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Butterflies and their floral partners: Diversity, foraging behaviour and potential pollination services for sustainable agriculture in Birbhum, West Bengal

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Abstract
Butterflies are important components of terrestrial ecosystems and may contribute substantially to pollination and plant reproductive success. The present study investigated butterfly–flower associations and potential pollination interactions in Birbhum district, West Bengal, India, during 2024 - 2026. Field observations were conducted across Santiniketan, Sriniketan, Ballavpur and Ganpur, covering cultivated crops, wild herbs, shrubs, ornamental plants and trees. Flower-visiting butterflies were documented through direct observations and photographic records, with emphasis on floral resources, feeding behaviour and interactions with reproductive structures. A diverse assemblage of lepidopteran visitors was recorded from several plant families. Butterflies showed frequent associations with tubular flowers, suggesting a relationship between floral corolla dimensions and butterfly proboscis length that may facilitate effective nectar foraging and pollen transfer. Repeated contact with anthers and stigmas indicated potential pollination services and a reciprocal relationship between butterflies and flowering plants. These interactions highlight the ecological importance of maintaining floral diversity and butterfly-friendly habitats. The findings also provide baseline information for the development and maintenance of butterfly parks and gardens. However, quantitative studies of pollen loads, stigma pollen deposition, fruit set and seed production are needed to confirm pollination efficiency.

Keywords: Butterfly-flower interactions, foraging, Lepidoptera, pollination

Introduction

Pollination is a key ecosystem service that supports the reproduction of flowering plants, crop production, biodiversity and food security. Animal-mediated pollination contributes substantially to the production of many food crops, while also supporting the maintenance of natural plant communities and ecosystem functioning (IPBES, 2016; Food and Agriculture Organization of the United Nations [FAO], 2023) [7, 10]. However, agricultural intensification, habitat loss and fragmentation, pesticide use, reduction in floral resources and climate change are increasingly affecting pollinator abundance, diversity and behaviour. The interactive effects of land-use change and climate change may pose particularly serious risks to pollination-dependent crops in tropical regions (Millard *et al*., 2023) [16]. Conservation of diverse pollinator communities and their floral resources is therefore essential for maintaining resilient ecosystems and sustainable agriculture.

Among insect pollinators, butterflies are conspicuous and ecologically important components of terrestrial ecosystems. Adult butterflies primarily obtain energy from floral nectar, whereas their larvae generally depend on specific host plants for feeding and development. Consequently, the abundance and distribution of butterfly populations are closely associated with the availability, diversity and seasonal continuity of larval host plants and adult nectar resources (Dennis *et al*., 2006) [4]. The availability of both resource types is particularly important for maintaining butterfly populations in fragmented and human-dominated landscapes. Because butterflies are sensitive to changes in habitat structure, resource availability, land-use patterns and climatic conditions, their diversity and community composition can provide useful information about habitat condition and ecological change (Bonebrake *et al*., 2010; Lee *et al*., 2021) [1, 14]. However, butterflies should be considered as one component of broader biodiversity monitoring rather than as universal surrogates for all pollinator groups (Segre *et al*., 2023) [18].

The interaction between butterflies and flowers is strongly influenced by floral morphology and pollinator behaviour. Floral colour, shape, nectar accessibility, scent and the presence of suitable landing surfaces can influence butterfly visitation and foraging behaviour (Corbet, 2000; Sinha *et al*., 2023; Watanabe, 2026) [3, 20, 23]. In particular, corolla dimensions may influence nectar accessibility according to the morphology of the butterfly proboscis (Corbet, 2000; Kunte, 2007; Stefanescu and Reim, 2020) [3, 13, 21]. Such morphological matching can facilitate effective foraging and repeated contact between visiting butterflies and floral reproductive structures, thereby creating opportunities for pollen transfer (Kunte, 2007) [13]. Floral traits are consequently important components of plant–pollinator interactions and may reflect ecological and evolutionary relationships between plants and their pollinators (Faegri and van der Pijl, 1979) [6].

Although bees are widely recognized as major pollinators, butterflies also visit a wide range of flowering plants and may contribute to pollen movement among flowers (Jennersten, 1984; Corbet, 2000) [3, 11]. Their role can be particularly important in diverse agricultural and semi-natural landscapes where flowering plants provide continuous nectar resources (Dennis *et al*., 2006) [4]. Animal pollination can influence not only fruit and seed production but also commercially important characteristics such as fruit size, shape, appearance and market quality (Gazzea *et al*., 2023) [8].

