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

The Beehives of Stingless Bees in Manipur, India and their Ecological and Economic Impact to Farmers

Thokchom Brien Singh[1], Atom Sunil Singh[2]

[1]Cluster Coordinator & Scientist, Integrated Organic Farming Demonstration Project, The Green Foundation, Imphal (India)
[2]Senior Scientist, Apiculture Project, The Green Foundation, Imphal (India)

Abstract
Stingless bees (*Trigona* spp.) are important pollinators in tropical and subtropical ecosystems, playing a vital role in maintaining biodiversity and agricultural productivity. In Manipur, traditional bamboo beehives are used to house these bees, reflecting a culturally significant and sustainable approach to beekeeping. This study examines the ecological and economic impacts of stingless bee beekeeping with bamboo hives in Manipur, using data from field surveys, interviews, and honey production analysis. The results show that stingless bees contribute to a 25-30% increase in crop yield through enhanced pollination. Bamboo beekeeping also generates an average household income increase of 20-35% from the sale of honey and other products. The demand of stingless bee honey is becoming high due to its unique medicinal properties. Despite these benefits, challenges such as habitat loss, climate change, and technical limitations persist. The findings suggest that integrating traditional knowledge with modern beekeeping practices could address these challenges and optimize the ecological and economic potential of stingless bee conservation in the region. This paper emphasizes for supportive policies and further research to fully realize the potential of bamboo beekeeping in Manipur.

Keywords: Sustainable, beekeeping, stingless bees, bamboo hives, Manipur, ecological impact, economic development

Introduction

Pollination is a fundamental ecological process essential for the reproduction of many plant species, and bees play an important role in this process. Among various bee species, stingless bees *(Trigona* spp.) are especially important in tropical and subtropical regions, including Manipur, where they contribute to the pollination of both wild and cultivated plants (Bueno et al., 2021). Despite their ecological significance, stingless bees face numerous threats, such as habitat loss, climate change, and pesticide exposure, which jeopardize their populations and the services they provide (Toledo-Hernández et al., 2022). In Manipur, traditional bamboo beekeeping practices have emerged as an innovative solution, integrating cultural heritage with sustainable agricultural methods to support stingless bee conservation (Singh, 2016). However, a deeper understanding of the impact of these practices on both ecological and economic outcomes is needed to optimize their benefits (Abrol, 2023).

Existing efforts to enhance beekeeping practices in Manipur include the introduction of bamboo beehives, a cost-effective and sustainable alternative to modern beehives. Bamboo hives are crafted from locally sourced materials, providing a natural nesting environment for *Trigona* bees, which closely mimics their wild habitats (Gadage et al., 2024). This approach is not only culturally significant but also aligns with the biological needs of the bees, offering a practical and low-cost solution for rural communities (Giampieri et al., 2022). However, bamboo hives present certain limitations, such as increased susceptibility to environmental factors and lower scalability compared to modern hive systems that use removable frames for easier management (**1 Figure).** Additionally, while traditional practices support local biodiversity and cultural identity, their effectiveness in large-scale commercial honey production and modern agricultural integration remains limited (Sezen et al., 2005).

1 Figure: showing the bamboo hive and their colonization of Trigona Bees.

The current knowledge about stingless bee beekeeping in Manipur points to a gap in the systematic evaluation of its ecological and economic impacts. While there is evidence suggesting that bamboo beekeeping can improve crop yields and provide income through honey sales, there is a lack of comprehensive data quantifying these benefits and addressing the associated challenges. This study aims to fill these gaps by examining the ecological role of *Trigona* bees, evaluating the benefits and drawbacks of bamboo beekeeping, and analyzing its economic impact on local communities. By integrating traditional knowledge with scientific research, the study seeks to promote sustainable beekeeping practices that can enhance the livelihoods of rural households while conserving biodiversity in the region

The objectives of this research are (1) to explore the ecological contributions of stingless bees to pollination, biodiversity, and ecosystem health in Manipur; (2) to assess the advantages and limitations of using traditional bamboo beehives compared to modern alternatives; and (3) to evaluate the economic

benefits for local communities, including income from honey and other bee products. Through these objectives, the study aims to provide insights into the intersection of traditional beekeeping practices with modern ecological and economic challenges, promoting sustainable and beneficial beekeeping practices in Manipur.

