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CURRENT STATUS OF *APIS MELLIFERA* BEEKEEPING IN SUMATRA: TOWARD THE DEVELOPMENT OF INDONESIA'S HONEY INDUSTRY

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Keywords

Apis mellifera; beekeeper proficiency; beekeeping status; colony productivity; honey price

ABSTRACT

Apis mellifera beekeeping in Sumatra has seen significant growth over the past decade, particularly since the COVID-19 pandemic began in early 2020, driven by high market demand for honey. Beekeeping activities are concentrated in Riau and Jambi provinces, where beekeepers primarily utilize extrafloral nectar from Acacia crassicarpa plantation forests. This study evaluates the current state of *A. mellifera* beekeeping in these regions, focusing on beekeeper proficiency and colony productivity. Data were collected through a survey of 42 beekeepers, addressing their characteristics, efforts to improve skills, perceptions of challenges, and colony productivity in 2024. The findings indicate that most beekeepers are young males aged 30–50 with secondary school education, managing between 100 and 500 hives despite limited knowledge. They primarily rely on self-directed learning and peer knowledge-sharing. Most beekeepers rated their apiaries as satisfactory but recognized their need for guidance to enhance productivity, ensure sustainability, and improve market access. In 2024, honey production averaged 25 kg per colony per year, or 2.1 kg per month, with Jambi slightly outperforming Riau (2.25 vs. 2.0 kg/colony/month). Honey prices averaged IDR 22,000/kg, with Riau prices higher (IDR 25,500-26,000/kg) than Jambi (IDR 19,800-20,300/kg). Sumatra is estimated to host around 250,000 A. mellifera colonies, contributing 92% to national honey output, compared to Java's 46,000 colonies and 8% of production.

INTRODUCTION

Beekeeping has long been recognized as playing a vital role in human life, contributing to the economic, health, and environmental sectors. From an economic perspective, beekeeping activities generate and increase income, create employment and business opportunities, and help alleviate poverty (Duah et al., 2019), particularly for rural communities and those living near forests. In the health sector, various beekeeping products are known to improve human nutrition and health due to their high nutritional value. Products such as propolis, bee venom, and royal jelly are even used for health treatments, both directly and indirectly (Obeidat et al., 2024).

Environmentally, honeybee play a crucial role in food security and ecosystem health through the pollination process (Sharma & Abrol, 2014). The regeneration of many plant species depends heavily on bee pollination (Tanda, 2022). Approximately 75% of the world's food supply comes from agricultural products that rely entirely on pollination activities (FAO, 2015). Globally, the demand for pollination services provided by honeybees is steadily increasing, driven by the growing dependence on agricultural production systems (Mashilingi et al., 2022).

Beekeeping activities in Indonesia have historically been dominated by the hunting and collection of wild honey from forest-dwelling honey bees, particularly *Apis dorsata* (Kahono et al., 2018). In the past, beekeeping was a small-scale side activity that utilized local honey bee species such as *Apis cerana* and other cryptic species (Kahono et al., 2018). The methods employed were basic, relying on traditional hollow logs or wooden boxes. These efforts primarily focused on harvesting honey bee brood as a food source and collecting honey.

Modern beekeeping techniques were introduced in the early 1970s with the arrival of European honeybees (*Apis mellifera*) in Java (Gratzer et al., 2019). The beekeeping of *A. mellifera* has flourished due to the availability of diverse bee forages, including plantation crops and forest plants. A migratory system is commonly employed in *A. mellifera* beekeeping, where colonies are moved to follow the flowering cycles of nectar and pollen-producing plants. These plants are distributed across various regions of Java and include cotton (*Ceiba pentandra*), rubber (*Hevea brasiliensis*), rambutan (*Nephelium lappaceum*), calliandra (*Calliandra calothyrsus*), corn (*Zea mays*), and mango (*Mangifera indica*).

On Sumatra, *A. mellifera* beekeeping has emerged only in the last decade. This development was driven by the arrival of beekeepers from Java who sought new migratory areas due to the decline in nectar sources on the island of Java (Pribadi et al., 2023). Beekeeping is primarily centered in two provinces: Riau and Jambi, where hundreds of thousands of hectares of *Acacia crassicarpa* plants are developed as Industrial Plantation Forests to supply raw materials for pulp and paper production (Purwanto et al., 2024). *A. crassicarpa* plants produce extrafloral nectar, which is secreted from nectar glands located at the base of the leaves. On the other hand, pollen is primarily sourced from oil palm (*Elaeis guineensis*) plants in nearby plantation forest. Consequently, beekeepers often position their colonies at the edges of plantation forest areas, adjacent to oil palm plantations, or within the bees' foraging range (Purwanto et al., 2024).

Apis mellifera beekeeping in Sumatra reached its peak during the lead-up to and early part of the COVID-19 pandemic in Indonesia. Tens of thousands of colonies were brought in waves from Java to two areas in Sumatra. The extraordinary increase in the number of colonies was a response to the soaring market demand and selling price of honey products during the pandemic (Pribadi et al., 2023; Purwanto et al., 2024). The COVID-19 period proved to be a blessing for honey producers and the industry in Indonesia (Indriani et al., 2022) and other countries (Sivakumar et al., 2023).

The "honeymoon" period for the beekeeping product business during the pandemic did not last long. The high demand for honey lasted only two years, from the beginning of the COVID-19 pandemic in 2020 to 2021 (Purwanto et al., 2024). Several factors are estimated to have contributed to the decline in market demand, including: (1) weakened purchasing power among the public, (2) increased vaccination rates, leading people to feel they have immunity, and (3) the availability of more treatment and prevention options for other infections.

Along with the decline in demand, there was also unhealthy competition among beekeepers, leading to a price war that caused the price of *Acacia crassicarpa* honey to drop to its lowest level in the market (Pribadi et al., 2023). This has become a problem for beekeepers that made significant

investments in procuring colonies, as they are still far from reaching the break-even point. In addition to the problem of declining demand and plummeting honey prices after COVID-19, *A. mellifera* beekeeping in Sumatra also faces other challenges. A survey by Purwanto et al. (2024) found a sharp decline in colony populations. According to information obtained from local beekeepers, in 2023, the colony populations in Riau and Jambi ranged from 45,000 to 15,000 colonies, respectively, down from around 125,000 and 45,000 colonies in 2021.

The significant decline in colony populations is believed to be caused by several factors, including outbreaks of *Varroa* and *Tropilaelaps* mites, as well as attacks by bee-eater birds. The relatively poor colony management skills of beekeepers are also thought to be a contributing factor with a significant impact. The majority of beekeepers in both areas are new beekeepers with work experience ranging from 3 to 5 years (Purwanto et al., 2024).

Acacia crassicarpa plantation forests are considered one of the most promising nectar sources to increase honey production and drive the development of the honey industry in Indonesia, especially to meet the open export market (Purwanto et al., 2024).

Firstly, this type of acacia plant has been developed on a very large scale. Currently, it is estimated that there are more than 5 million hectares of industrial plantation forests across Indonesia, with 65% of them being *Acacia* plants. Secondly, *A. crassicarpa* plants produce nectar from the sapling stage to the tree level. However, based on observations by Suhesti et al. (2024) in Riau, beekeepers predominantly place colonies only on acacia stands aged 3 to 18 months. Thirdly, *A. crassicarpa* nectar secretion continues throughout the year, making it possible to carry out stationary beekeeping with lower operational costs.

