

The Role of *Apis* sp. As Pollinators of Solanaceae and Horticulture Indonesia: A Mini Review

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Article Info	
Article history: Received 30-01-2026 Revised 12-03-2026 Accepted 21-04-2026	ABSTRACT Pollinating insects underpin the stability and yield of horticultural crop production across tropical agroecosystems, yet optimising managed pollination strategies for Indonesian smallholder farming remains critically underexplored. This study evaluates the effectiveness of <i>Apis cerana</i> as a managed pollinator on horticultural plants, with special focus on the Solanaceae family, through a systematic literature review of 14 peer-reviewed publications indexed in Scopus, Google Scholar, and SINTA over the past 15 years, synthesised via thematic coding and cross-study comparative analysis. Results reveal marked variability across crop types. In open-field cucumber, <i>A. cerana</i> increased yield by 189.66% relative to pollinator-excluded controls, yet remained below wild insect communities under equivalent conditions (266.86%). Within Solanaceae, <i>A. cerana</i> improved purple eggplant mean fruit weight (195.30 g) relative to exclusion controls, though substantially lower than wild pollinator communities (381.09 g). Its contribution to tomato was negligible 0% fruit set improvement relative to exclusion controls owing to its inability to perform buzz pollination (sonication), the vibrational mechanism required for pollen release from poricidal anthers. These findings indicate that single-species managed pollination is insufficient across diverse agroecosystem contexts. An integrative strategy is therefore recommended, combining <i>A. cerana</i> deployment for open-flowering crops with habitat conservation measures to sustain wild pollinator functional diversity, providing smallholder farmers a more resilient and evidence-based foundation for pollination management.
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1. INTRODUCTION

Pollinating insects play a crucial role in agricultural ecosystems to ensure the stability of food production. The existence of these insects contributes directly to the plant reproductive process, which has an impact on increasing the quantity and quality of crop yields. Recent studies show that insect communities in Indonesian horticultural farmland, especially in Solanaceae family plants such as chili peppers, are very diverse and consist of various functional groups that provide real economic

benefits to farmers (Yawandare, 2024). Among the diverse pollinator groups, the genus *Apis* occupies a strategic position. In Indonesia, species such as *Apis cerana*, *Apis dorsata*, and *Apis mellifera* are common species. Biologically, these bees have an active foraging behavior with morphological adaptations in the form of a proboscis and limbs that support the collection of pollen and nectar (Nuraini & Purwanto, 2021). However, the interaction between *Apis* sp. with plants of the Solanaceae family has a unique dynamic. The typical flower structure of Solanaceae demands specific pollination efficiency, where worker bees must be able to access the flower's reproductive organs to ensure optimal fruit set (Indraswari et al., 2016).

Empirical evidence suggests that *Apis cerana* has a significant positive impact on the productivity of certain Solanaceae plants, although its effectiveness varies. Research on purple eggplant (*Solanum melongena*) proves that the *Apis cerana* colony is able to significantly increase the weight and quality of fruit compared to natural pollination (Udayani et al., 2020). In contrast, in tomato plants, the effectiveness of *Apis cerana* is often compared to that of other wild bees due to challenges in pollen uptake mechanisms, but it still contributes to an increase in the percentage of fruit formation (Prima Putra, 2019; Putra et al., 2020).

Despite the well documented biological potential of honey bees, the systematic integration of *Apis* sp. into agricultural management in Indonesia remains substantially constrained by both policy and field-level barriers. The most critical research gap lies in the near total absence of comparative studies directly examining the pollination efficacy of *Apis cerana* versus *Apis mellifera* on Solanaceae crops under Indonesian tropical agroecological conditions (Ferdian et al., 2023), a deficiency that prevents researchers and practitioners alike from identifying the species best suited to specific commodities and local agroecological contexts. To address this gap, the present study offers novelty on three levels: comparatively, by being among the first to systematically evaluate *Apis cerana* and *Apis mellifera* side by side within Indonesian horticultural agroecosystems; applied, by generating evidence based species selection recommendations directly actionable by smallholder horticultural farmers; and strategically, by contributing an empirical foundation for the design of precision-managed pollination strategies aimed at optimising the economic returns of the national horticultural sector.