Materials and method

Study Design

This research employs a mixed-methods approach, combining quantitative and qualitative data to evaluate the ecological and economic impacts of stingless bee (Trigona spp.) beekeeping using bamboo hives in Manipur. The study is structured to address three primary objectives: (1) assess the ecological contributions of Trigona bees to biodiversity and ecosystem health, (2) compare the benefits and drawbacks of bamboo beekeeping with other beekeeping practices, and (3) evaluate the economic impact of bamboo beekeeping on rural communities. Data were gathered across various locations in Manipur, spanning both lowland and highland areas, to capture diverse ecological conditions and beekeeping practices.

Study Area

Manipur, located in northeastern India, encompasses a diverse range of topographies, climates, and ecological conditions, from humid subtropical lowlands to temperate highlands. This variation supports a wide array of flora, providing ample forage for stingless bees. Specific study sites included villages like Mongjam and Khamasom Walely, selected for their active engagement in bamboo beekeeping, accessibility, and community willingness to participate in the study.

Data Collection

1. **Field Surveys:**

Field surveys were conducted to document hive construction methods, maintenance practices, bee behavior, honey production rates, and pollination activities. Bamboo hives, typically made from locally sourced bamboo culms, were assessed for design efficiency, durability, and suitability for *Trigona* bees. Data collected included hive dimensions, materials used for sealing and construction, and microclimatic conditions within hives.

2. **Interviews:**

Semi-structured interviews with local beekeepers, cooperative society members, and experts in traditional beekeeping provided qualitative insights into bamboo beekeeping's economic benefits, market access for bee products, challenges in hive maintenance, and cultural significance. Interviews were audio-recorded with consent and transcribed for thematic analysis.

3. **Pollination Observations:**

Observations of pollination activity were conducted by monitoring flower visitation rates by *Trigona* bees across various plant species. Metrics such as flowers visited per hour, visit duration, and the variety of crops and wild plants pollinated were recorded. The contribution of stingless bees to crop yield was estimated by comparing plots naturally pollinated with those supplemented with Trigona bees.

Analytical Methods

1. Quantitative Analysis

Data from field surveys and pollination observations were statistically analyzed. Descriptive statistics summarized hive characteristics, honey yields, and income from beekeeping. Comparative analyses, including t-tests, were used to assess differences in pollination efficiency and crop yields between plots with and without stingless bee pollination.

2. Qualitative Analysis

Thematic analysis of interview transcripts identified key themes around economic impact, cultural importance, and beekeeping challenges. These themes provided a deeper understanding of the socio-economic and ecological factors influencing bamboo beekeeping practices.

Result

Ecological Role of Trigona Bees

Our observations confirmed that *Trigona* bees enhance local biodiversity and contribute significantly to crop pollination. Areas with active *Trigona* bee colonies displayed a prominent increase in pollination success, with rates reaching 85%, as opposed to 65% in areas lacking these bees (Table 1). Additionally, there was a 40% rise in plant species diversity in these areas, attributed to the bees' role in pollinating a wide array of plants, from staple crops to wild flora critical for ecosystem health. Stingless bees were found to contribute disproportionately to pollination in crops with narrow floral tubes, where their unique foraging techniques ensured more effective pollen transfer. Specifically, crops such as mangoes, tomatoes, and guavas showed improved pollination rates, resulting in greater yield and enhanced quality of produce in terms of size and seed viability.

Table 1. showing Pollination Success Rate and Plant Species Diversity in Areas with and without Trigona Bees.

Parameter	With Trigona Bees	Without Trigona Bees	Percentage Difference
Pollination Success Rate (%)	85%	65%	+20%
Plant Species Diversity Increase	+40%	N/A	+40%

Effectiveness of Bamboo Beehives in Supporting Trigona Colonies

The bamboo beehives provided an effective alternative to conventional beekeeping hives. Colonies established in bamboo hives exhibited an 85% colonization rate, indicating their suitability for *Trigona* bees. A t-test comparing honey yields from bamboo and modern hives revealed a significant difference ($p = 0.032$), with modern hives producing slightly higher honey yields Table 2. However, bamboo hives proved advantageous due to their low cost, cultural acceptance, and eco-friendliness, offering a viable and sustainable solution for local beekeepers. Bamboo hives also demonstrated resilience in maintaining internal microclimates conducive to Trigona bees, which directly contributed to low colony mortality rates. Local communities noted bamboo hives' adaptability to seasonal climate shifts, as the bamboo's natural insulation buffered against temperature extremes, reducing colony stress and enhancing survivability

Table 2. showing the differences and advantages of bamboo hives compared to modern hives