Despite the ecological importance of butterfly–flower interactions, information on their diversity and potential pollination roles remains limited in many regions of eastern India (Selvarathinam *et al*., 2009; Chowdhury, 2014) [2, 19]. Therefore, the present study investigates butterfly–flower associations in Birbhum district, West Bengal, with particular emphasis on flower-visiting behaviour, floral characteristics, nectar foraging and potential pollen transfer (Selvarathinam *et al*., 2009; Panda *et al*., 2019) [17, 19]. The study also examines associations between butterfly morphology and floral architecture and provides baseline information relevant to the conservation and development of butterfly-friendly gardens and parks (Corbet, 2000; Majewska and Altizer, 2019) [3, 15].

Materials and Methods

Study Area and Sampling

Field investigations were conducted at selected sites in Birbhum district, West Bengal, India, with particular emphasis on Santiniketan, Sriniketan, Ballavpur, and Ganpur. These sites were selected to represent diverse semi-natural, agricultural, and vegetation-dominated habitats supporting a variety of flowering plants and associated insect fauna. Field collections and observations were carried out from July, 2024 to June, 2026, covering different seasons to account for temporal variation in insect abundance and plant–insect interactions.

Collection and Preservation of Insects

Insects associated with flowering plants, including potential pollinators and phytophagous insects, were collected using hand-picking and sweep-net techniques. Both small-bodied insects, such as aphids and mealybugs, and larger insects were sampled. Larger specimens were collected carefully and euthanized using appropriate insect-killing agents before preservation. Small and soft-bodied insects were preserved in 70–90% ethyl alcohol in labelled glass vials. For insects associated with foliage, infested leaves were collected in airtight polyethylene bags and transported to the laboratory. The specimens were subsequently examined under a binocular stereomicroscope, and the associated insects were carefully removed for further examination, identification, and documentation.

Observation of Flower Visitors and Pollination Behaviour

Flower-visiting insects were observed directly in the field during periods of floral activity. Following established pollination-observation protocols (Kearns and Inouye, 1993) [12], foraging duration, visitation frequency, feeding behaviour, floral resources utilized, and diet composition were recorded. Particular attention was given to the interaction between floral morphology and visitor behaviour to characterize probable pollination syndromes. Field observations were supplemented with photographic and videographic documentation. The collected specimens and field observations were subsequently used for taxonomic identification and assessment of plant–pollinator associations.

Results and Discussion

Diversity of butterfly - flower associations

Field observations conducted during the study period revealed a diverse assemblage of lepidopteran flower visitors associated with cultivated, semi-natural and wild flowering plants in the study area. The photographic records documented repeated visitation by butterflies and moths to flowers belonging to several plant families, indicating a considerable diversity of plant–lepidopteran interactions. The recorded associations involved both generalist and relatively specialized flower visitors and included nectar-feeding, landing, crawling over floral surfaces and direct contact with anthers and stigmas.

Table 1: Plant Species belonging the family Cucurbitaceae and their associated Butterfly visitors

Family	Name of the plant	Flower visitors
Cucurbitaceae	*Cucurbita pepo* L	*Freyeria putili* (Small Grass Jewl) (Family- Lycaenidae)
	Cucurbita maxima Duchesne	*Borbo* sp. (Family- Hesperiidae)
	Benincasa hispida (Thunb.) Cogn.	*Borbo* sp.,(Family - Hesperiidae) *Macroglossum* sp. (Family- Sphingidae)
	Cucumis sativus L.	*Abisara echerius* (Family- Riodinidae) *Borbo* sp. (Family- Hesperiidae) *Hypolimnas bolina* (Family- Nymphalidae) *Eurema hecabe* (Family- Pieridae)
	Citrullus colocynthis (L.) Schrad.	*Borbo* sp. (Family- Hesperiidae)
	Trichosanthes anguina L.	*Deudorix Isocrates* (Family- Lycaenidae)
	Momordica charantia L.	*Pieris canidia* (Family- Pieridae)

The first group of observations primarily involved flowers of Cucurbitaceae (Table 1). *Freyeria putli* was recorded visiting *Cucurbita pepo* (Fig. 1a), while *Borbo* sp. was observed on *Cucurbita maxima* (Fig. 1b), *Cucumis sativus* (Fig. 1d), and *Citrullus colocynthis* (Fig. 1e). *Borbo* sp. was also observed visiting *Cucumis sativus* in another floral context (Fig. 1f). *Deudorix isocrates* was recorded visiting *Trichosanthes anguina* (Fig. 1g), whereas *Macroglossum* sp. was observed hovering at the flowers of *Benincasa hispida* (Fig. 1h). *Pieris canidia* was documented on *Momordica charantia* (Fig. 1i). These observations demonstrate that cucurbitaceous flowers attracted several lepidopteran visitors and may function as important nectar resources within the local agricultural landscape.