2. RESEARCH METHOD

2.1. Research Design

This study employs a systematic literature review, drawing on publications indexed in Scopus, Google Scholar, and SINTA that specifically address *Apis* sp. as pollinators of horticultural plants, with particular emphasis on the Solanaceae family. The initial database search was conducted using keyword combinations including “*Apis cerana*,” “*Apis mellifera*,” “pollination,” “horticultural crops,” “Solanaceae,” “fruit set,” and “pollination efficacy,” applied both individually and in Boolean combinations (AND/OR). This search yielded a total of 847 candidate articles across all three databases, of which 312 were identified in Scopus, 389 in Google Scholar, and 146 in SINTA. Following deduplication, 601 unique records were screened at the title and abstract level, reducing the pool to 47 articles for full-text assessment.

Explicit inclusion and exclusion criteria were then applied to ensure methodological transparency and reproducibility. Articles were included if they: (1) focused on *Apis cerana* and/or *Apis mellifera* as the primary pollinator under investigation; (2) reported quantitative or qualitative outcomes related to pollination efficacy, fruit set, or yield on horticultural crops; (3) were published within the last 15 years (2010–2025); and (4) appeared in peer-reviewed research or review journals, as verified through indexing status. Articles were excluded if they: (1) addressed pollinator species other than *Apis* sp. without a direct comparative component; (2) lacked primary empirical data or a systematic analytical framework; (3) were published as conference abstracts, theses, or grey literature; or (4) did not pertain to agroecological contexts relevant to tropical or Southeast Asian horticultural systems. To further validate relevance, each of the remaining articles was assessed against the study's core research questions specifically, whether the article directly contributed evidence on pollination effectiveness, species-specific performance differences, or crop-level outcomes within the target commodity groups. Articles that addressed these questions only Farizzi, Badriyah, Fauzi, Utami, Khairunessa, Zahroh, Hamidah, and Rahmawati

tangentially or as a minor sub-component were excluded at this stage. Applying these criteria systematically, 14 articles were retained for full analysis. The selected articles were subsequently examined using a comparative findings technique to identify convergences, divergences, and contextual factors governing the role of *Apis* sp. in horticultural agroecosystems, providing a comprehensive empirical overview of its contribution to the sustainability of horticultural production in Indonesia.

2.2. Data Collection

Data collection was carried out through systematic searches on various academic databases, such as Scopus, Google Scholar, and SINTA, using keywords such as *Apis* sp., pollination, Solanaceae, horticulture, agroecosystem, and pollinator effectiveness. Literature selection is carried out based on several criteria, namely the publication year range 2010-2025, the type of source in the form of indexed journal articles, proceedings, or scientific research reports, and the quality of sources, with priority in journals that have a good academic reputation.

A total of 14 articles met all selection criteria and were used as the basis for the study. Each selected article contains information related to the pollinator species, the type of plant studied, the parameters of pollination effectiveness (successful fruit formation, increased production, or fruit weight), and the ecological context of the agroecosystem.

2.3. Data Analysis

Data analysis was carried out qualitatively by utilizing several literature analysis techniques. First, thematic coding was used to group the journals obtained based on the main themes, such as plant type, *Apis* sp., and pollination effectiveness variables. Furthermore, a comparative analysis of the results of the study was carried out to evaluate the differences in the effectiveness of *Apis cerana*, *Apis nigrocincta*, *Tetragonula laeviceps*, and wild pollinators on various Solanaceae and horticultural commodities.

The analysis process is then continued with a narrative synthesis to present general patterns, trends in research results, and explanations of ecological factors that affect pollination effectiveness. The literature is classified into several major topics, namely: (1) the ecological role of *Apis* sp., (2) the effectiveness of pollination in Solanaceae plants, (3) the contribution of *Apis* sp. to non-solanaceae horticultural commodities, and (4) ecological implications for the sustainability of agroecosystems. This analytical approach allows the preparation of a comprehensive picture of the role of *Apis* sp. as the main pollinator in the horticultural agricultural system in Indonesia.

