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Insect pollinators on *Ananas comosus* Linn. in pineapple cultivation hub at Tangkit Baru Village, Jambi Province: A preliminary study

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ABSTRACT

The flowers of *Ananas comosus*, pineapple, are generally self-sterile which means seeds will only develop if cross-pollination occurs. Therefore, insect pollinators play a crucial role in fostering and preserving genetic diversity in pineapple plants. Our research aimed as a preliminary study to gain insight into the key pollinators that play a significant role in the pollination of *A. comosus* in Tangkit Baru village, a prominent pineapple cultivation hub in Jambi Province. Sampling was done in 20 sampling points, five times at five-day intervals. Sampling was carried out using yellow sticky traps, sweep net, and direct observation. All the collected insects were identified to species level, then species diversity and evenness were assessed using Shannon's diversity index (H') and Pielou's evenness index (J'). A total of 1167 individuals, representing 31 distinct species of insect pollinators belonging to 14 families were found in our sampling sites. We found four dominant species that could potentially serve as the key pollinators of *A. comosus* in our sampling site, i.e. *Dolichoderus thoracicus*, *Pygophora enigma, Pygophora respondens*, and *Anoplolepis gracilipes*. The diversity and evenness of insect pollinators in the sampling site were at a moderate level, with Shannon's diversity index (H') value of 2.0785 and pielou's evenness index (J') value of 0.6053. Habitat enhancement measures are needed to preserve and improve the existing pollinator diversity and evenness in the agroecosystem.

Keywords: Abundance, diversity, pineapple, pollinators, richness

INTRODUCTION

Ananas comosus Linn., commonly known as pineapple, ranks as the third most significant tropical fruit worldwide, trailing behind bananas and mangos. Indonesia holds the fourth position among the leading global producers of pineapple, following Costa Rica, Philippines, and Brazil (Hikal et al., 2021). Jambi province is among the top ten producers of pineapple in Indonesia, having produced up to 119.862 tons of pineapple in 2022 (BPS, 2023). Tangkit Baru Village, situated within the Sungai Gelam District, Muaro Jambi Regency, serves as a pivotal hub for pineapple cultivation in Jambi province. With a substantial land area of 995.25 hectares devoted to this purpose, this village has consistently achieved an average daily production of 20 tons of pineapples (Kemenkumham, 2022).

A. comosus is a monocotyledon belonging to the large genus Ananas of the family Bromeliaceae, which has a short stem, and rosette of waxy leaves (Wijeratnam, 2016). A mature plant yields numerous flowers that are arranged in a helical pattern along the axis. Each of these flowers contributes a fleshy fruitlet, which presses against the fruitlets of nearby flowers. This process results in the formation of what seems to be a singular fleshy fruit (Hassan et al., 2011). The fruit development of pineapples takes on a distinctive characteristic known as parthenocarpy (Westerkamp & Gottsberger, 2000). This botanical phenomenon denotes that the pineapple fruit can develop without the necessity of fertilization (Kudom & Kofi, 2010; Py et al., 1987). Pollination is only required for seed formation, but the flowers of the pineapple plant are generally self-sterile which means they cannot pollinate themselves (Bubar 1959; Py et al. 1987; Wijeratnam 2016). Seeds will only develop if there is cross-pollination between different varieties of *A. comosus* (Reinhardt, et al. 2018). Therefore, they typically require external agents such as insects or wind for cross-pollination to occur.

Due to their parthenocarpic nature, pollination may not be a critical factor in the fruit development of pineapples, but it plays a crucial role in pineapple breeding programs. Cross-pollination is greatly important for genetic variation in the genus Ananas (Cabral et al., 2009), and increasing plants' diversity and adaptability in changing environments (Pattemore, 2017). Greater genetic variation increases a chance of producing individuals with natural resistance to pest and disease attacks, as evidenced by a report showing that 121 out of 246 pineapple germplasms in the Pineapple Active Germplasm Banks exhibit resistance to *Fusarium subglutinans* (Cabral et al., 2009). Furthermore, cross-pollination can contribute to the creation of pineapple plants with desirable characteristics, such as larger fruit size, increased soluble solids, ascorbic acid and caroten content (Chan, 2006). This underscores the broader impact of cross-pollination in shaping not only the resilience but also the quality and productivity of pineapple crops.