The photographs further indicate that several visitors contacted the reproductive structures while foraging. In cucurbit flowers, the relatively large and conspicuous corollas, exposed reproductive structures and accessible floral rewards provided suitable sites for insect visitation. The repeated occurrence of lepidopterans on these flowers suggests that they may contribute to pollen movement, although the relative effectiveness of individual visitors requires quantitative assessment.

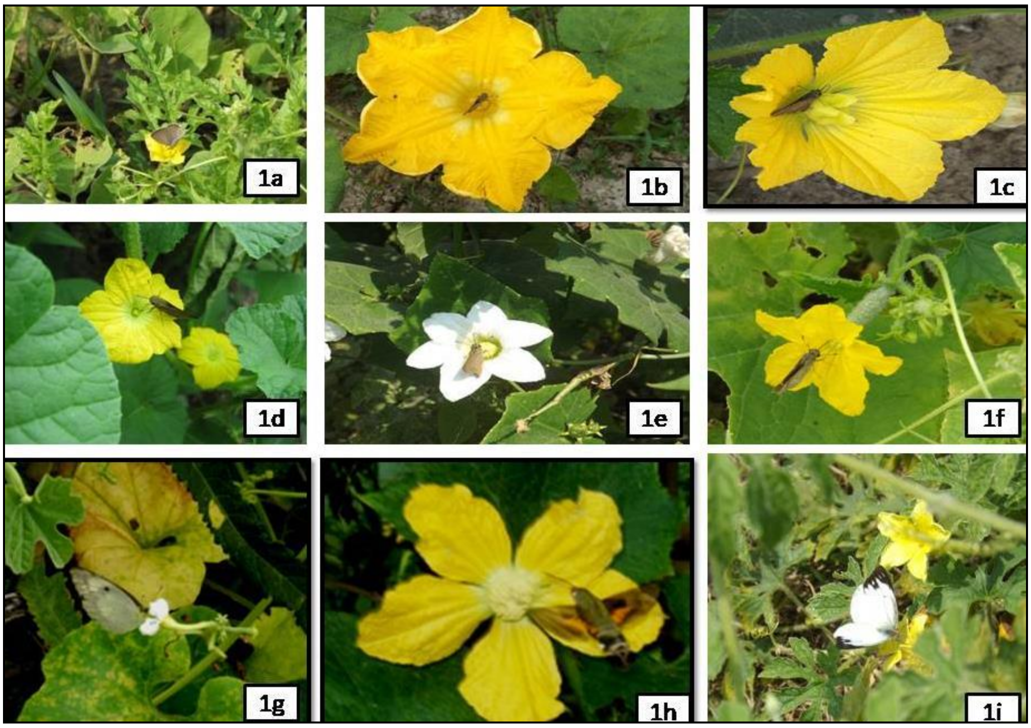

Fig 1: Lepidopteran flower visitors associated with cucurbitaceous crops: (a) *Freyeria putli* on *Cucurbita pepo*; (b) *Borbo* sp. on *Cucurbita maxima*; (c–d) *Borbo* sp. visiting *Cucumis sativus*; (e) *Borbo* sp. on *Citrullus colocynthis*; (f) *Borbo* sp. on *Cucumis sativus*; (g) *Deudorix isocrates* on *Trichosanthes anguina*; (h) *Macroglossum* sp. hovering near *Benincasa hispida* and (i) *Pieris canidia* on *Momordica charantia*.

Flower visitation by butterflies and floral characteristics

Additional associations were recorded between butterflies and a range of herbaceous and crop plants (Table 2). *Eurema hecabe* and *Borbo* sp. were observed visiting *Sida acutifolia* (Fig. 2a–b), while *Hypolimnas misippus* was recorded on *Coriandrum sativum* (Fig. 2c). *Eurema hecabe* also visited *Foeniculum vulgare* (Fig. 2d). *Delias eucharis* was observed on the inflorescence of *Grevillea dielsiana* (Fig. 2e), while *Danaus chrysippus* and *Cepora nerissa* were associated with the flowers of *Brassica campestris* (Fig. 2f–g). *Phalanta phalantha* was recorded visiting *Allium cepa* (Fig. 2h). Further observations included *Parantica aglea* and other hesperiid visitors such as *Matapa druna* and *Borbo* sp. on *Corchorus capsularis* (Fig. 2i–j).