Therefore, various efforts to improve the management of beekeeping activities need to be continuously enhanced to establish a strong and healthy domestic honey industry, including its potential to meet the export market. This study was conducted to explore the current conditions of beekeeping in Sumatra and identify the urgent needs required to increase productivity, sustainability, and the development of beekeeping in the region and Indonesia as a whole.

The current research on Apis mellifera beekeeping in Acacia crassicarpa plantation forests in Sumatra presents several novel contributions compared to previous studies, such as Gratzer et al. (2019) and Purwanto et al. (2024). It specifically focuses on the Riau and Jambi provinces, highlighting the unique challenges and dynamics of beekeeping in these regions, especially during and after the COVID-19 pandemic, which influenced colony migration and market demand. The study quantifies current colony productivity averages (25 kg/colony/year) and contrasts them with historical data, while also examining beekeeper proficiency and learning methods, revealing a reliance on self-directed learning rather than formal training. Furthermore, it emphasizes the importance of collaboration among stakeholders—government, NGOs, and corporations—to enhance honey production and economic outcomes, a dimension less explored in prior literature. By addressing these contemporary issues, the research provides a comprehensive framework for improving beekeeping practices and livelihoods in Indonesia's honey industry.

METHODS

The research was conducted through a survey of *Apis mellifera* beekeepers in Jambi and Riau Provinces. The survey was carried out by distributing questionnaires containing a set of prepared questions to selected respondents. The questionnaire included the following topics: (1) beekeepers profile, (2) efforts by beekeepers to improve their abilities and competencies, (3) honey: production, productivity, selling price, (4) Survey of beekeepers perceptions of beekeeping and marketing activities.

The questionnaire on beekeeper profiles included questions related to personal data (name, age, education) and beekeeping activities (work experience, number of colonies, annual production). All questions regarding the respondent profile were open-ended. Additionally, the section on efforts to improve beekeepers' abilities and competencies consisted of multiple-choice questions designed to explore the extent of the respondents' efforts to enhance their knowledge and skills in managing a beekeeping business.

The questionnaire on production and the selling price of bulk honey included open-ended questions to gather information on the level of production, average productivity of managed colonies, and the selling price of honey at the beekeeper level (raw honey) over the course of one year, specifically in 2024. A questionnaire regarding beekeepers' perceptions of beekeeping was used to explore respondents' views on issues and problems related to beekeeping activities and product marketing. Two main issues were addressed in beekeeping management: (1) beekeeping conditions and (2) beekeeper competence. Beekeeping problems include two primary concerns: (1) threats to production and (2) support from various parties.

In terms of marketing bee products, four main issues were identified: (1) marketing facilities and efforts, (2) threats in marketing, (3) marketing guidance. Respondents were asked to evaluate various issues in beekeeping and marketing using scoring system. Beekeeping management issues were rated on a scale of 1 - 4 (1 = bad, 2 = poor, 3 = good, and 4 = excellent), while marketing issues were rated from 1 - 4 (1 = low, 2 = moderate, 3 = high, and 4 = very high).

In addition to the survey and beekeeping workshop in Sumatra, we also conducted a Focus Group Discussion (FGD) on Java with experienced beekeepers to assess the status and position of beekeeping activities in Indonesia. The goal was to evaluate the current conditions of beekeeping, including the estimated number of colonies in each region where *A. mellifera* beekeeping is practiced, productivity levels, and production volumes to determine the shared production level.

The study was conducted in December 2024, targeting beekeepers whose beekeeping locations were in several districts of Jambi and Riau Provinces. In addition to interviews, workshops were held to discuss and provide guidance on beekeeping techniques and colony management. Workshop participants were beekeepers selected as respondents. The workshops took place over two days in each province: from December 13-14, 2024, in Jambi, and from December 14-15, 2024, in Siak Regency, Riau Province. A Focus Group Discussion (FGD) on the status of *A. mellifera* beekeeping in Indonesia was held in Semarang, Central Java, on December 23, 2024.

The respondent sample was selected based on prior research by Purwanto et al. (2024), conducted in 2023. A structured questionnaire was distributed to each respondent for completion. To ensure clarity and resolve any ambiguities in the initial responses, validation was conducted through face-to-face meetings during the workshop. This validation process was critical for refining the data. Additionally, further research was undertaken to gain a more detailed understanding of each beekeeper's level of competence.

Data collection also included a Focus Group Discussion (FGD) to gather additional insights into *Apis mellifera* beekeeping in Java. This event involved 20 experienced beekeepers from West Java, Central Java, and East Java, each with over 15 years of experience, to provide a more comprehensive understanding of the conditions, challenges, and opportunities in *A. mellifera* beekeeping across Indonesia.

The data analysis process consisted of two phases: (1) tabulation of questionnaire responses and (2) comprehensive data analysis.

The research data were categorized into three distinct groups: (1) beekeeper profiles, (2) beekeeper capabilities, and (3) honey production levels.

1) Beekeeper Profiles: This category captures the characteristics of each respondent, including personal data (name, age, education) and details about their beekeeping activities (work experience, number of colonies, and annual production).
2) Beekeeper Capabilities: This section summarizes survey data on three key aspects of beekeeping activities: (a) Efforts to enhance beekeeping knowledge and skills, (b) Respondents' perceptions of issues and challenges in colony and apiary management, and (c) Respondents' perceptions of issues and challenges in marketing their production. Beekeeper capabilities were assessed based on the cumulative scores assigned to each respondent's answers across the main components of beekeeping activities.
3) Honey Production Levels: This category includes graphical representations of monthly honey production and bulk honey selling prices throughout 2024.

The analysis focused on beekeeping activities at each site and across Sumatra as a whole. A descriptive qualitative approach was applied to analyze data on beekeeper profiles, beekeeper capabilities, honey production levels, and selling prices.

RESULTS

A total of 42 respondents participated in the survey. These respondents are active beekeepers managing *Apis mellifera* beekeeping operations within the *Acacia crassicarpa* plantation forest areas in Sumatra. Of the total, 27 beekeepers were from Jambi Province, while 15 were from Riau Province, representing various districts where beekeeping activities are concentrated. Respondents from Jambi Province were located in Tanjung Jambung Barat Regency and Muaro Jambi Regency. Meanwhile, respondents from Riau Province were from Siak Regency, Pelalawan Regency, and Dumai Regency.

Beekeeper Characteristics, Skills and Perceptions

Beekeeper Characteristics

The characteristics of respondents in Jambi and Riau Provinces reveal demographic variations and work experience reflective of the social context in each region. A summary of the respondent profiles is presented in Table 1. The majority of respondents are male, comprising 95% of the total. Most respondents are between 30-50 years old (66.7%), followed by those over 50 years old (23.8%) and those under 30 years old (9.5%). Educational attainment is predominantly at the secondary level (junior high school and high school), accounting for 64.3%, while 19% have a basic education, and 4.7% have a higher education.

In terms of work experience, most respondents (73.8%) have been beekeeping for 3-5 years, indicating that a large proportion started beekeeping during the Covid-19 pandemic. Meanwhile, 19% are relatively new to beekeeping, with 0-2 years of experience, and only 7.2% have more than 5 years of experience.

