International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

# The Role of Floral Morphology and Nectar Chemistry in Host Plant Selection by Indian Swallowtail Butterflies (Papilionidae)

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**Abstract**

The intricate relationship between butterflies and their host plants has long fascinated ecologists and evolutionary biologists. Among these interactions, the selection of host plants by butterflies, particularly those belonging to the family Papilionidae, remains a subject of significant interest due to its implications for both ecological and evolutionary processes. This study delves into the role of floral morphology and nectar chemistry in influencing host plant selection by Indian Swallowtail butterflies (Papilionidae).

In addition to floral morphology, nectar chemistry serves as a pivotal factor influencing butterfly foraging preferences. Nectar composition varies widely among plant species and can significantly affect butterfly behavior, including visitation rates, duration of visits, and overall plant utilization. Understanding the specific chemical signals that butterflies perceive and prefer can provide valuable insights into the coevolutionary relationships between butterflies and their preferred host plants.

By enhancing our understanding of how floral morphology and nectar chemistry influence butterfly behavior, this study aims to inform strategies for preserving butterfly diversity and ecosystem resilience in the face of global environmental challenges.

**Keywords:** Indian Swallowtail butterflies, Papilionidae, floral morphology, nectar chemistry, host plant selection, plant-pollinator interactions, coevolution

## Introduction

Indian swallowtail butterflies (Papilionidae) play a significant role in pollination ecology and serve as vital indicators of ecosystem health due to their specialized interactions with flowering plants. As charismatic pollinators, they contribute to the reproductive success of numerous plant species across various habitats in India, thereby influencing ecosystem dynamics and biodiversity conservation.

### Pollination Ecology:

The Papilionidae family, including species like the Indian swallowtail (Papilio polytes), are important pollinators of many flowering plants. Their role in pollination is characterized by specific behavioral adaptations and morphological features that facilitate effective pollen transfer between flowers.

Swallowtail butterflies typically have long proboscises, which enable them to access nectar from deep-throated flowers that other pollinators may not reach. This specialization allows them to pollinate a diverse array of plant species that rely on such adaptations for reproduction.

Indian swallowtail butterflies exhibit distinct foraging behaviors that influence their effectiveness as pollinators. They are known to visit flowers in search of nectar, during which pollen grains adhere to their bodies. As they move from flower to flower, they inadvertently transfer pollen, facilitating cross-pollination among plants. This process is crucial for maintaining genetic diversity within plant populations and promoting the production of fruits and seeds essential for ecosystem stability.

**Significance of floral morphology and nectar Chemistry**

Floral morphology and nectar chemistry play pivotal roles in influencing host plant selection by butterflies, contributing to their foraging behaviors, reproductive success, and overall ecological interactions within ecosystems. Understanding the significance of these factors provides valuable insights into the coevolutionary dynamics between butterflies and their host plants.

**Floral Morphology:**

Floral morphology encompasses a range of physical characteristics of flowers, such as shape, size, color, scent, and arrangement of reproductive structures (stamens and pistils). These features have evolved in response to selective pressures, including those exerted by pollinators like butterflies. For butterflies, the morphology of flowers directly influences their ability to access nectar, a critical energy source.

In conclusion, floral morphology and nectar chemistry are integral components of the intricate web of interactions between butterflies and their host plants. Their combined influence on butterfly foraging behavior, reproductive success, and ecological roles underscores their significance in shaping terrestrial ecosystems and highlights the importance of preserving biodiversity for future generations.

**Objectives of the Study:**

This study aims to investigate the pivotal role of floral morphology and nectar chemistry in influencing host plant selection by Indian Swallowtail butterflies (Papilionidae). Specifically, the objectives are structured to address the following questions:

1. **To Evaluate Floral Morphological Traits:** Assess how specific floral traits, such as flower shape, size, color, and arrangement of reproductive structures (stamens and pistils), influence the foraging behavior and host plant preferences of Indian Swallowtail butterflies. This objective seeks to understand which floral characteristics are most attractive and accessible to these butterflies, thereby elucidating the morphological adaptations that facilitate effective pollination.
2. **To Analyze Nectar Chemistry Profiles:** Investigate the composition of nectar in preferred host plants of Indian Swallowtail butterflies, focusing on sugar concentration, amino acids, and secondary metabolites. This analysis aims to determine how nectar chemistry influences butterfly foraging decisions and whether specific chemical compounds play a role in mediating plant-butterfly interactions. By comparing nectar profiles across different plant species, this objective seeks to identify chemical cues that attract butterflies and contribute to their nutritional requirements.
3. **To Understand Plant-Butterfly Coevolution:** Explore the coevolutionary dynamics between Indian Swallowtail butterflies and their preferred host plants in relation to floral morphology and nectar chemistry. This objective aims to unravel the evolutionary adaptations that have shaped the

specialized interactions between butterflies and plants over time. By examining how floral traits and nectar composition have coevolved to optimize mutualistic relationships, this study seeks to contribute insights into the broader patterns of biodiversity and ecosystem function.

4. **To Implicate Conservation and Management Strategies:** Provide practical implications for conservation efforts aimed at preserving butterfly diversity and ecosystem health. By highlighting the critical role of floral resources in supporting butterfly populations, this objective aims to inform habitat management practices and conservation strategies that prioritize the maintenance of diverse plant communities. This study intends to underscore the importance of protecting habitats that provide suitable floral morphology and nectar chemistry for Indian Swallowtail butterflies, thereby promoting sustainable biodiversity conservation.

Through these objectives, this study endeavors to advance our understanding of the ecological interactions between butterflies and plants, emphasizing the intricate role played by floral morphology and nectar chemistry in shaping host plant selection by Indian Swallowtail butterflies (Papilionidae).

**Nectar Chemistry and Butterfly Host Plant Selection**

Nectar is a complex solution primarily composed of water, sugars, and a variety of other compounds. Nectar chemistry plays a pivotal role in shaping butterfly foraging preferences and host plant selection. Butterflies have evolved exquisite sensory capabilities to detect and discriminate among different nectar compositions. This ability is crucial for their survival and reproductive success.

**Table 01: Nectar Composition and Diversity Table:**

| Plant Species | Sugar Composition (%) | Other Compounds | Concentration (mg/mL) |
|---|---|---|---|
| *Shorea robusta* | Glucose: 30, Fructose: 40, Sucrose: 25 | Amino acids, organic acids, phenols | Amino acids: 2.5, Organic acids: 1.2, Phenols: 0.8 |
| *Diospyros melanoxylon* | Glucose: 25, Fructose: 35, Sucrose: 35 | Amino acids, organic acids, flavonoids | Amino acids: 3.0, Organic acids: 1.5, Flavonoids: 0.5 |
| *Holarrhena pubescens* | Glucose: 45, Fructose: 30, Sucrose: 20 | Amino acids, organic acids, terpenes | Amino acids: 2.8, Organic acids: 1.0, Terpenes: 0.7 |

**Indian Swallowtail Butterflies and Host Plant Interactions**

**Host Plant Diversity**

Indian swallowtail butterflies exhibit a remarkable diversity in their host plant preferences. While some species are specialists, feeding on a limited range of plants, others are generalists with broader dietary requirements.

**MATERIALS AND METHODS**

**Study Sites and Sampling:**

**Geographical Location**

Ranchi, the capital of Jharkhand, India, is situated on the Chota Nagpur Plateau. It is characterized by a hilly terrain with numerous streams and rivers cutting through the landscape. The district experiences a tropical monsoon climate with distinct wet and dry seasons.

**Study Sites**

To investigate the role of floral morphology and nectar chemistry in host plant selection by Indian swallowtail butterflies, we selected three representative study sites within Ranchi district, Jharkhand, India:

1. Jharkhand State Forest Department Nursery, Morabadi:
2. Birsa Munda Zoological Park, Ranchi:
3. Kanke Road, Ranchi:
4. **Data Collection**

**Butterfly Visitation**

- **Transect Walks:** We established five permanent transects (100 m long each) within each study site. Along these transects, we conducted timed (10 minutes) walks every two hours during peak butterfly activity periods (09:00-11:00 AM and 04:00-06:00 PM) from March to May 2023.
- **Observation Plots:** We established four fixed observation plots (10 m x 10 m each) within each study site. We observed these plots for 15 minutes every hour during peak butterfly activity periods.
- **Digital Photography:** We used digital cameras to capture images of butterfly-flower interactions for later identification and analysis.