Given the recognized significance of insect pollinators in fostering and preserving genetic diversity in pineapple plants, coupled with the existing knowledge gap regarding these pollinators on *A. comosus* in the Tangkit Baru village, there is a pressing need for a more comprehensive investigation. A crucial initial stride in enhancing pollination services for a crop involves gaining insight into the key pollinators that play a significant role in the pollination of that particular crop (Villa-Galaviz et al., 2023). This research aims to serve as a preliminary study, addressing this gap by exploring the diversity and abundance of insect pollinators intricately linked to *A. comosus* within the distinctive agricultural setting of Tangkit Baru village, Jambi province. By providing valuable information, this research is essential for improving pollination services, enhancing pineapple yields, and supporting sustainable agricultural practices, with long-term benefits for local farmers and biodiversity conservation.

METHOD

Field and laboratory work

This research was conducted in June 2023 in one of the pineapple plantations in the village of Tangkit Baru, Muaro Jambi Regency, Jambi Province (1°36'18.8"S 103°43'24.1"E), covering an area of 1.8 hectares. Climatic conditions at the sampling site were recorded daily. Twenty sampling points were purposively determined, with each point serving as a representative replication. Sampling was carried out using yellow sticky traps, sweep net, and direct observation. Sampling was performed five times at five-day intervals, starting from the first day of flower blooming. Samples were collected between 08:00 to 11:00 AM. The captured insects were placed in sample bottles containing 70% alcohol. Insects belonging to the Lepidoptera order were placed in papillote envelopes for further transportation to the laboratory for identification. All the collected insects were sorted to individual morphospecies (i.e. a typological species distinguished solely on the basis of morphology) before they were identified to species level specifically. The systematic confirmation of the role of insects as pollinators was achieved by carefully examining scientific references (Appendix 1).

Data analysis

Rarefaction curves were employed to visualize the adequacy of sampling and to estimate species richness at our sampling site, following the approach outlined by Chao et al. (2014). Extrapolation for estimating species richness involved the use of 95% confidence intervals derived from 1,000 bootstrap resamplings, as suggested by Colwell et al. (2012). The curves were extrapolated up to twice our sample size. The analyses were conducted using the iNEXT Online (Chao et al., 2016). Species diversity and evenness were assessed using Shannon's diversity index (H') and Pielou's evenness index (J'), respectively (Magurran, 1988).

RESULTS AND DISCUSSION

The sampling conducted at a pineapple plantation in Tangkit Baru village recorded a total of 1167 individuals, representing 31 distinct species of insect pollinators. The Sampling completeness curve confirms that sampling effort was adequate since it shows high value (99.49%) of sampling coverage (Figure 1a). The rarefaction curve reveals that when reaching the observed 31 species in 1167 individuals, the lower and upper 95% confidence intervals were 27 and 35 species, respectively.

