributed comparatively little. At the species level, Nomia sp. was the most abundant pollinator (18.69% of individuals), while *Xylocopa pubescens*, *Colotis danae* and *Belenois aurota* were the least frequent (0.47% each). Overall, the results demonstrate a clear dominance of hymenopteran pollinators, particularly Apidae, Formicidae and Halictidae, highlighting their likely importance for effective pollination and reproductive success in ridge gourd.

The predominance of hymenopteran pollinators observed here is in close agreement with earlier studies. [36] reported that honey bees comprised 76.46% of ridge gourd visitors, with *A. florea*, *A. dorsata* and *A. cerana* as major species, while other families made up only 23.54% of visitors, reflecting the strong contribution of Apidae in our study found *Apis mellifera* (20.0%), *A. dorsata* (16.7%) and *Xylocopa fenestrata* (15.9%) to be dominant, and several of these taxa (*A. dorsata*, *Xylocopa* sp., *Musca* sp.) were recorded in the present work.[37] also reported *Apis* spp. as frequent ridge gourd visitors and noted higher abundances of *Xylocopa* spp., Megachilidae and Syrphidae on ridge gourd than on other crops; the exclusive occurrence of Megachilidae in our data supports a possible crop-specific association. Similarly, [38] documented Hymenoptera as nearly 80% of pollinators, followed by Diptera and Lepidoptera, reflecting our results. Contrasting findings, such as those of [39]who reported Lepidoptera as the dominant group, likely reflect differences in location, climate, cropping systems and seasonal floral resources. Taken together, these studies highlight the vital role of hymenopterans, particularly Apidae, in ridge gourd pollination and highlight the need to conserve bee communities to sustain crop productivity.

Table 2: Relative abundance of insect pollinators on Bitter gourd (Momordica charantia L.)

S. No.	Order	Family	Species	Species Abundance within Order (%)	Species Abundance among the Order (%)	Total Abundance (%)
1.	Hymenoptera	Apidae	*Tetragonula* sp.	13.16	11.68	**88.78**
			Apis florea Fabricus	3.95	3.50	
			Apis dorsata Fabricius	5.26	4.67	
			Xylocopa sp.	1.32	1.17	
			Xylocopa (Koptortosoma) *pubescens*	0.53	0.47	
			Amegilla sp.	9.21	8.18	
			Amegilla violacea (Lepeletier)	2.63	2.34	
			Ceratina binghami Cockerell	2.1	1.87	
			Sub total	**38.16**	**33.88**	
		Megachilidae	*Lithurgus* sp.	21.05	2.34	
			Sub total	**21.05**	**2.34**	
		Halictidae	*Nomia* sp.	2.63	18.69	
			Sub total	**2.63**	**18.69**	
		Formicidae	*Camponotus compressus* Fab.	17.11	15.18	
			Crematogaster sp.	14.47	12.85	
			Solenopsis sp.	6.58	5.84	
			Sub total	**38.16**	**33.87**	
2.	Lepidoptera	Nymphalidae	*Danaus chrysippus* Linn.	21.05	0.93	**4.44**
			Sub total	**21.05**	**0.93**	
		Pieridae	*Eurema hecabe* Linn.	31.58	1.4	
			Colotis danae Fabricius	10.53	0.47	
			Belenois aurota	10.53	0.47	
			Sub total	**52.64**	**2.34**	
		Hesperiidae	*Baoris* sp.	26.31	1.17	
			Sub total	**26.31**	**1.17**	
3.	Diptera	Syrphidae	*Ischidon scutellaris* Fabricius	27.59	1.87	**6.78**
			Eristalinus quinquestriatus Fabricius	34.48	2.34	
			Sub total	**62.07**	**4.21**	
		Calliphoridae	*Chrysoma* sp.	17.24	1.17	
			Sub total	**17.24**	**1.17**	
		Muscidae	*Musca* sp.	20.69	1.40	
			Sub total	**20.69**	**1.40**	
				Total	**100**	

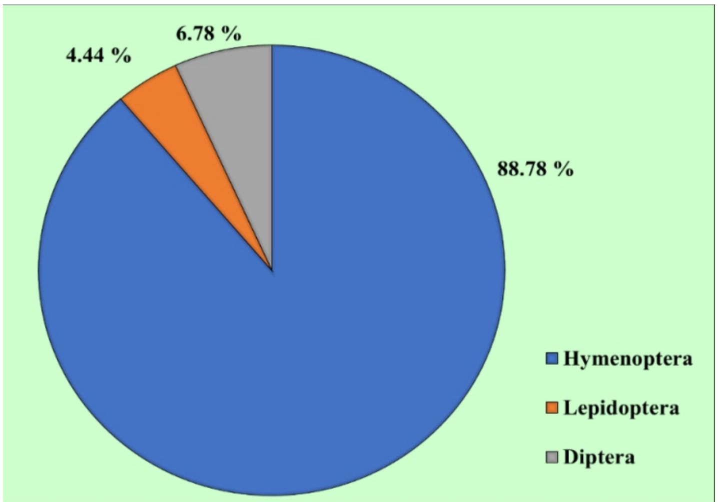

Fig. 1. Relative abundance of insect pollinator orders recorded on ridge gourd flowers