Table 2: Plant Families, flowering plant species and their associated Butterfly visitors

Family	Name of the plant	Flower visitors
Malvaceae	*Sida acutifolia* Steud.	*Eurema hecabe* (Family- Pieridae) *Borbo* sp. (Family- Hesperiidae)
Apiaceae	*Coriandrum sativum* L.	*Hypolimnas misippus* (Danaid Eggfly) (Family- Nymphalidae)
	Foeniculum vulgare Mill.	*Eurema hecabe* (Family- Pieridae)
Proteaceae	*Grevillea dielsiana* C.A. Gardner	*Delias eucharis* (Family- Pieridae)
Brassicaceae	*Brassica campestris* L.	*Danaus chrysippus* (Family- Nymphalidae) *Cepora nerissa* (Family- Pieridae)
Liliaceae	*Allium cepa* L.	*Phalanta phalantha* (Family- Nymphalidae)
Malvaceae	*Corchorus capsularis* L.	*Parantica aglea* (Family- Nymphalidae) *Matapa druna* (Family- Hesperiidae) *Borbo* sp. (Family- Hesperiidae)

The diversity of floral forms represented in these observations indicates that butterfly visitation was not restricted to a single floral architecture. Open, bowl-shaped, clustered and relatively shallow flowers were frequently visited, presumably because they permitted relatively easy access to nectar and pollen. For many butterflies, broad floral surfaces may also provide suitable landing platforms during feeding. Floral colour is another important visual cue for diurnal Lepidoptera, particularly where flowers are exposed against green vegetation. These observations are broadly consistent with the concept of psychophilous floral characteristics, which commonly include conspicuous colour, diurnal anthesis, accessible nectar and structures that facilitate landing and nectar extraction (Faegri and van der Pijl, 1979; Willmer, 2011) [6, 24].

Foraging behaviour and potential pollen transfer

The photographs in Fig. 3 provide further evidence of repeated interaction between lepidopteran visitors and flowering plants (Table 3). *Hypolimnas bolina* (Fig. 3a), *Abisara echerius* (Fig. 3b), and *Eurema hecabe* (Fig. 3c) were observed visiting *Cucumis sativus*. During feeding, the insects generally landed on or near the floral reproductive structures and subsequently moved towards the nectar-bearing region. Such movements can result in contact between the insect body and pollen-bearing anthers and may facilitate subsequent pollen deposition on receptive stigmas.
Zizeeria karsandra was recorded visiting *Pisum sativum* (Fig. 3d) and *Phaseolus vulgaris* (Fig. 3e), whereas *Borbo* sp. was observed on *Tephrosia purpurea* (Fig. 3f). These observations are particularly relevant because flowers of Fabaceae possess specialized floral architecture in which the

vexillum, wings and keel influence access to the reproductive organs. In such flowers, insect movement may bring the stigma and anthers into contact with specific regions of the visiting insect's body. Consequently, floral architecture can influence both the direction and efficiency of pollen transfer.