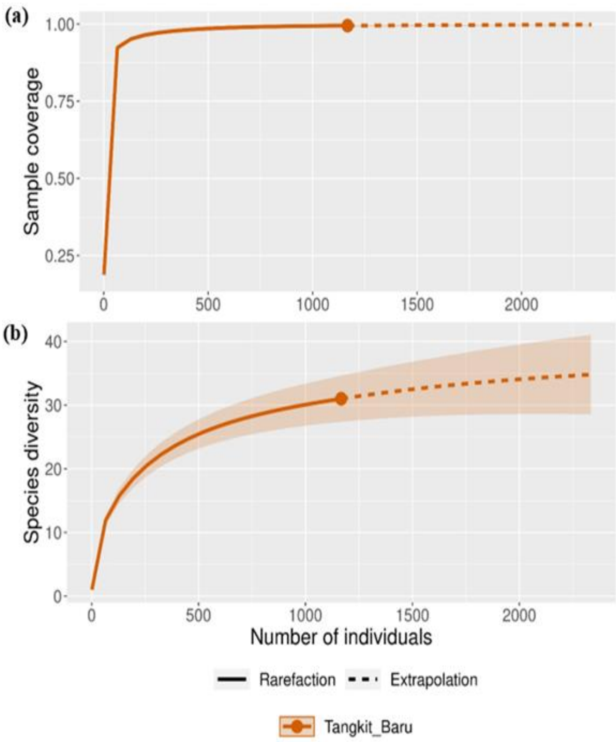

Figure 1. (a) Sample completeness curve, and (b) Integrated rarefaction and extrapolation curves of species diversity base on the Hill numbers q = 0. Shaded areas represent 95 % confidence intervals obtained by 1,000 resamplings through bootstrapping.

Table 1. Shannon-Wienner diversity index and Pielou's evenness index (J') calculation

Order	Family	Species	Pi	Pi(lnPi)
Hymenoptera	Vespidae	*Vespa affinis*	0.0034	-0.0195
		Vespa tropica	0.0017	-0.0109
		Rhynchium haemorrhoidale	0.0017	-0.0109
		Ropalidia marginata	0.0094	-0.0440
		Ropalidia jacobsoni	0.0163	-0.0670
		Ropalidia sumatrae	0.0009	-0.0061
		Ropalidia flavopicta	0.0009	-0.0061
		Allorhyncium snelleni	0.0060	-0.0307
		Allorhyncium moerum	0.0026	-0.0153
		Stenodynerus krombeini	0.0034	-0.0195
	Apidae	*Xylocopa confusa*	0.0034	-0.0195
	Sphecidae	*Sceliphron destillatorium*	0.0026	-0.0153
	Halictidae	*Nomia melanderi*	0.0103	-0.0471
		Augochlora pura	0.0051	-0.0271
	Scoliidae	*Scolia superciliaris*	0.0009	-0.0061
	Formicidae	*Anoplolepis gracilipes*	0.1517	-0.2861
		Camponotus tricoloratus	0.0300	-0.1052
		Dolichoderus thoracicus	0.3316	-0.3660
		Polyrhacis armata	0.0094	-0.0440
Lepidotera	Pieridae	*Appias libythea*	0.0034	-0.0195
		Ascia monuste	0.0009	-0.0061
	Nymphalidae	*Hypolimnas bolina*	0.0026	-0.0153

Order	Family	Species	Pi	Pi(lnPi)
		Junonia atlites	0.0009	-0.0061
	Erebidae	*Amata huebneri*	0.0051	-0.0271
Diptera	Syrphidae	*Eumerus figurans*	0.0403	-0.1294
	Conopidae	*Physocephala rufipes*	0.0009	-0.0061
	Micropezidae	*Rainieria antennaepes*	0.0291	-0.1030
	Sarcophagidae	*Sarcophaga crassipalpis*	0.0043	-0.0234
	Muscidae	*Musca domestica*	0.0017	-0.0109
		Pygophora respondens	0.1517	-0.2861
		Pygophora enigma	0.1680	-0.2996
Total			1	-2.0785
Shannon diversity index (H')			2.0785	
H' max			3.4340	
Pielou's evenness index (J')			0.6053	

The extrapolation demonstrates that by doubling the sample size (2334 species), the expected number of species would be 35 species (lower and upper 95% confidence intervals of 29 and 41 species, respectively) (Figure 1b). Shannon's diversity index (H') is 2.0785, and Pielou's evenness index (J') is 0.6053 which indicates moderate level of evenness in the community (Table 1). Climatic conditions at the sampling site throughout the study were generally normal, with no occurrence of extreme events (Table 2).