Overall, the dominance of the 30-50 age group and secondary education reflects a productive workforce with a reasonable educational background. Significant differences are evident in work experience, with beekeepers in Riau exhibiting higher levels of experience compared to those in Jambi. Gender is also an important variable, with male dominance in both provinces, although Riau shows slightly lower female participation.

Table 1. Characteristics of respondents in Jambi and Riau Provinces, 2024

Location	Respondent	Percentage of Total Respondents (%)										
		Age (years)			Gender		Education			Experience (Years)		
		<30	*30-50*	*>50*	*Male*	*Female*	*Basic*	*Interme-diate*	*Uni-versity*	*0-2*	*3-5*	*>5*
Jambi	27	11.1	74.1	14.8	100.0	-	18.5	66.7	14.8	18.5	19.0	3.0
Riau	15	6.7	53.3	40.0	86.7	13.3	20.0	60.0	20.0	20.0	80.0	-
Total	64	4.0	28.0	10.0	40.0	2.0	8.0	27.0	7.0	8.0	31.0	3.0

The characteristics of beekeeping businesses in Jambi and Riau Provinces reveal significant differences in terms of scale and production outcomes. Based on the number of colonies, the majority of beekeepers in Jambi (88.9%) and Riau (73.3%) manage 100-500 hives (Table 2), accounting for 83.3% of the total. Businesses with 500-1000 hives are relatively rare, comprising only 3.7% in Jambi and 6.67% in Riau. However, larger-scale operations with more than 1,000 hives are more prevalent in Riau (20%) compared to Jambi (7.4%), highlighting the proportionally larger business scale in Riau.

Most *A. mellifera* beekeeping activities are independently operated. Overall, 81% of respondents reported managing their beekeeping activities independently, with 81.5% in Jambi and 80% in Riau. The remaining 19% of operations involve cooperation with other parties (Table 2).

Annual production also varies significantly between the two provinces. In Jambi, the average annual production is 13.65 tons, considerably lower than Riau's average of 319.79 tons. Combined, the average production across both provinces is 122.99 tons per year. In Jambi, 48.1% of respondents produced more than 2 tons annually, with 25.9% producing 2-5 tons and another 25.9% exceeding 5 tons. In contrast, in Riau, only 6.7% of respondents produced more than 2 tons or 2-5 tons, while the majority (86.7%) produced more than 5 tons.

Table 2. Characteristics of beekeeping businesses in Jambi and Riau Provinces, 2024

Description	Jambi	Riau	Aggregate
Beekeeping business status (% of respondents)			
▪ Own business	81.5	80	81
▪ Collaborative efforts	18.5	20	19
Number (%) of respondents according to the range of number of colonies			
▪ 100-500	88.9	73.3	83.3
▪ 500-1000	3.7	6.7	4.8
▪ >1000	7.4	20.0	11.9
Average/year (Ton)	13.6	319.8	123.0
Production range (% of respondents)			-
▪ >2 Ton	48.1	6.7	33.3
▪ 2-5 tons	25.9	6.7	19.1
▪ >5 Ton	25.9	86.7	47.6

In aggregate, 33.33% of respondents across both provinces fall into the category of producing more than 2 tons annually, 19.05% produce 2-5 tons, and 47.62% produce over 5 tons. These differences indicate that beekeeping businesses in Riau tend to operate on a larger scale with significantly higher production yields compared to Jambi. This highlights Riau's potential as a more dominant center for honey production.

Beekeeper Skills

Learning methods for beekeeping can be obtained through courses, internships, independent learning, or by engaging experienced beekeepers. However, the course-based method for learning beekeeping was not utilized by any respondents (Table 3). The majority of respondents in Jambi (92.6%) and Riau (86.7%) prefer independent learning as their primary method, with an aggregate average of 90.5%. The internship method is chosen by a small proportion of respondents, with 6.7% in Jambi and 2.4% in Riau opting for this approach. Additionally, some respondents combine independent learning with internships by bringing in experienced workers from Java. This hybrid approach is used by 7.4% of respondents in Jambi and 6.7% in Riau, with an aggregate of 7.1%.

The overwhelming preference for independent learning reflects an adaptation to local resources and the practical nature of beekeeping knowledge. It highlights the importance of self-reliance and hands-on experience in managing beekeeping operations effectively.

In terms of skills development, the data shows that all respondents in Jambi (100%) reported having made efforts to improve their knowledge, while only 60% of respondents in Riau did so. For independent knowledge enhancement, 100% of respondents in Jambi, and 86.7% in Riau, engaged in self-learning, with an aggregate average of 95.2%. A small proportion of respondents in Riau (40%) stated that they had never made efforts to improve their knowledge, which contributed **to** a total aggregate of 14.3% of respondents who did not focus on enhancing their knowledge.

Table 3. Methods of learning beekeeping used by respondents in Jambi and Riau, 2024

Skill Development	Participants (% of respondents)		
	Jambi	***Riau***	***Aggregate***
Learning methods			
a. Course	0	0	0
b. Apprenticeship	0	6.7	2.4
c. Learn to be independent	92.6	86.7	90.5
d. Independent learning & internship	7.4	6.7	7.1
Skills development			
a. Try to increase knowledge	100.0	60.0	85.7
b. Increase knowledge independently	100.0	86.7	95.2
c. Never try to increase knowledge	0	40.0	14.3

Table 4 illustrates the types of media accessed by beekeepers. A total of 61.9% of respondents, on average, chose to learn by asking other beekeepers, with 70.4% in Jambi and 46.7% in Riau. Reading guidebooks was selected by 7.1% of respondents, while online media such as YouTube was chosen by 4.8%. A combination of media, such as reading books and asking beekeepers, was used by 7.1% of respondents, and a combination of asking beekeepers and using online media was chosen by 19%. According to Mansourian (2024), media platforms like YouTube are valuable tools for beekeepers, as they allow users to share helpful advice and foster community support through user-generated videos. Beekeepers can exchange experiences and useful tips

through these platforms. Additionally, this engagement can enhance skills and build community support. It is evident that user-generated content is a powerful tool for education and communication among beekeepers and those seeking beekeeping services. Therefore, media platforms are an effective way for beekeepers to learn, and it is crucial to create content that is both engaging and relevant to advance the field of beekeeping.

Table 4. Learning media used by respondents in Jambi and Riau, 2024

Media used	Participants (% of respondents)		
	Jambi	**Riau**	**Aggregate**
a. Read the manual	7.4	6.7	7.1
b. Ask other beekeepers	70.4	46.7	61.9
c. Online (e.g., Youtube)	3.7	6.7	4.8
d. (a and b)	0	20.0	7.1
e. (b and c)	18.5	20.0	19.0

The data on the respondents' preferred learning media shows that beekeepers tend to learn by directly asking other beekeepers, especially those who are experienced and considered successful. This method is favored because the information and experiences shared are typically based on practical, location-specific knowledge, making it easier for learners to understand and apply. With the growing trend of online digitalization, beekeepers have also started to expand their knowledge through online platforms such as YouTube, Facebook, and others.

Table 5 presents the various motivations and expectations of beekeepers when participating in beekeeping training. The most common expectations are increased income and market access, with an aggregate of 35.7% (48.1% in Jambi and 13.3% in Riau). Expectations for increased productivity and sustainability account for an aggregate of 28.6%. A total of 31% of respondents hoped to benefit from all aspects of the training, with a larger proportion in Riau (53.3%) compared to Jambi (18.5%). Only a small percentage of respondents, 2.4% in total, hoped to gain knowledge and practical skills.