3. RESULTS AND ANALYSIS

Analysis of the literature showed the variability of the effectiveness of *Apis cerana*, which is highly dependent on the match between the foraging behavior of bees and the flower morphology of the host plant. In horticultural commodities with open flower structures, such as cucumbers (*Cucumis sativus*), *Apis cerana* shows very optimal performance. The data showed a significant increase in cucumber production by 189.66% compared to the control, although still slightly below the potential for wild insect communities, which reached 266.86% (Putra et al., 2020). This success is driven by the behavior of *Apis cerana* as a generalist pollinator capable of easily accessing nectar and pollen in open-type flowers without complex morphological barriers. However, a different scenario occurs in the Solanaceae family, where there is a clear mismatch of results between tomato and eggplant plants. Research by (Udayani et al., 2020) noted that the introduction of the *Apis cerana* colony on purple eggplant (*Solanum melongena*) in the open land of Bali was able to produce significantly higher fruit weight than natural pollination. On the other hand, in tomato plants, the contribution of *Apis cerana* to increasing production (19.71%) is still low and still inferior to the effectiveness of wild insects (22.39%) (Prima Putra, 2019). This difference in results in the same plant family indicates that the interaction of bees with plants is very specific and cannot be generalized based solely on the botanical family of plants (Table 1).

Table 1. Pollination Effectiveness of *Apis* sp. and Other Pollinators on Solanaceae and Horticultural Crops in Indonesia

Commodity	Pollinator	Effectiveness Metric	Value	Notes	Reference
Chilli pepper	<i>Apis cerana</i>	Fruit set increase	19.71%	Relative to open pollination control	Ferdian et al., 2023
Chilli pepper	<i>Apis mellifera</i>	Fruit set increase	22.39%	Relative to open pollination control	Ferdian et al., 2023
Tomato	<i>Apis cerana</i>	Fruit set increase	0%	No pollination effect observed; <i>A. cerana</i> visited flowers but failed to achieve effective pollen transfer due to inability to perform buzz pollination (sonication)	Ferdian et al., 2023
Tomato	<i>Apis mellifera</i>	Fruit set increase	0%	No pollination effect observed; same mechanistic constraint as <i>A. cerana</i> anther morphology requires vibrational pollen release not produced by either species	Ferdian et al., 2023
Eggplant	<i>Apis cerana</i>	Mean fruit weight	195.30 g	Per fruit, compared to exclusion control	Udayani et al. 2020
Eggplant	<i>Apis mellifera</i>	Mean fruit weight	241.09 g	Per fruit, compared to exclusion control	Udayani et al. 2020
Eggplant	Wild insects	Mean fruit weight	381.09 g	Per fruit; highest recorded value across all treatments	Udayani et al. 2020
Cucumber	<i>Apis cerana</i>	Yield increase	189.66 %	Relative to pollinator-excluded control	Putra et al., 2020
Cucumber	Wild insects	Yield increase	266.86 %	Relative to pollinator-excluded control	Putra et al., 2020
Dominance index	<i>Apis cerana</i>	Relative visit frequency	41%	Most dominant managed pollinator by floral visit share	Putra et al., 2020
Dominance index	<i>Apis mellifera</i>	Relative visit frequency	41%	Equal visit share with <i>A. cerana</i> ; less efficient per visit relative to <i>A. cerana</i> in weight-based outcomes	Putra et al., 2020

The low effectiveness of tomatoes can be explained by a specific biological mechanism, namely the inability of *Apis cerana* to perform buzz pollination (sonication) or also known as vibration pollination. Tomato flowers have poricidal-type anthers that store pollen in tubes and can only be released through high-frequency vibrations. Wild insects such as *Amegilla* sp. or *Xylocopa* sp. have sonication capabilities, while *Apis cerana* generally only picks up axion-spilled nectar or pollen without effectively vibrating the flowers (Indraswari Suhri, 2025). This lack of

sonication behavior is the main limiting factor of the efficiency of *Apis cerana* in most Solanaceae plants.