Table 2. Climatic condition at study site

Climatic factors	Means ± SD
Minimum temperature (°C)	24.4 ± 0.6
Maximum temperature (°C)	32.6 ± 1.7
Relative humidity (%)	84.6 ± 3.6
Rainfall (mm)	3.76 ± 10.5

SD = standard deviation

The validation of insects' role as pollinators was systematically confirmed through a thorough examination of scientific references. The 31 species of insect pollinators identified belong to 14 different families. Among these families, Vespidae was the most prominent with 10 species, followed by Formicidae with 4 species, and Muscidae with 3 species (Table 1). Moreover, the data highlights that a substantial portion of the total abundance, specifically 80.29%, is concentrated within four species. These key contributors to the pollinator community are *Dolichoderus thoracicus*, *Pygophora enigma*, *Pygophora respondens*, and *Anoplolepis gracilipes*, as depicted in the species rank abundance curve (Figure 2).

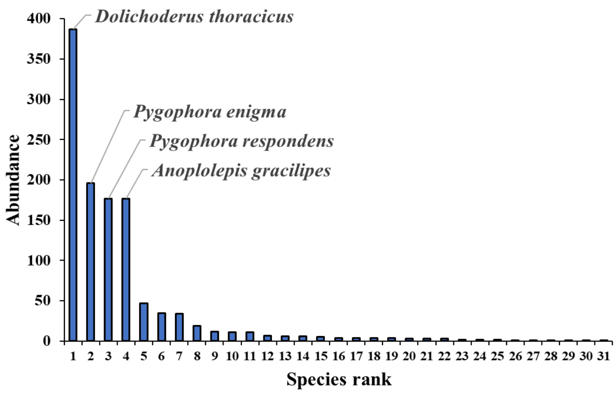

Figure 2. Species rank abundance curve with the four most abundant species pointed out.

A comprehensive examination of the sampling site revealed a rich diversity of insect pollinators, totaling 31 distinct species. The Sampling completeness curve affirms that the sampling effort was sufficient, and extrapolation suggests that, even with a doubled sample size, the incremental addition of species would be modest, reaching a maximum of 35 species. All those 31 species belong to three taxonomic orders, i.e. hymenoptera, diptera, and lepidoptera. Notably, a significant majority, 61.29% of pollinator species richness, fell within the taxonomic order of hymenoptera. This finding highlights the significant role of hymenopteran species in shaping the pollination dynamics of the *A. comosus* agroecosystem. The presence of many hymenopteran species in a certain location may be influenced by their visual abilities and their preference for specific colours (Koneri et al., 2020). Csanády et al. (2021) reported that the three most preferred colour by hymenopteran species are yellow, white, and purple. In our distinctive agricultural setting of a pineapple plantation, the pineapple flower exhibits white petals with a yellowish hue from the base to the middle, and the color shifts to purple from the middle to the tips, matching with the reported color preferences of hymenopterans. Consequently, a significant number of hymenopteran species were observed being attracted to visit *A. comosus* flowers.

Vespidae and formicidae are the two most prominent families of hymenopterans found at the sampling site, exhibiting a high level of species richness. Vespidae and formicidae both belong to the infraorder aculeata within the order hymenoptera (Brothers, 2019). Vespidae, known as the family of wasps, plays important roles in ecosystems by acting as both parasitoids and pollinators, as most wasps species feed their larvae on other insects, while the adult wasps feed on nectar (Fateryga, 2010; Rojas-Nossa et al., 2023). Particularly, the aculeate wasps, among the most diverse insect taxa, exhibit varied co-evolutionary and exploitative associations with other organisms, providing at least 10 ecosystem services across the key areas of regulating, supporting, provisioning, and cultural services (Brock et al., 2021). Similarly, various ants of the formicidae family may also have multiple roles in ecosystem, serving as seed disperser, predator, and pollinator (Das & Das, 2023). Thus, the coexistence of vespidae and formicidae at the sampling site may contribute significantly to the agroecosystem's vitality and resilience through their high species richness and diverse ecological roles.