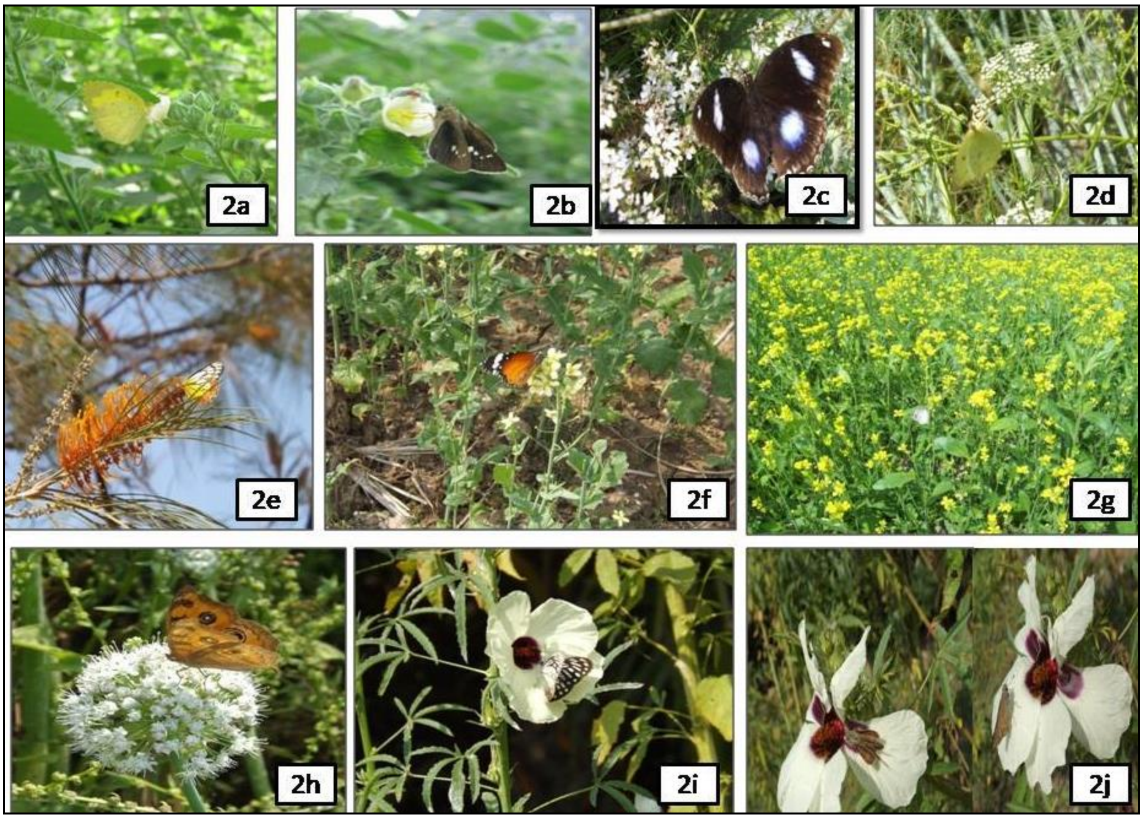

Fig 2: Butterfly visitation to diverse cultivated and wild flowering plants: (a–b) *Eurema hecabe* and *Borbo* sp. on *Sida acutifolia*; (c) *Hypolimnas misippus* on *Coriandrum sativum*; (d) *Eurema hecabe* on *Foeniculum vulgare*; (e) *Delias eucharis* on *Grevillea dielsiana*; (f) *Danaus chrysippus* on *Brassica campestris*; (g) *Cepora nerissa* on *Brassica campestris*; (h) *Phalanta phalantha* on *Allium cepa*; and (i–j) lepidopteran visitors on *Corchorus capsularis*.

Table 3: Plant Families, flowering plant species and their associated Butterfly visitors

Family	Name of the plant	Flower visitors
Fabaceae	*Pisum sativum* L.	*Zizeeria karsandra* Dark Grass Blue (Family- Lycaenidae)
	Phaseolus vulgaris L.	*Chilades pandava* Plains Cupid (Family- Lycaenidae)
	Tephrosia purpurea (L.) Pers.	*Borbo* sp. (Family- Hesperiidae)
	Lens culinaris Medik.	*Gomalia elma* African Marbled Skipper (Family- Hesperiidae)
	Acacia nilotica (L.) Delile	*Borbo* sp. (Family- Hesperiidae) *Danaus chrysippus* (Family- Nymphalidae)
Verbenaceae	*Clerodendrum abilioi* R.Fern.	*Danaus chrysippus*
Rubiaceae	*Anthocephalus cadamba* (Roxb.) Miq.	*Acraea terpsicore* (Family- Nymphalidae)
Solanaceae	*Lycopersicon esculentum* Mill.	*Eurema hecabe* (Family- Pieridae)

Danaus chrysippus was observed visiting *Clerodendrum abilioi* (Fig. 3g), while *Acraea terpsicore* was recorded on *Anthocephalus cadamba* (Fig. 3h). *Gomalia elma* was observed visiting *Lens culinaris* (Fig. 3i), and *Eurema hecabe* was recorded on *Lycopersicon esculentum* (Fig. 3j). The occurrence of butterflies on crop plants is particularly noteworthy because repeated visitation may contribute to pollen transfer where floral morphology and visitor behaviour permit effective contact with reproductive structures. Nevertheless, direct measurements of stigma pollen deposition, fruit set and seed set would be necessary to quantify their actual contribution to crop pollination.

Floral architecture and visitor-mediated pollination

The observed interactions suggest that floral morphology plays an important role in determining the accessibility and behaviour of flower visitors. In several of the recorded associations, butterflies landed on the expanded corolla or near the reproductive structures before extending their proboscis towards the nectar source. During this process, pollen grains may become attached to different parts of the insect body. Subsequent visitation to another flower provides an opportunity for pollen transfer.

The cucurbitaceous flowers represented in Fig. 1 are particularly conspicuous and provide accessible floral resources. The broad corolla and exposed reproductive structures facilitate insect access, while the position of the nectar-producing region encourages visitors to move across the floral surface. The repeated visitation of *Borbo* spp. and other lepidopterans to *Cucurbita*, *Cucumis*, *Citrullus*, *Benincasa* and *Momordica* indicates that these crops represent important floral resources for insects in the study region.