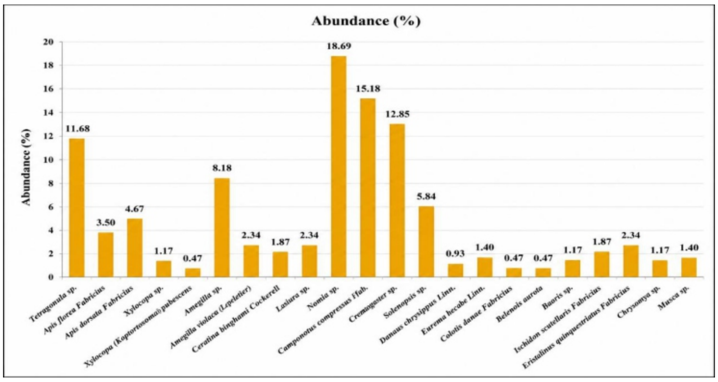

Fig. 2. Species-wise relative abundance of insect pollinators recorded on ridge gourd flowers

***Camponotus compressus* Fab. *Nomia* sp. *Amigella* sp.**

***Baoris* sp. *Apis dorsata* Fabricius *Tetragonula* sp.**

Fig. 3. Representative insect pollinators visiting Bitter gourd (Momordica charantia L.)

Shannon-Wiener Diversity Index and Simpson Index (D)

The insect pollinator community in bottle gourd exhibited a Shannon-Wiener diversity index (H′) of 2.55, suggesting considerable species diversity and a relatively even distribution of individuals among species. Simpson's diversity index (1-D) was 0.89, indicating a highly diverse pollinator community with a low probability of dominance by any single species. Amaximum Shannon diversity index of 2.52 for insect pollinators in bitter gourd, which is nearly similar to the current study [40].

Conclusion

The present study provides a comprehensive assessment of the diversity, abundance, and temporal distribution of insect pollinators associated with bitter gourd (*Momordica charantia* L.) under the agro-climatic conditions of Nagpur, Maharashtra, India. A total of 51 insect pollinator species belonging to four orders—Hymenoptera, Lepidoptera, Diptera, and Coleoptera—were recorded visiting bitter gourd flowers during the flowering period. Hymenoptera emerged as the dominant order, with *Tetragonula iridipennis*, *Apis florea*, *Halictus* sp., and *Apis cerana indica* identified as the most abundant and efficient floral visitors. Among non-bee pollinators, *Syrphus ribesii* and several butterfly species also contributed to flower visitation, indicating a diverse pollinator assemblage.

Peak pollinator activity and species richness were observed during the morning hours (08:00–10:00 h), coinciding with maximum floral reward availability and stigma receptivity, highlighting the importance of this period for effective pollination.

The predominance of native bee species underscores their vital ecological role in ensuring efficient pollen transfer, fruit set, and seed production in bitter gourd.

The findings provide valuable baseline information on the pollinator community associated with bitter gourd cultivation in central India and emphasize the need for pollinator conservation through sustainable agricultural practices. Avoiding pesticide applications during peak foraging hours, maintaining flowering field margins, conserving natural habitats, and promoting integrated pest and pollinator management strategies are essential to sustain pollinator populations and enhance crop productivity. The present study contributes to a better understanding of plant–pollinator interactions in *Momordica charantia* and offers useful information for developing pollinator-friendly cultivation practices aimed at improving yield, conserving biodiversity, and ensuring sustainable vegetable production under changing agricultural landscapes.

Declaration of AI Use

This manuscript was prepared through the combined contributions of all author(s), including contributions to the study design, data, content development, results, interpretation, and related scholarly work. The author(s) acknowledge the use of Grammarly and ChatGPT to assist with grammar checking, language refinement, and reference formatting. These AI-assisted tools were not used by the author (s) and did not replace the intellectual contributions or scholarly judgment of the author(s).

All AI-assisted outputs, including content, references, and interpretations, were carefully reviewed, revised, verified, and approved by the author(s). The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

COMPETING INTERESTS DISCLAIMER

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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