This study revealed that the diversity and evenness of insect pollinators in the surveyed site were at a moderate level, as the values fall within two-thirds of their maximum values. Reasonably, there are few dominant species and several subdominants to rare species among the 31 insect pollinator species identified in this study. The insect pollinator community in the studied site was dominated by four species, i.e. *Dolichoderus thoracicus*, *Pygophora enigma*, *Pygophora respondens*, and *Anoplolepis gracilipes*, accounting for 80.29% of the total abundance. These four insect species could potentially serve as the key pollinators of *A. comosus* plantation in Tangkit Baru Village, given that insects with higher abundance tend to visit flowers more frequently and transport larger amounts of pollen (Villa-Galaviz et al., 2023). Among those high abundance species, these two flies, i.e. *Pygophora enigma* and *Pygophora respondens*, may be particularly more effective in cross-pollinating flowers due to their hairy bodies and legs, coupled with their ability to fly, allowing them to transport more pollen over longer distances (Holloway, 1976; Inouye et al., 2015; Stavert et al., 2016; Thorp, 2000; Villa-Galaviz et al., 2023).

The 27 remaining species, comprising only 19.71% of the total individuals sampled, are classified as subdominant to rare within the agroecosystem. Nevertheless, the significance of their presence should not be underestimated in the broader ecological context. Some ecologists have documented the cumulative impact of less common species on the overall diversity and dynamics of the system. For instance, rare species can act as buffers, enhancing ecosystem processes in response to disturbances within the ecosystem (Walker et al., 1999; Yachi & Loreau, 1999). Temporal variability in species abundance dynamically occurs, and the collective contribution of all species, including subdominant and rare species, is necessary to reach a threshold essential for ensuring sufficient crop pollination (Kremen et al., 2002). Thus, the subdominant and rare species may also play integral roles in the ecosystem.

The pollination success of insect-pollinated plant species usually depends more on a diverse community of pollinators rather than on a single, highly specialized pollinator species (Steffan-Dewenter & Westphal, 2008). A study by Gómez et al. (2007) revealed that the maximum pollination success on *Erysimum mediohispanicum* occurs when pollinator diversity is at a moderate level. Similarly, intermediate levels of pollinator species richness have resulted in optimum pollination services on *Raphanus sativus* (Albrecht et al., 2012). However, it is essential to note that the specific relationship between pollinator diversity and pollination success can vary depending on factors such as weather, plant varieties and diversity, pollen quality and quantity, pollinator traits, and the presence of predators (Gavini et al., 2021; Gintoron et al., 2023; Kortsch et al., 2023). Thus, further studies are needed to elucidate the relationship between pollinator diversity and pollination success on *A. comosus* at our study site. We suggest that the existing moderate level of pollinator diversity and evenness in the pineapple agroecosystem at Tangkit Baru village needs to be maintained and enhanced to ensure successful pollination and promote overall ecosystem health.

CONCLUSION

In summary, this study highlights a diverse community of insect pollinators in *A. comosus* plantation in Tangkit Baru Village, comprising 31 distinct species across three taxonomic orders. Hymenoptera, particularly Vespidae and Formicidae, emerge as prominent families, demonstrating high species richness. The moderate diversity and evenness of insect pollinators, as indicated by Shannon's indices, reveal a nuanced ecosystem where a few dominant species, including *Dolichoderus thoracicus*, *Pygophora enigma*, *Pygophora respondens*, and *Anoplolepis gracilipes*, may exert considerable influence. These key pollinators, especially those with more effective cross-pollination traits like *Pygophora enigma*, and *Pygophora respondens*, are vital for the pollination success of *A. comosus* plantation in Tangkit Baru Village. We recommend implementing habitat enhancement measures, introducing diverse plantings, minimizing pesticide use through integrated pest management, and fostering community awareness to further support and improve the existing moderate level of pollinator diversity and evenness in the agroecosystem.