Table 5. Beekeepers' expectations from participation in training

Description	Participants (% of respondents)		
	Jambi	***Riau***	***Aggregate***
a. Improving Knowledge and Practical Skills	3.7	0	2.4
b. Increased Productivity and Sustainability	29.6	26.7	28.6
c. Understanding Technology and Innovation	0	0	0
d. Increased Revenue and Market Access	48.1	13.3	35.7
e. b and d	0	6.7	2.4
d. All	18.5	53.3	31.0

Beekeepers' Perceptions of Beekeeping Issues and Problems

The survey results regarding respondents' perceptions of issues and challenges in A. mellifera honey bee beekeeping are presented in Tables 6 and 7. Table 6 outlines the respondents' views on issues related to honeybee beekeeping, while Table 7 focuses on issues related to the marketing of honey products.

Overall, respondents perceived the condition of beekeeping as fairly good, with average scores above 3 for honey productivity (3.09), colony condition (3.15), and queen health (3.19).

However, a lower score was given to beekeeper competence, particularly in the mastery of beekeeping techniques and the development of beekeeping knowledge. The average score for various aspects of beekeeping competence was 2.92, with specific areas such as colony management (2.86), critical condition management (2.86), and determination of beekeeping location (3.16) receiving lower scores.

Table 6. Respondents' perception scores regarding issues and problems in beekeeping with *Apis mellifera* in Sumatra

No	Beekeeping Issues and Problems	Respondent Perception Score		
		Jambi	**Riau**	**Aggregate**
I	Baseline of Bees and location/Beekeeping Conditions			
1	Honey Productivity	2.9 ± 0.76	3.3 ± 0.90	3.1 ± 0.80
2	Condition of bee colony	3.1 ± 0.58	3.2 ± 0.86	3.2 ± 0.68
4	Quality of bee forages	3.0 ± 0.71	3.4 ± 0.51	3.2 ± 0.67
5	Colony health	2.9 ± 0.62	3.3 ± 0.72	3.1 ± 0.70
6	Queen's condition	3.1 ± 0.62	3.3 ± 0.96	3.2 ± 0.75
		2.99	**3.30**	**3.13**
II	HR Baseline/Beekeepers Competence			
1	Colony management skills	2.7 ± 0.51	3.0 ± 0.84	2.9 ± 0.65
2	Ability to manage critical conditions	2.5 ± 0.50	3.2 ± 0.94	2.9 ± 0.74
3	Ability to select bee forages location	3.1 ± 0.55	3.3 ± 0.70	3.2 ± 0.61
5	Level of knowledge mastered by beekeepers	2.7 ± 0.47	3.1 ± 0.88	2.9 ± 0.66
6	The level of ease in obtaining the necessary knowledge	2.5 ± 0.79	2.7 ± 1.1	2.6 ± 0.83
7	Speed of learning in increasing productivity	2.8 ± 0.42	2.6 ± 0.83	2.7 ± 0.60
8	The level of desire to learn to increase production/solve problems	3.3 ± 0.64	3.2 ± 0.68	3.2 + 0.65
9	Innovations/improvements made	3.1 ± 0.55	2.9 ± 0.64	3.0 ± 0.58
		2.84	**3.00**	**2.92**
III	Threat level to honey production			
1	Bird threat level	3.1 ± 0.60	3.0 ± 1.0	3.0 ± 0.76
2	Bear threat level	3.1 ± 0.64	3.3 ± 0.88	3.2 ± 0.73
3	Monkey threat level	3.1 ± 0.78	3.2 ± 0.68	3.1 ± 0.74
4	Social threat level	2.3 ± 0.89	2.3 ± 0,00	2.3 ± 0.88
5	Rainy weather threat level	2.8 ± 0.58	2.8 ± 0.86	2.8 ± 0.68
6	Hot weather threat level	2.6 ± 0.93	1.8 ± 0.83	2.2 ± 0.96
7	Level of threat in feeding availability	2.3 ± 0.74	2.9 ± 1.19	2.6 ± 0.94
8	The level of threat of competition with others	2.4 ± 0.84	2.9 ± 1.24	2.6 ± 1.02
9	The level of threat to the availability of bee forages	2.2 ± 0.89	2.5 ± 1.19	2.4 ± 1.00
10	Varroa threat level	2.3 ± 0.68	2.8 ± 0.94	2.6 ± 0.80
		2.62	**2.8**	**2.70**
IV	Support from the parties			
1	Technical guidance from Government	1.3 ± 0.74	1.9 ± 0.74	1.60 ± 0.77
2	Technical guidance from local Government	1.4 ± 0.80	2.1 ± 0.70	1.72 ± 0.82
3	Technical guidance from non-governmental organizations	1.4 ± 0.70	2.5 ± 0.74	1.9 ± 0.86
4	Guidance from Village Officers	1.6 ± 0.89	2.0 ± 0.92	1.8 ± 0.91
5	Support From corporate	2.2 ± 1.14	2.9 ± 1.19	2.5 ± 1.21
		1.59	**2.3**	**1.92**

In terms of threats to production, respondents from both Jambi and Riau agreed that some of the most serious pest threats include bears (3.18), monkeys (3.13), and birds (3.03). The next most significant threat to production is the rain factor (2.80). Other threat factors with slightly lower risk values include competition with other beekeepers, availability of feed sources, varroa mite attacks, social factors, and others.

As a small-scale business, beekeeping requires support from external parties to facilitate business operations, enhance capacity, and access capital, among other needs. From the respondents' perspective, the support from external parties for beekeeping businesses is considered very low. The average score for various forms of assistance or support from other parties was below 2. The only exception was support from the managers of feed crops, specifically plantation forest management, which received a score of 2.51.

Table 7. Respondents' perception scores regarding issues of honey marketing on Sumatra.

No	Marketing Issues and Problems	Respondent Perception Score		
		Jambi	Riau	Aggregate
I	**Marketing Tools and Efforts**			
1	Offline promotions	2.5 ± 0.97	2.8 ± 0.94	2.6 ± 0.96
2	Exhibition held by Village	1.9 ± 0.90	2.6 ± 1.05	2.2 ± 0.99
3	Exhibition held by Local Government	1.9 ± 1.02	2.6 ± 1.05	2.2 ± 1.06
4	Exhibition held by Government	1.9 ± 1.25	2.6 ± 0.29	2.3 ± 1.21
5	Online promotions	2.3 ± 1.15	3.3 ± 0.49	2.8 ± 1.13
6	Website	1.5 ± 0.83	2.5 ± 1.35	2.1 ± 1.12
7	Facebook	2.4 ± 1.10	3.1 ± 1.06	2.8 ± 1.12
8	Instagram	2.3 ± 1.01	2.6 ± 1.03	2.4 ± 1.10
9	YouTube	1.8 ± 1.04	2.4 ± 1.12	2.1 ± 1.06
10	TikTok	2.0 ± 0.86	2.6 ± 1.07	2.3 ± 0.96
11	Snack Video	1.6 ± 0.80	2.5 ± 0.89	2.1 ± 1.08
		2.01	**2.69**	**2.35**
II	**Threats in Marketing**			
1	Honey market absorption	1.9 ± 0.92	3.2 ± 0.94	2.5 ± 1.10
2	Marketing skills	2.1 ± 0.70	3.1 ± 0.91	2.7 ± 0.89
3	Off taker availability	1.6 ± 0.80	3.2 ± 2.76	2.4 ± 0.99
4	Availability of Foster Parent	1.6 ± 0.78	2.7 ± 0.64	2.2 ± 0.92
5	Market competition	2.7 ± 1.03	3.4 ± 0.74	3.1 ± 0.99
6	Product Quality	3.0 ± 0.84	3.0 ± 0.82	3.0 ± 0.88
7	Market introduction	2.4 ± 0.88	2.9 ± 0.80	2.7 ± 0.89
8	Market preference	2.4 ± 0.80	3.3 ± 0.70	2.8 ± 0.86
		2.23	**3.09**	**2.66**
III	**Marketing Guidance Source**			
1	Government	1.3 ± 0.62	2.8 ± 1.22	1.7 ± 1.94
2	Local Government	1.3 ± 0.78	2.2 ± 1.21	1.8 ± 1.02
3	Non-governmental organizations	1.6 ± 0.89	2.8 ± 1.21	2.2 ± 1.16
4	Corporate	1.3 ± 0.62	3.1 ± 0.91	2.2 ± 1.15
		1.68	**2.55**	**2.11**