The interaction between floral structure and visitor behaviour was also apparent in *Corchorus capsularis*, *Allium cepa*, *Brassica campestris* and Fabaceae members. The large or spreading floral surfaces of some species provide suitable landing sites, whereas clustered inflorescences can offer multiple floral resources during a single foraging bout. Such characteristics may increase the energetic efficiency of flower visitation and promote repeated movements among flowers.

Flower visitors in woody and ornamental plants

The observations presented in Fig. 4 demonstrate that butterfly visitation was not limited to herbaceous crops. Several woody and ornamental plants also supported lepidopteran visitors (Table 4). Butterflies were recorded in association with flowers or inflorescences of *Pentaptera arjuna*, *Acacia nilotica*, *Heliotropium abbreviatum*, *Ixora accedens*, *Murraya paniculata*, *Murraya koenigii* and *Catharanthus roseus* (Fig. 4a–i). These observations indicate that perennial vegetation can provide additional floral resources and may contribute to maintaining flower visitors beyond the flowering period of seasonal agricultural crops.

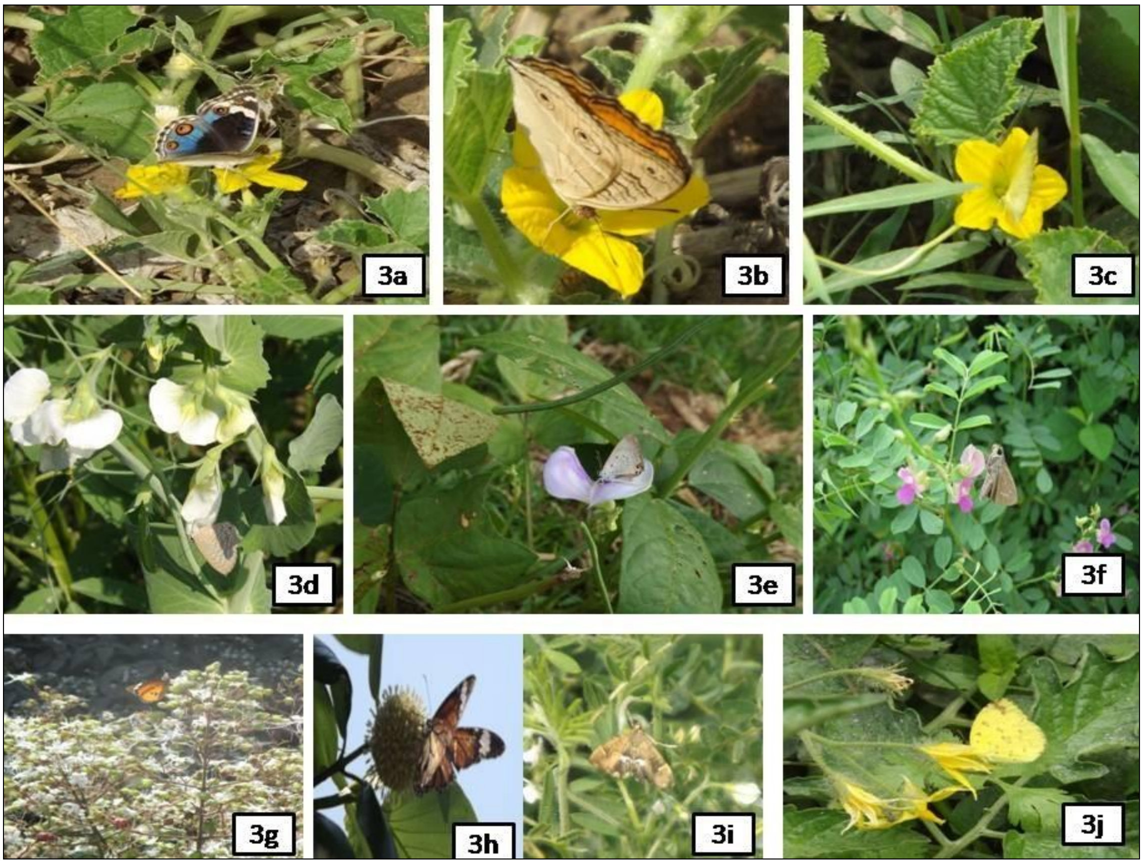

Fig 3: Lepidopteran visitors and potential pollination interactions: (a) *Hypolimnas bolina*; (b) *Abisara echerius*; and (c) *Eurema hecabe* on *Cucumis sativus*; (d) *Zizeeria karsandra* on *Pisum sativum*; (e) *Zizeeria karsandra* on *Phaseolus vulgaris*; (f) *Borbo* sp. on *Tephrosia purpurea*; (g) *Danaus chrysippus* on *Clerodendrum abilioi*; (h) *Acraea terpsicore* on *Anthocephalus cadamba*; (i) *Gomalia elma* on *Lens culinaris* and (j) *Eurema hecabe* on *Lycopersicon esculentum*.