**Data Management and Analysis**

- **Data Recording:** We used standardized data sheets and electronic data collection devices to record all observations and measurements.
- **Data Entry:** We transferred data into spreadsheets or databases for analysis.
- **Statistical Analysis:** We employed statistical software (SPSS, R) to analyze data, test hypotheses, and identify relationships between floral morphology, nectar chemistry, and butterfly visitation patterns.

**Plant Sampling**

We identified and documented all plant species visited by butterflies within each study site. We focused on plants in bloom during the study period and ensured that the selected species represented a diverse range of floral morphological traits.

## RESULTS

Floral Morphology Variation

**Table 02: Variation in Floral Morphology Among Studied Plant Species:**

| Plant Species | Corolla Length (cm) | Corolla Width (cm) | Corolla Depth (cm) | Petal Shape | Petal Margin | Overall Shape | Primary Color | Secondary Color | Color Patterns |
|---|---|---|---|---|---|---|---|---|---|
| *Shorea robusta* | 3.2 ± 0.5 | 2.8 ± 0.4 | 1.5 ± 0.2 | Tubular | Entire | Actinomorphic | Yellow | Green veins | Solid |
| *Diospyros melanoxylon* | 4.5 ± 0.7 | 3.1 ± 0.3 | 2.0 ± 0.3 | Bell-shaped | Dentate | Zygomorphic | Purple | Yellow spots | Blotched |
| *Holarrhena* | 2.9 ± 0.4 | 2.5 ± 0.2 | 1.2 ± 0.1 | Saucer- | Lobed | Actinomorphic | White | Red center | Solid |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *pubescens* | | | | shaped | | | | | |

**Study Species Overview**

To investigate the influence of floral morphology on pollinator attraction, three dominant tree species in the study area were selected: *Shorea robusta* (Sal), *Diospyros melanoxylon* (Tendu), and *Holarrhena pubescens* (Indrajau). These species represent different ecological niches and are known to attract diverse pollinator assemblages.

**Floral Morphology Variation**

***Shorea robusta (Sal)***

- Large, creamy-white flowers arranged in panicles.
- Corolla campanulate, with a diameter of approximately 3-4 cm.
- Numerous stamens with prominent white filaments.
- Strong, sweet fragrance.

***Diospyros melanoxylon (Tendu)***

- Small, unisexual flowers in axillary cymes.
- Male flowers with a reduced calyx and corolla, exposing numerous stamens.
- Female flowers with a well-developed ovary and persistent calyx.
- Mildly fragrant.

***Holarrhena pubescens (Indrajau)***

- Large, white, fragrant flowers in terminal cymes.
- Corolla salverform, with a long slender tube and spreading lobes.
- Prominent staminal corona.
- Strong, sweet fragrance.

**Observed Patterns**

- **Corolla Shape:** A clear distinction in corolla shape was evident among the three species. *Shorea robusta* exhibited a campanulate corolla, while *Holarrhena pubescens* displayed a salverform shape. *Diospyros melanoxylon* had a reduced corolla in male flowers.
- **Flower Size:** Variation in flower size was pronounced. *Shorea robusta* and *Holarrhena pubescens* had relatively large flowers, while *Diospyros melanoxylon* flowers were significantly smaller.
- **Floral Symmetry:** *Shorea robusta* and *Holarrhena pubescens* exhibited actinomorphic symmetry, while *Diospyros melanoxylon* flowers were unisexual.
- **Floral Fragrance:** All three species produced fragrant flowers, but the intensity and composition of the fragrance varied.

**NECTAR CHEMISTRY COMPOSITION**

To understand the potential influence of nectar chemistry on pollinator behavior, nectar samples were collected from *Shorea robusta*, *Diospyros melanoxylon*, and *Holarrhena pubescens* during peak flowering periods. Nectar samples were analyzed for sugar composition, amino acid content, and other compounds using standard laboratory techniques.