The majority of respondents rated the marketing sector below a score of 3 (moderate) for all aspects addressed, including marketing facilities, efforts, threats, and guidance received (Table 7).

From the respondents' perspective, various promotional efforts, both online and offline, aimed at facilitating marketing have not yielded the expected results. Out of the 11 aspects covered in the survey, the average score for respondents' perceptions was 2.35, ranging from 2.02 to 2.78. Regarding threats in the marketing sector, most were perceived at a "moderate" level, with an average score of 2.66 across the eight aspects surveyed. However, two aspects were identified as significant threats to marketing: market competition (score 3.06) and product quality (score 3.01).

When it comes to receiving marketing guidance, respondents felt that government support, both at the central and regional levels, was insufficient, with an average score below 2. In contrast, marketing guidance from non-governmental sources, including both non-profit organizations and profit-driven companies, received higher scores, reflecting a moderate level of support. The scores for guidance from these non-governmental sources were 2.22 and 2.20, respectively. This indicates that there are notable challenges in marketing the products of their beekeeping activities.

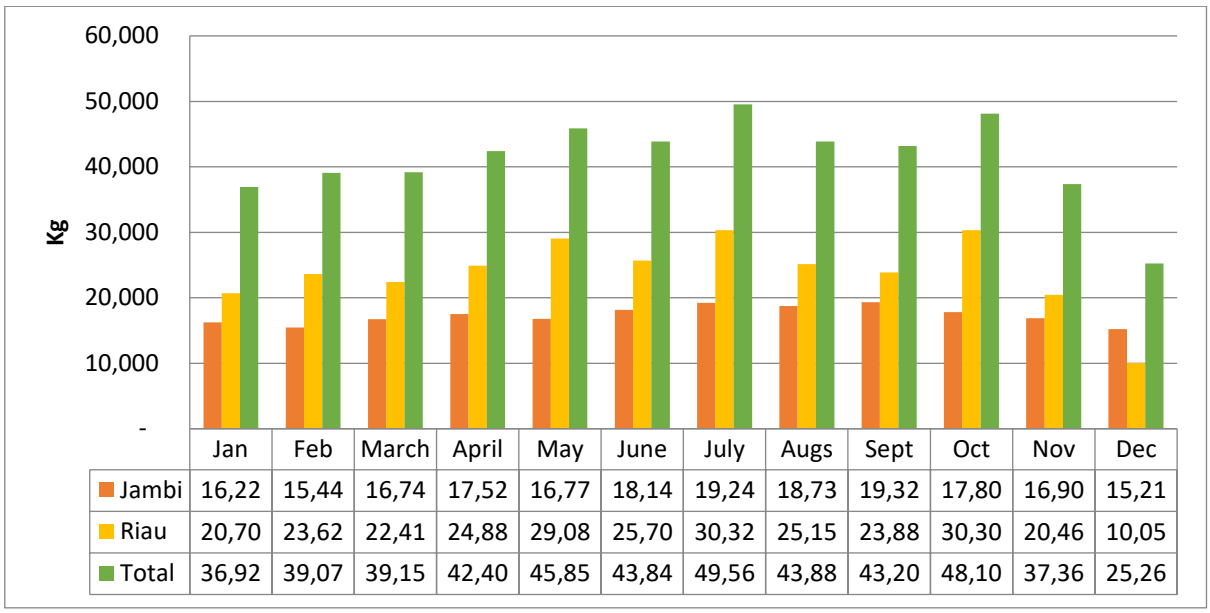
Honey Production and Prices

Development of Honey Production

Figure 1 illustrates the development of carpa honey production in Jambi and Riau Provinces, as well as the aggregate production throughout 2024. The production figures represent the average honey production reported by the surveyed beekeepers. Overall, honey production in Jambi was lower than in Riau, except in December. The production patterns in both regions followed a similar trend throughout the year, starting with low production at the beginning of the year, increasing mid-year, and then declining towards the end of the year. The production fluctuations observed were relatively moderate.

In Jambi, the lowest production volume was recorded in December at 15.21 tons, while the highest was in September at 19.32 tons, with an annual average of 17.58 ± 1.54 tons per month. Conversely, in Riau, the lowest production was also in December at 10.05 tons, while the highest was in October at 30.3 tons, with an annual average of 23.88 ± 5.48 tons per month. On an aggregate level, the average carpa honey production in Sumatra, as reported by 42 respondents, reached 41.21 ± 6.43 tons per month.

Climate change significantly influences honey production, as nectar availability, colony health, and climatic conditions collectively impact seasonal production patterns. Honey production typically peaks in the middle of the year due to optimal *A. crassicarpa* flowering and favorable weather conditions for foraging (Klein et al., 2008). The greater variability in Riau's production may be attributed to larger plantations and differences in colony management practices. Efforts to stabilize and increase production in both regions should focus on improving beekeeping skills, effective colony management, and monitoring nectar flow cycles. These measures will help address regional disparities and support the continued growth of A. crassicarpa honey production.