Table 4: Plant Families, flowering plant species and their associated Butterfly visitors

Family	Name of the plant	Flower visitors
Combretaceae.	*Pentaptera arjuna* Roxb. ex DC.	*Melanitis leda* (Family- Nymphalidae) *Junonia almanac* (Family- Nymphalidae)
Boraginaceae	*Heliotropium abbreviatum* Rusby	*Danaus chrysippus* (Family- Nymphalidae)
Rubiaceae	*Ixora accedens* Valeton	*Euploea core* (Family- Nymphalidae)
Rutaceae	*Murraya paniculata* (L.) Jack	*Borbo* sp. (Family- Hesperiidae)
	Murraya koenigii L	*Prosotas noreia* (White-tipped Lineblue) (Family - Lycaenidae)
Apocynaceae	*Catharanthus roseus* (L.) G.Don	*Borbo* sp. (Family- Hesperiidae)

The dense floral arrangements of some of these plants may be particularly advantageous to butterflies because they provide multiple feeding opportunities within a small area. Repeated visitation to clustered inflorescences can increase the likelihood of pollen acquisition and subsequent deposition. However, the ecological significance of these interactions depends on visitor abundance, visitation frequency, pollen load, movement between conspecific flowers and the reproductive biology of the host plant.

Evidence for psychophilous pollination

Several characteristics observed in the study are broadly compatible with psychophily or butterfly-associated pollination. These include brightly coloured flowers, diurnal flower opening, accessible nectar, broad landing surfaces, conspicuous floral displays and floral structures that permit contact between visiting insects and reproductive organs. Butterflies primarily, use visual cues for locating floral resources, while floral odours may provide additional information during resource selection (Honda *et al*., 1998; Stefanescu and Traveset, 2009) [9, 22].