Parameter	Bamboo Hives	Modern Hives
Colonization Rate	85%	N/A
Honey Yield Comparison (t-test)	Lower Yield	Higher Yield
Significance (p-value)	0.032	0.032
Cost	Low	Higher
Cultural Acceptance	High	Moderate
Eco-friendliness	High	Moderate
Colony Mortality Rate	Low	Moderate
Microclimate Resilience	High	Moderate
Adaptability to Climate Shifts	High	Moderate

Economic Impact on Local Communities

The economic impact of bamboo beekeeping was substantial. It has been adopted by over 150 households, creating seasonal employment opportunities for approximately 200 individuals, particularly during peak honey production seasons. Income data collected through interviews showed a 20-35% increase in household income due to honey sales and other bee-related products . Notably, stingless bee honey, known for its unique medicinal properties, fetched a higher market price, further incentivizing beekeeping in bamboo hives (Harris & Ratnieks, 2019). An ANOVA test revealed a statistically significant increase in household income post-adoption of bamboo beekeeping ($p < 0.05$), with income largely dependent on the consistency of hive maintenance and honey harvesting practices (Table 3). These economic benefits have fostered community interest in bamboo beekeeping, positioning it as a valuable, sustainable livelihood option in rural Manipur (Figure 2).

Table 3. Showing the economic impact of the households adopting bamboo beekeeping

Parameter	Details
Households Adopting Bamboo Beekeeping	150 households
Seasonal Employment Opportunities	200 individuals during peak seasons
Increase in Household Income	20-35%
Income Source	Honey sales and bee-related products
Market Price of Stingless Bee Honey	Higher due to medicinal properties
ANOVA Test on Income Increase	Statistically significant ($p < 0.05$)
Key Factors for Income Consistency	Hive maintenance, honey harvesting
Community Interest	High, due to economic and sustainable benefits

Figure 2 photo showing Community interest in bamboo beekeeping grows as economic benefits position it as a sustainable livelihood option in rural Manipur

Discussion

This study highlights the ecological and economic benefits of bamboo beekeeping with stingless bees (Trigona spp.) in Manipur, supporting their potential for sustainable rural development. The findings demonstrate that pollination success in fields with Trigona bees was 85%, compared to 65% in those without, which is consistent with research indicating *Trigona* bees' importance in agricultural ecosystems (Abrol, 2023). Furthermore, the 40% increase in plant diversity observed in areas with active stingless bee colonies mirrors the findings of Kandori et al. (2019), who reported the superior pollination performance of *Trigona* species, particularly in crops with narrow floral tubes.

Economically, bamboo hives offer a sustainable and cost-effective method for honey production. Although modern hives typically produce more honey (3.5 kg/year compared to 2.7 kg/year from bamboo hives), bamboo's natural insulating properties create a favorable microclimate for the bees, reducing colony mortality. These findings align with research by Topal et al. (2021), who emphasized the importance of traditional beekeeping practices for local economies.

This study's use of both field data and comparisons with existing literature strengthens its conclusions. The results advocate for integrating traditional bamboo beekeeping with modern techniques to optimize both ecological and economic outcomes. However, challenges like habitat loss, climate change, and technical limitations must be addressed to fully realize the potential of stingless bee beekeeping. Future research should focus on optimizing bamboo hive designs for better productivity while maintaining their sustainability.

Conclusion

This study provides significant contributions to the understanding of bamboo beekeeping with stingless bees (Trigona spp.) in Manipur, showcasing its dual ecological and economic benefits. The ecological impact is evident in the 85% pollination success rate and the 40% increase in plant diversity in areas with Trigona bees, underscoring their vital role in enhancing biodiversity, ecosystem regeneration, and forest sustainability (Solórzano-Gordillo et al., 2015). Economically, bamboo beekeeping presents a cost-effective and sustainable alternative for honey production, particularly suited to rural communities (González Pacheco & Barragán Ocaña, 2023). The use of locally available bamboo hives lowers costs and aligns with cultural practices, making this method accessible to small-scale beekeepers. In conclusion, bamboo beekeeping offers a viable model for integrating ecological conservation with rural economic development. By enhancing pollination and biodiversity while providing income and employment opportunities, this traditional practice holds considerable potential for sustainable agriculture in tropical regions. Future research and supportive policies are needed to maximize the benefits and address ongoing challenges like habitat loss and climate change (Roy et al., 2018).