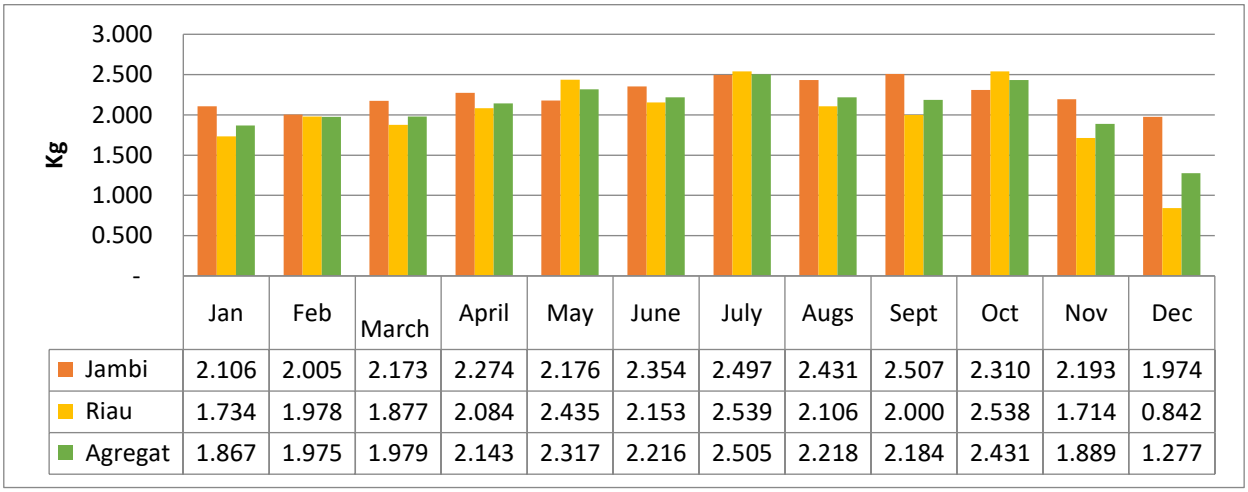
	Jan	Feb	March	April	May	June	July	Augs	Sept	Oct	Nov	Dec
Jambi	16,22	15,44	16,74	17,52	16,77	18,14	19,24	18,73	19,32	17,80	16,90	15,21
Riau	20,70	23,62	22,41	24,88	29,08	25,70	30,32	25,15	23,88	30,30	20,46	10,05
Total	36,92	39,07	39,15	42,40	45,85	43,84	49,56	43,88	43,20	48,10	37,36	25,26

Figure 1. Development of *Acacia crassicarpa* honey production in 2024

In terms of colony productivity, there is no significant difference between Jambi and Riau, although colony productivity in Jambi shows a slight tendency to be higher (Figure 2). The average colony productivity in Jambi is 2.25 ± 0.17 kg/colony/month, with the lowest productivity recorded in February and December at 2.0 kg/colony/month each, and the highest productivity observed in July and September at 2.5 kg/colony/month each.

In comparison, Riau's average colony productivity is slightly lower at 2.0 ± 0.46 kg/colony/month. The lowest productivity in Riau is recorded at 0.8 kg/colony/month, while the highest matches Jambi at 2.5 kg/colony/month.

Aggregated across both regions, the overall colony productivity averages 2.1 ± 0.3 kg/colony/month, with the lowest average productivity of 1.3 kg/colony/month occurring in December and the highest of 2.5 kg/colony/month in July.



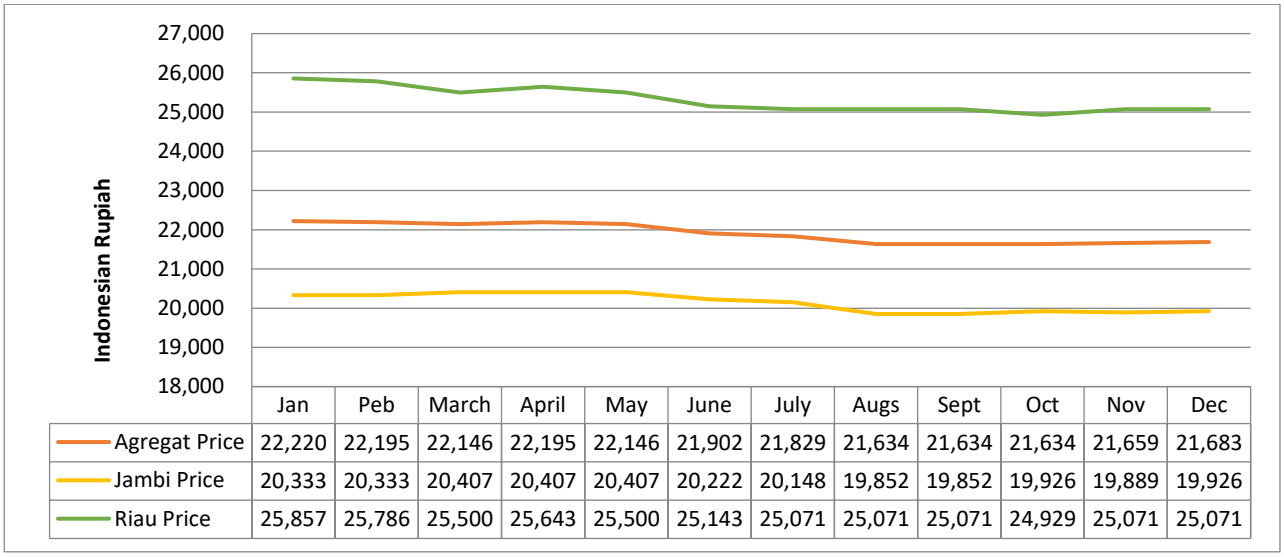
	Jan	Feb	March	April	May	June	July	Augs	Sept	Oct	Nov	Dec
Jambi	2.106	2.005	2.173	2.274	2.176	2.354	2.497	2.431	2.507	2.310	2.193	1.974
Riau	1.734	1.978	1.877	2.084	2.435	2.153	2.539	2.106	2.000	2.538	1.714	0.842
Agregat	1.867	1.975	1.979	2.143	2.317	2.216	2.505	2.218	2.184	2.431	1.889	1.277

Figure 2. Productivity of *Apis mellifera* colonies (kg/colony/month) in 2024

Honey Price Development

Figure 3 illustrates the development of *A. crassicarpa* honey prices at the beekeeper level throughout 2024, with an average price of approximately IDR 22,000/kg. Honey prices in Jambi

tend to be lower, averaging around IDR 20,000/kg, compared to the prices in Riau, which range between IDR 25,000 and IDR 26,000/kg.



	Jan	Peb	March	April	May	June	July	Augs	Sept	Oct	Nov	Dec
Agregat Price	22,220	22,195	22,146	22,195	22,146	21,902	21,829	21,634	21,634	21,634	21,659	21,683
Jambi Price	20,333	20,333	20,407	20,407	20,407	20,222	20,148	19,852	19,852	19,926	19,889	19,926
Riau Price	25,857	25,786	25,500	25,643	25,500	25,143	25,071	25,071	25,071	24,929	25,071	25,071

Figure 3. Price development of *Acacia crassicarpa* honey in 2024

Over the course of the year, prices exhibited fluctuations within a relatively narrow range. The trend shows a seasonal pattern, with prices generally increasing during the early to mid-year months before declining in the final quarter. This pattern suggests a degree of price stability, despite minor variations likely caused by differences in honey quality or slight changes in local supply and demand. Factors such as market demand and the honey production season likely play a significant role in influencing price movements.

Status of A. mellifera Beekeeping in Indonesia

Java and Sumatra are the two main regions for the development of *Apis mellifera* beekeeping in Indonesia. Beekeeping activities in Java have been established since the early 1970s, whereas in Sumatra, they began around 2015. Significant differences exist in the beekeeping models between the two regions. In Java, *A. mellifera* beekeeping is conducted using a migratory system, adapting to the flowering patterns and calendars of various bee forages. Conversely, in Sumatra, particularly in Jambi and Riau, beekeeping is primarily stationary. This difference in approach results in Java producing various types of honey, such as rambutan honey, cotton honey, rubber honey, calliandra honey, and others in smaller production volumes targeted for the domestic market. Meanwhile, Jambi and Riau focus solely on producing carpa honey in larger production volumes.