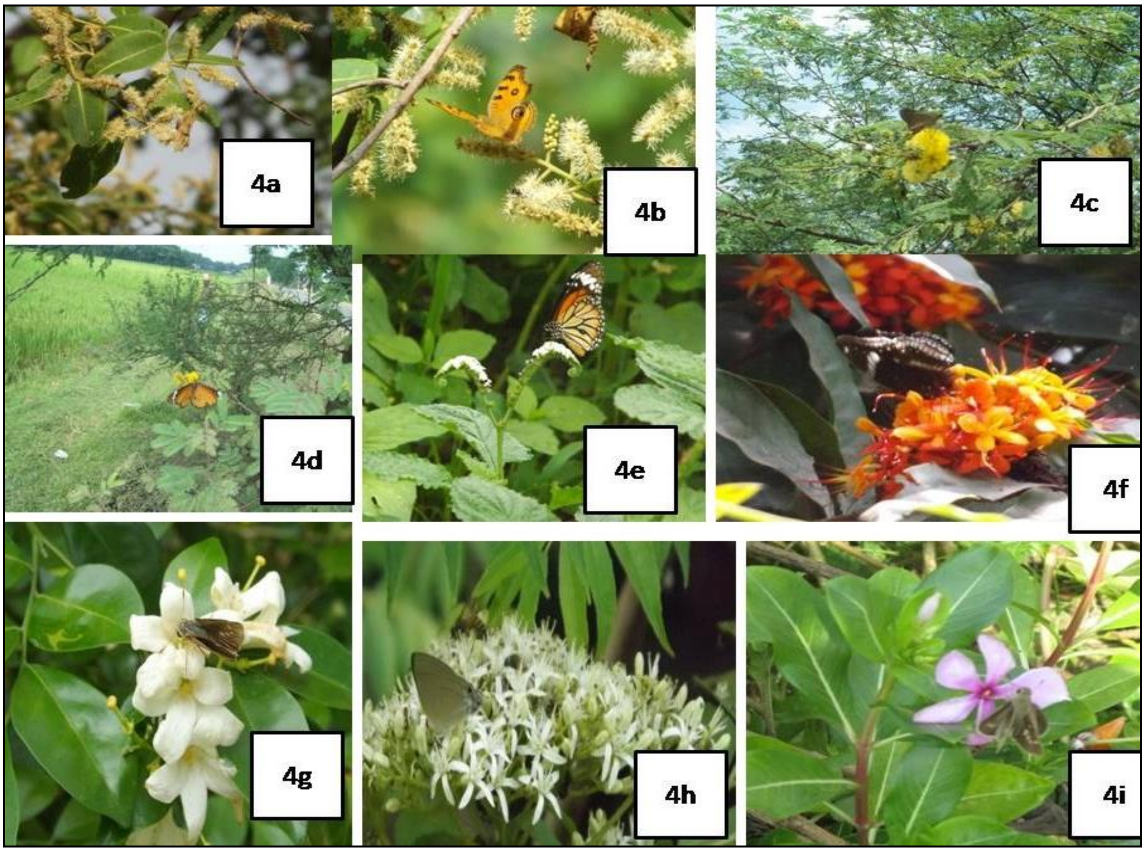

Fig 4: Lepidopteran visitation to woody and ornamental flowering plants: (a–b) butterfly visitation associated with *Pentaptera arjuna*; (c–d) visitors associated with *Acacia nilotica*; (e) *Danaus chrysippus* on *Heliotropium abbreviatum*; (f) *Euploea core* on *Ixora accedens*; (g) *Borbo* sp. on *Murraya paniculata*; (h) *Prosotas noreia* on *Murraya koenigii*; and (i) *Borbo* sp. on *Catharanthus roseus*.

The photographs demonstrate that butterflies frequently positioned themselves on the corolla or inflorescence while extending the proboscis towards the nectar source. Such behaviour can result in pollen contact with the head, thorax, legs, wings or abdomen, depending on the relative position of the anthers and stigma. When the insect subsequently visits another flower, pollen attached to its body may be deposited on the stigma. Therefore, the observed behaviour provides a plausible mechanism for insect-mediated pollen transfer.

It is important, however, to distinguish between flower visitation and effective pollination. A visitor becomes an effective pollinator only when its behaviour results in the transfer of compatible pollen to a receptive stigma and contributes to fertilization and subsequent reproductive success. The present photographic observations (Fig. 1-4) establish flower visitation and indicate potential pollen-transfer pathways but do not independently establish reproductive effectiveness.

Ecological significance of butterfly - plant interactions

The diversity of associations documented in Figs. 1–4 highlights the ecological importance of butterflies and other lepidopterans within the study area. Butterflies participate in plant–pollinator networks while simultaneously functioning as important components of terrestrial food webs. Their dependence on particular larval host plants and adult nectar resources also makes them sensitive to changes in vegetation composition, habitat fragmentation and agricultural management.

The present observations support the view that plant–pollinator relationships are dynamic interactions influenced by floral morphology, resource availability, visitor behaviour and environmental conditions. The relationship between flowering plants and their visitors can also have evolutionary consequences, because floral traits and pollinator characteristics may influence one another over ecological and evolutionary timescales (Ehrlich and Raven, 1964; Faegri and van der Pijl, 1979) [5, 6].

The extensive use of pesticides and herbicides, reduction of flowering vegetation, habitat fragmentation and climate-driven changes in flowering and insect phenology may negatively affect these interactions. Conservation of diverse flowering plants, maintenance of semi-natural vegetation, reduction of indiscriminate pesticide use and establishment of butterfly-friendly habitats can therefore contribute to the maintenance of pollinator diversity.

Overall, the present study documents a diverse set of butterfly-flower associations involving cultivated crops, herbs, shrubs and trees in Birbhum district. The photographic evidence presented in Figs. 1–4 demonstrates repeated visitation and several plausible mechanisms of pollen transfer. These findings emphasize the importance of maintaining floral diversity within agricultural and semi-natural landscapes. Future investigations should quantify visitation frequency, duration of floral visits, pollen loads, stigma pollen deposition, fruit set and seed production to determine the relative pollination efficiency of individual lepidopteran species and to distinguish casual flower visitors from effective pollinators.

Conclusion

The present study demonstrates a diverse and ecologically important assemblage of butterfly–flower interactions in Birbhum district, West Bengal. Butterflies were recorded visiting a wide range of cultivated crops, herbs, shrubs, ornamental plants, and trees, with floral morphology, colour, accessibility of nectar, and landing surfaces influencing visitation behaviour. Repeated contact with anthers and stigmas suggests that several lepidopteran visitors may contribute to pollen transfer and potentially support plant reproduction. However, the present photographic observations establish flower visitation rather than confirmed pollination effectiveness. Conservation of floral diversity, semi-natural habitats, and butterfly-friendly vegetation, together with reduced indiscriminate pesticide use, is therefore important. Quantitative studies of visitation, pollen deposition, fruit set, and seed production are recommended to establish pollination efficiency.

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