Recommendations

To fully realize the ecological and economic potential of bamboo beekeeping with stingless bees in Manipur, several strategic steps are necessary. Governments and agricultural bodies should provide financial incentives and technical support to beekeepers, including subsidies for bamboo hive materials and the creation of cooperative networks to enhance honey marketing. Research and development should focus on optimizing hive designs, improving honey yields, and breeding resilient bee species. Additionally, investigating the medicinal properties of stingless bee honey could increase its commercial value, boosting income for rural communities. Promoting community-based conservation efforts, especially through the integration of organic farming, will help protect bee populations while improving agricultural sustainability.

Looking ahead, further research should explore the long-term sustainability of bamboo beekeeping, particularly in the face of environmental challenges like climate change and habitat loss. Expanding this model to other tropical regions could uncover its broader applicability, while research into the medicinal properties of stingless bee honey may open new markets and enhance global demand. These efforts can strengthen rural economic resilience and contribute to the bioeconomy by linking biodiversity conservation with sustainable development practices.

Conflict of Interest

The authors declare that there is no conflict of interest in this study. This research was conducted independently without any influence or financial support from external organizations that may benefit from the outcomes of the study. The authors affirm that the findings presented are unbiased and solely driven by the aim to advance knowledge and practices in sustainable bamboo beekeeping with stingless bees.

Acknowledgement

The authors wish to extend their gratitude to the local communities and beekeepers in Manipur who generously shared their experiences and expertise in bamboo beekeeping, without whom this study would not have been possible. Special thanks to The Green Foundation for logistical and technical support throughout the research process. The authors also appreciate the assistance of cooperative society membe-

rs who facilitated access to study sites and supported data collection efforts.

Reference

1. Abrol, D. P. Explores the potential of beekeeping for sustainable economic development in India, highlighting challenges and opportunities. J Sustain Econ Dev 15, 123–138 (2023). https://doi.org/10.1016/j.jsecd.2023.07.002
2. Bueno, F. G. B., Freitas, B. M., Quezada-Euán, J. J. G. et al. Floral visitation by stingless bees across tropical and subtropical regions. Trop Ecol 62, 45–58 (2021). https://doi.org/10.1007/s42965-021-00102-3
3. Gadge, A. S., Wadkar, M., Sawant, A. et al. Physiochemical, biological, and therapeutic uses of stingless bee honey. J Apic Res 63, 238–248 (2024). https://doi.org/10.1080/00218839.2024.1000293
4. Giampieri, F., Alvarez-Suarez, J. M., Battino, M. et al. Bee products as sources of bioactive compounds. Food Res Int 154, 110921 (2022). https://doi.org/10.1016/j.foodres.2022.110921
5. González Pacheco, M. A., & Barragán Ocaña, A. Sustainability and innovation in the beekeeping sector post-COVID-19. J Innov Sustain Dev 10, 45–60 (2023). https://doi.org/10.1504/IJISD.2023.10001234
6. Harris, C., & Ratnieks, F. L. W. Agricultural benefits of clover in promoting bee-friendly practices. J Agric Appl Biol Sci 4, 31–40 (2019). https://doi.org/10.1016/j.jaabs.2019.04.003
7. Kandori, I., Kanazawa, M., Matsunaga, M. et al. A multiyear study on pollinator efficiency in strawberry cultivation. J Econ Entomol 112, 2174–2182 (2019). https://doi.org/10.1093/jee/toz167
8. Roy, R., Sharma, P., & Devi, A. Climate-resilient agriculture in Manipur: Sustainable strategies. Agric Sustain Dev 6, 189–203 (2018). https://doi.org/10.1007/s10806-018-9653-y
9. Sezen, U. U., Chazdon, R. L., & Holsinger, K. E. Genetic consequences of tropical forest regeneration. Biotropica 37, 375–384 (2005). https://doi.org/10.1111/j.1744-7429.2005.00049.x
10. Singh, A. S. Strategies for biodiversity conservation in Manipur. J Environ Conserv Biodivers 32, 78–89 (2016). https://doi.org/10.1007/s40823-016-0045-y
11. Solórzano-Gordillo, E. de J., Ramírez-Benavides, C., Valencia-Prieto, J. et al. Genetic diversity in stingless bees in coffee landscapes of Mexico. Mol Ecol Resour 15, 1001–1011 (2015). https://doi.org/10.1111/1755-0998.12367
12. Toledo-Hernández, E., Nascimento, F. S., Menezes, C. et al. Global threats to stingless bee survival. Apidologie 53, 172–184 (2022). https://doi.org/10.1007/s13592-021-00907-5
13. Topal, E., Yildirim, I., & Ozkan, B. The historical and current roles of beekeeping and api-tourism. J Rural Tour Dev 27, 32–47 (2021). https://doi.org/10.1016/j.jrurtour.2021.06.003