Although beekeeping in *A. crassicarpa* industrial plantation forests in Sumatra has been ongoing since 2015, significant growth occurred during the early stages of the COVID-19 pandemic. This surge in development was driven by the relocation of colonies from Java, either through migratory efforts to enhance honey production or by new beekeepers in Jambi and Riau purchasing colonies. The relocation of colonies to Sumatra has further exacerbated the decline in colony numbers in Java, a trend that began after the 1998 reformation due to reductions in the availability of bee forages. The rate of decline in bee forage areas accelerated in the lead-up to and throughout the second decade of the 2000s.

Table 8. Estimation of the Number of Colonies and Honey Production of *Apis mellifera* in Indonesia

No	Description	Number of Colonies (boxes)	Productivity (Kg honey/colony/ year)	Honey Production (tons)	Proportion of Colonies Number (%)	Honey Production Proportion (%)
1	Sumatra					
a	Riau	150,000	30	4,500		
b	Jambi	100,000	30	3,000		
	Sumatra	250,000		7,500	84	92
2	Java					
a	Central Java	35,000	15	525		
b	East Java	10,000	15	150		
c	West Java	1,000	15	15		
	Java	46,000		690	16	8
	Total Indonesia	296,000		8,190		

Beekeepers in Java have been facing increasingly challenging conditions. During focus group discussions (FGDs), many beekeepers shared testimonies that a significant number of *Apis mellifera* beekeepers in Java have abandoned the practice and transitioned to other professions. This shift is primarily due to the high costs of sugar supplementation during dearth seasons and the escalating competition for bee forage areas.

Table 8 indicates that the number of *Apis mellifera* colonies in Java has declined to approximately 46,000, representing 84% of the region's colony proportion. Colony productivity has also decreased, averaging around 15 kg/colony/year. This results in a total honey production of 690 tons per year, accounting for 8% of the total production proportion. In contrast, Sumatra is estimated to host around 250,000 colonies, representing 16% of the colony proportion. These colonies demonstrate an average productivity of 30 kg/colony/year, with total honey production reaching 7,500 tons annually, contributing to 92% of the total honey production proportion.

Discussion

The utilization of *Acacia crassicarpa* as a nectar source for beekeeping and the production of carpa honey in Sumatra has only emerged significantly over the past decade. The development of *Apis mellifera* beekeeping in this region is closely tied to the suitability of *A. crassicarpa*, a plant that serves as a key raw material for the pulp and paper industry, as a highly productive source of extrafloral nectar (Pribadi & Purnomo, 2013b, 2013a). This plant is cultivated extensively in plantation forests (Purwanto et al., 2024) and has gained prominence partly due to the significant reduction in forage areas in Java (Kahono et al., 2018).

Acacia plantation forests provide new opportunities for beekeeping in Indonesia, particularly for *A. mellifera* beekeeping, which has experienced a population decline over the last two decades. With approximately 5.3 million hectares of plantation forests across Indonesia (KLHK, 2022), there is considerable potential to support honeybee beekeeping. In Sumatra alone, plantation forests span 4 million hectares, distributed across the provinces of Riau, Jambi, and South Sumatra. A significant portion of these plantations (65%) consists of monoculture acacia crops (BPS, 2022). According to (Purwanto et al., 2024), this vast potential creates opportunities for carpa honey to thrive in the honey industry due to its high productivity, increasing colony populations, and capacity for sustainable production.

Currently, *A. mellifera* beekeeping in Sumatra is primarily concentrated in Jambi and Riau provinces. Although a sharp decline in colony populations was reported in these regions in 2023 (Purwanto et al., 2024), by 2024, the population is estimated to have rebounded to levels close to those in 2021. This resurgence follows the migration of many Javanese beekeepers to Sumatra during the pandemic to meet the surge in market demand for honey. According to Budiman Harahap (2024, personal communication), an administrator of the Riau Beekeepers Association and a beekeeper mentor for PT Arara Abadi, there are currently an estimated 150,000 colonies in Riau and around 100,000 colonies in Jambi.

The growing population of bee colonies in Riau and Jambi underscores the continued attractiveness of *A. crassicarpa* as a honey-producing plant for beekeepers. To further understand the current state of beekeeping in these regions, a follow-up survey was conducted. This survey aimed to anticipate potential population declines, as observed in the previous study (Purwanto et al., 2024). While the initial survey focused on production, marketing, and honey prices, the second survey addressed two key aspects: (1) evaluating beekeepers' abilities to manage their operations and (2) monitoring the development of honey production and market prices.

Beekeeper Skills and Beekeeping Management

Governance in Beekeeping and Its Challenges

Governance is a critical component of livestock farming, significantly influencing livestock health and productivity (Balasundram et al., 2023). In honey bees, management becomes particularly complex as it cannot be fully controlled. Oldroyd (2012) classifies honey bees as semi-domesticated animals. While honey bee colonies can be housed in maintenance hives, the bees must fly freely to forage for food in the surrounding environment. This makes the selection of colony or apiary locations by beekeepers a key factor in determining colony development, productivity, and the success of beekeeping operations.

In addition to location selection, many other factors play vital roles in successful beekeeping. The Food and Agriculture Organization (FAO, 2015) recommends 16 steps for good beekeeping practices, including site selection, thorough colony inspections, maintaining colony health records, implementing productivity control systems, regular replacement of queens and nests, ensuring colony strength, providing reliable water sources, and supplementing feed under certain conditions.

The complexity of honey bee farming, as outlined above, highlights the need for adequate skills and knowledge to become a successful beekeeper. Honey bee farming is a complex system (Horn et al., 2021). In several European countries, aspiring beekeepers must obtain approval from competent authorities before initiating beekeeping activities (Sperandio et al., 2019).

Knowledge Gaps and Its Challenges

A case study in Sumatra revealed that most beekeepers (90.5%) are self-taught, with only 2.4% gaining experience through internships, and the remainder having no formal training (Table 3). The majority of respondents (73.8%) have 3–5 years of beekeeping experience (Table 1), having started during the early stages of the COVID-19 pandemic when honey demand and prices surged (Purwanto et al., 2024). This suggests that many beekeepers began with limited knowledge.

The lack of expertise becomes evident when colonies face challenges such as pest attacks, food shortages, or other issues. For instance, many beekeepers (personal communication) believe that sugar syrup supplementation during nectar dearth periods is unnecessary, even when colonies struggle to find nectar for extended periods. This lack of intervention contributes to high colony

mortality rates. Purwanto et al. (2024) reported 1,170 colony deaths in Jambi and 2,230 in Riau from a survey of 40 respondents.

Despite these challenges, most respondents actively seek to improve their knowledge, often independently (Table 3), primarily through peer discussions (Table 4). Interestingly, when asked about preferred training topics, the highest responses were for improving income and market access (35.7%) and enhancing productivity and business sustainability (28.6%) (Table 5).

Key Challenges in Beekeeping

Beekeeping faces numerous challenges today. Bee health is a critical issue, with far-reaching consequences for community economies, biodiversity, and long-term sustainability (Kristiansen et al., 2024). Colony stress factors include parasitic and pathogenic infections, low-nutrient food sources, pesticide exposure, and adverse climate and environmental conditions (Mayack et al., 2022).

Improving beekeeping skills and knowledge is essential for achieving sustainable production systems. In Jambi and Riau, most *Apis mellifera* beekeepers demonstrate a good understanding of their colonies' conditions. Survey results indicate an average score of "good" (>3) for honey productivity, colony health, beeforage quality, and queen conditions.