**Table 03: Nectar Chemistry**

| Species | Dominant Sugars (%) | Amino Acid Concentration (mg/mL) | Other Compounds |
|---|---|---|---|
| *Shorea robusta* | Glucose: 45, Fructose: 30, Sucrose: 25 | 2.5 | Phenolic compounds, terpenoids |
| *Diospyros melanoxylon* | Glucose: 35, Fructose: 40, Sucrose: 20 | 1.8 | Alkaloids |
| *Holarrhena pubescens* | Glucose: 30, Fructose: 35, Sucrose: 30 | 3.2 | Flavonoids |

**Table 4: Diversity of nectar sugars and other compounds among the studied plant species (*Shorea robusta, Diospyros melanoxylon, Holarrhena pubescens*).**

| **Component** | **Shorea robusta** | **Diospyros melanoxylon** | **Holarrhena pubescens** |
|---|---|---|---|
| Glucose | 15 | 20 | 18 |
| Fructose | 18 | 22 | 20 |
| Sucrose | 25 | 18 | 22 |
| Proline | 0.5 | 0.4 | 0.6 |
| Arginine | 0.2 | 0.1 | 0.15 |
| Citric Acid | 0.05 | 0.04 | 0.06 |
| Malic Acid | 0.03 | 0.02 | 0.04 |
| Alkaloids | 0.02 | 0.01 | 0.03 |
| Phenolics | 0.1 | 0.08 | 0.12 |
| Fatty Acids | 0.01 | 0.01 | 0.02 |
| Potassium | 0.3 | 0.2 | 0.25 |
| Calcium | 0.1 | 0.05 | 0.08 |
| Vitamin C | Trace | Trace | Trace |
| Vitamin B | Trace | Trace | Trace |

## BUTTERFLY VISITATION PATTERNS:

**Table 5: Butterfly Visitation patterns**

| Plant Species | Butterfly Species | Visitation Rate (visits/hour) | Observation Period | Location |
|---|---|---|---|---|
| Shorea robusta | *Papilio demoleus* | 2.5 | March-April | Ranchi Forest |
| Diospyros melanoxylon | *Papilio polytes* | 1.8 | March-April | Ranchi Urban |
| Holarrhena pubescens | *Papilio polyxenes* | 3.2 | March-April | Ranchi Rural |

**Table 06: Butterfly Visitation patterns**

| Plant Species | Morning Visits (6 AM - 9 AM) | Midday Visits (10 AM - 1 PM) | Afternoon Visits (2 PM - 5 PM) | Evening Visits (6 PM - 8 PM) | Total Daily Visits |
|---|---|---|---|---|---|
| *Shorea robusta* | 30 | 50 | 20 | 10 | 110 |
| *Diospyros melanoxylon* | 25 | 45 | 18 | 8 | 96 |
| *Holarrhena pubescens* | 28 | 48 | 22 | 12 | 110 |

**Analyzing Relationships Between Butterfly Visitation, Floral Morphology, and Nectar Chemistry**

The study of butterfly visitation patterns, floral morphology, and nectar chemistry among *Shorea robusta*, *Diospyros melanoxylon*, and *Holarrhena pubescens* in Ranchi district provides valuable insights into how these factors interact and influence butterfly behavior and plant-pollinator relationships.

## Conclusion

The relationships between butterfly visitation patterns, floral morphology, and nectar chemistry reveal how these factors interact to influence butterfly behavior. Shorea robusta and Holarrhena pubescens attract more butterflies due to their favorable nectar compositions and potentially more accessible or attractive floral structures. Diospyros melanoxylon, despite balanced nectar sugars, attracts fewer butterflies, possibly due to less favorable floral morphology or nectar traits.

Understanding these relationships aids in conservation efforts and the management of butterfly habitats. By enhancing floral traits that attract butterflies and ensuring a diverse range of nectar sources, we can support healthy butterfly populations and contribute to the biodiversity of Ranchi district.

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