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Appendix 1. List of insects collected in the pineapple plantations, with references explaining its role as pollinators

No.	Species	References
1	*Vespa affinis*	Asra *et al.* 2022; Koneri et al. 2021; Syari *et al.* 2023; Syarifuddin *et al.* 2018
2	*Vespa tropica*	Angriani *et al.* 2015; Asra *et al.* 2022; Erniwati and Kahono 2010; Handani *et al*. 2015; Koneri et al. 2021
3	*Rhynchium haemorrhoidale*	Asra *et al.* 2022; A'yunin *et al.* 2019; Koneri et al. 2021; Palupi *et al.* 2023
4	*Ropalidia marginata*	Erniwati and Kahono 2010; Palupi *et al.* 2023; Wardhani and Fadjratun 2018
5	*Ropalidia jacobsoni*	Erniwati and Kahono 2010; Palupi *et al.* 2023; Pham 2014
6	*Ropalidia sumatrae*	Erniwati and Kahono 2010; Pham 2014
7	*Ropalidia flavopicta*	Erniwati and Kahono 2010; Pham 2014
8	*Allorhyncium snelleni*	Anoosha 2018; Erniwati and Kahono 2010; Koneri et al. 2021; Palupi *et al.* 2023; Syarifuddin *et al.* 2018
9	*Allorhyncium moerum*	Anoosha 2018; Erniwati and Kahono 2010; Koneri et al. 2021; Palupi *et al.* 2023; Syarifuddin *et al.* 2018;
10	*Stenodynerus krombeini*	Adams *et al.* 2010; Espinosa 2015
11	*Xylocopa confusa*	Angriani *et al*. 2015; Erniwati and Kahono 2010; Handani *et al*. 2015; Hasan *et al*. 2017; Hidayat *et al.* 2016; Syari *et al.* 2023
12	*Sceliphron destillatorium*	Can and Gulmez 2021; Yuan *et al.* 2022
13	*Nomia melanderi*	Bodlah *et al*. 2016; Koneri *et al.* 2021; Widhiono 2015;
14	*Augochlora pura*	Short and Lucky 2018; Widhiono 2015;
15	*Scolia superciliaris*	Erniwati and Kahono 2009; Liu *et al.* 2021
16	*Anoplolepis gracilipes*	Ahmad *et al.* 2022; Sukmawati 2019
17	*Camponotus tricoloratus*	Asra *et al.* 2022; Octaviana 2021; Wardhani and Fadjratun 2018
18	*Dolichoderus thoracicus*	Mudrofin 2021; Muhamat *et al.* 2015; Nugroho *et al.* 2019
19	*Polyrhacis armata*	Asra *et al.* 2022
20	*Appias libythea*	Angriani *et al.* 2015; Maryuni *et al.* 2018; Syari *et al.* 2023
21	*Ascia monuste*	Anyz 2019; Castro and Singer 2019
22	*Hypolimnas bolina*	Angriani *et al.* 2015; Erniwati and Kahono 2010; Handani *et al*. 2015; Masawet *et al.* 2019; Syari *et al.* 2023
23	*Junonia atlites*	Koneri et al. 2021; Siregar 2016; Sumah and Apriniarti 2019;
24	*Amata huebneri*	Mamangkay *et al.* 2022; Masawet *et al.* 2019; Syari *et al.* 2023; Syarifuddin *et al.* 2018
25	*Eumerus figurans*	Susilawati *et al.* 2017
26	*Physocephala rufipes*	El-Hawagry *et al.* 2022; Smith 1969
27	*Rainieria antennaepes*	Hasyimuddin *et al*. 2017
28	*Sarcophaga crassipalpis*	Asra *et al.* 2022; Labibah *et al.* 2023; Syarifuddin *et al.* 2018; Wardhani and Fadjratun 2018; Maryuni 2018
29	*Musca domestica*	Asra *et al.* 2022; Lesari *et al.* 2014; Syarifuddin *et al.* 2018
30	*Pygophora respondens*	Bharti 2008
31	*Pygophora enigma*	Bharti 2008