However, respondents rated their proficiency in colony management, handling critical conditions, and acquiring knowledge as "poor" (<3). Only two aspects—site selection and the desire to learn—received "fair" scores (>3) (Table 6). Interestingly, many respondents reported gaining insights from more experienced Javanese beekeepers.

Threats and Stakeholder Support

Beekeepers in Jambi and Riau identified wildlife disturbances (e.g., birds, bears, and monkeys), pest attacks, and climate factors as the primary threats to their operations. Despite these challenges, the 3–5 years of experience many respondents have gained seem to have improved their ability to identify threats and address challenges.

Support from stakeholders, however, remains limited. Respondents rated support from central and local governments, non-governmental organizations, and village authorities as "poor" (<2). The only exception was support from forest plantation managers, which received a "fair" rating (>2).

Challenges for Improvement

The findings underscore the urgent need for guidance and training to enhance the knowledge and competence of *Apis mellifera* beekeepers in Jambi and Riau. Government intervention, both at the central and regional levels, is crucial to elevate beekeepers to a higher level of proficiency. Enhanced training programs focusing on colony management, productivity improvement, queen bee breeding, and market access could help address the current challenges and ensure the sustainability of honey production in these regions.

Honey Production and Price Development

Honey Production Pattern

Purwanto et al. (2024) found that *Apis mellifera* beekeeping in *Acacia crassicarpa* plantation forests can produce honey year-round. However, honey production can be disrupted under specific conditions, particularly during prolonged rainy seasons with high rainfall. High productivity in these areas is attributed to the continuous secretion of extrafloral nectar by *A. crassicarpa*,

particularly in plants aged 3–18 months (Suhesti et al., 2024), and up to four years of age (Pribadi et al., 2023).

Figure 1 illustrates the fluctuations in carpa honey production during 2024 in Jambi and Riau. Both regions exhibit similar production patterns, with low yields at the beginning of the year, a rise in mid-year, and a decline toward the year's end. This pattern mirrors the trends observed in 2022 but contrasts with the relatively stable production seen in 2023 (Purwanto et al., 2024). Weather conditions, particularly rainfall, are believed to significantly influence honey production, alongside other factors such as colony health, pest attacks, and the technical skills of beekeepers. Beekeeper perceptions of these influencing factors are summarized in Table 7.

Colony Productivity and Comparative Analysis

Figure 2 illustrates that the average aggregate colony productivity in Jambi and Riau in 2024 is 2.1 kg/colony/month, or approximately 25.2 kg/colony/year. This is lower than the productivity reported by Purwanto et al. (2024) for 2023 and significantly below the levels observed by Pribadi et al. (2023) and Ramadan (2020) in Riau, which were 5.68 kg/colony/month (68.16 kg/year) and 5.19 kg/colony/month (62.28 kg/year), respectively. However, it exceeds the global average productivity of 17.9 kg/colony/year in 2022 and the European average of 21 kg/colony/year for the same period. Nonetheless, productivity in Jambi and Riau remains far below the levels achieved in Canada and China, where average colony productivity reached 56 kg/year and 52 kg/year, respectively, in 2019 (POPESCU et al., 2024).

This comparison suggests that colony productivity in *A. crassicarpa* plantations has the potential to increase to levels observed in previous studies, such as 5 kg/colony/month (60 kg/year) (Pribadi et al., 2023; Suhesti et al., 2024). Further research is needed to identify the factors that could enhance production.

Market Dynamics and Pricing

Carpa honey is generally sold at the average price of IDR 22,000/kg, similar to 2023 but lower than the 2022 average of IDR 28,000/kg (Purwanto et al., 2024). Prices in Riau (IDR 25,500–26,000/kg) were consistently higher than in Jambi (IDR 19,800–20,300/kg) (Figure 3). Honey prices are influenced by several factors, including seasonal variations in nectar availability, local and national market dynamics, and demand surges during periods such as Ramadan and holidays. Efficient distribution systems also play a crucial role in maintaining price stability. In Jambi, better distribution infrastructure has contributed to stable honey prices, while Riau's prices exhibit greater fluctuation due to supply-demand dynamics.

Factors Influencing Honey Bee Productivity

Honey bee productivity is affected by a combination of biotic and abiotic factors (Neov et al., 2019). Uncontrollable elements such as climate, weather, and landscape changes, as well as pesticide use, pose significant challenges. However, colony management practices also play a crucial role in determining productivity. Effective practices include:

1) Placing colonies near abundant food sources.
2) Maintaining strong colony populations.
3) Protecting colonies from pests and disturbances.
4) Preparing colonies for harvest seasons.
5) Using high-productivity queens.
6) Providing adequate support during nectar dearth periods.

Sufficient experience and knowledge are essential for implementing these practices effectively and ensuring sustainable honey production (Kristiansen et al., 2024).

Beekeeping Experience and Knowledge Development

Although most *A. mellifera* beekeepers in Sumatra have only 3–5 years of experience, their field exposure has provided valuable insights into the advantages and challenges of beekeeping in *A. crassicarpa* monoculture forests. To optimize production, beekeepers must continue improving their skills and knowledge through independent learning, peer discussions, and formal training programs.

Opportunities for Carpa Honey Development

Carpa honey holds significant potential to become a cornerstone of the Indonesian honey industry, accounting for a dominant 92% share of production. Despite the extensive *Acacia crassicarpa* plantation areas, only a small portion is currently utilized for beekeeping. Most apiaries are situated on the edges of these plantations, enabling bees to access essential pollen from adjacent oil palm (*Elaeis guineensis*) plantations (Pribadi et al., 2023; Purwanto et al., 2024). The main obstacle to expanding beekeeping in these plantations is the limited availability of pollen sources. Addressing this issue through plantation enrichment with pollen-producing plants or the development of pollen supplements could significantly boost carpa honey production.

Further Challenges

Knowledge plays a crucial role in adopting advanced beekeeping methods (Mehra et al., 2018). Targeted and sustainable training programs are essential for enhancing the productivity and quality of *Apis mellifera* beekeeping in Sumatra. These initiatives not only enhance the livelihoods of beekeepers but also make a significant contribution to regional and national economic growth. Furthermore, additional research is essential to drive innovation, enabling more productive and efficient beekeeping practices while fostering product development.

Increasing both the quantity and quality of honey production is vital, as it enhances market access and competitiveness. Achieving these goals requires strong collaboration among the government, private sector, and civil society. By addressing existing challenges and capitalizing on opportunities in carpa honey production, Indonesia can further advance its honey industry and strengthen its position in the global market.

CONCLUSION

Field research reveals that honey production from Apis mellifera in the Acacia crassicarpa plantation forests of Sumatra, particularly in Riau and Jambi provinces, accounts for 92% of Indonesia's national honey output, with an average colony productivity of 25 kg/colony/year. There is substantial potential to enhance this productivity by improving beekeepers' technological skills and addressing existing challenges in beekeeping practices. Optimizing colony productivity and ensuring stable honey marketing could raise beekeepers' income, currently averaging IDR 22,000/kg. To realize this potential, support from stakeholders—including government, universities, NGOs, and corporations—is essential for research and intervention projects. Future research should focus on developing training programs for beekeepers, investigating effective marketing strategies, and examining stakeholder collaboration to facilitate improvements. Longitudinal studies could further assess the impact of these initiatives on the livelihoods of beekeepers and the dynamics of the honey production sector in Indonesia.

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