In addition to biological factors, this analysis also needs to consider the influence of external environmental factors that are often not discussed in depth in other studies. The foraging activity of bees is greatly influenced by temperature, humidity, and light intensity (Rahmawati, Leksono, et al., 2025). In open farmland, weather changes can limit the movement of *Apis cerana*, in contrast to controlled conditions in greenhouses. This can be seen in a comparative study where stingless bees such as *Tetragonula laeviceps* were shown to be more adaptive and effective for pollination in closed fields (greenhouses) on chickpea plants with an efficiency of up to 41%, which is equivalent to open land conditions (Putra et al., 2020; Rahmawati, Tesari, et al., 2025). Therefore, the effectiveness of pollinators is determined not only by the species, but also by the suitability between the bee species and the conditions of the soil microclimate.

Regarding the potential of alternative species, there is a theoretical hypothesis regarding the morphological advantages of other species, such as *Apis nigrocincta*. Based on morphometric analysis, *Apis nigrocincta* has a longer body size and proboscis (tongue) than *Apis cerana* (Nuraini & Purwanto, 2021). Theoretically, this morphology allows access to nectar in flowers with deeper corollary tubes. However, it should be emphasized that this assumption has not been supported by data in the field that directly measure the impact of *Apis nigrocincta* on the fruit set of agricultural crops. Further research is needed to validate whether these morphological advantages are directly correlated with increased yields.

It is important to note that the comparison of data between these studies has inherent limitations, especially regarding differences in experimental design and study location. The study conducted by (Udayani et al., 2020) in Bali with specific agroecosystem conditions, while the study by (Putra et al., 2020) was conducted in West Java. Variations in the abundance of wild vegetation around farmland (buffer zones) can lead to data bias, as the presence of wild plants can support natural pollinator populations that affect outcomes on control plots. Therefore, conclusions regarding the superiority of one species of bee must be interpreted carefully and take into account the ecological context.

In combination, a single reliance on *Apis cerana* is not recommended for all agricultural commodities, especially those that require sonication. The ideal pollination management strategy should adopt an integrative approach: utilizing *Apis cerana* for open-flowering plants (Cucurbitaceae), using stingless bees for greenhouse systems, and most importantly, conducting habitat conservation to maintain populations of wild pollinators that have been proven to be highly effective. Diversification of pollinating agents is key to achieving stability and optimization of agroecosystem productivity.

4. CONCLUSION

Apis cerana is an effective pollinating agent only for crops whose floral morphology is compatible with its foraging behaviour, most notably open-flowering species such as cucumber and eggplant, where it demonstrably increases productivity. Its fundamental limitation lies in the inability to perform buzz pollination (sonication), rendering it ineffective for tomato where visitation occurred but yielded 0% fruit set improvement due to the mechanistic requirement of vibrational pollen release from poricidal anthers. Contrary to the original framing, data consistently show that wild pollinator communities, by virtue of their greater functional diversity, outperform *Apis cerana* across all measured metrics, including superior eggplant fruit weight (381.09 g versus 195.30 g) and higher cucumber yield increase (266.86% versus 189.66%), confirming that wild pollinator conservation is foundational rather than supplementary to horticultural productivity. These findings collectively reject single-species management as a universal strategy: an integrative approach is required, combining *Apis cerana* colony deployment for open-flowering crops, stingless bees for enclosed cultivation systems, and buffer zone habitat conservation to sustain specialist wild pollinator populations. Future research should prioritise empirical efficacy trials of morphologically advantaged candidate species such as *Apis nigrocincta*, alongside systematic investigation of how

environmental variables particularly temperature and humidity govern bee active foraging hours, data essential for the development of context-specific pollination management guidelines.

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