International Journal of Zoology and Applied Biosciences
Volume 10, Issue 4, pp: 69-75, 2025
https://doi.org/10.55126/ijzab.2025.v10.i04.006
ISSN: 2455-9571
http://www.ijzab.com
Research Article

STUDIES ON BEE DIVERSITY IN INDIAN COFFEE VARIETIES AND IMPACT OF BEE POLLINATION ON COFFEE QUALITY

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Article History: Received 25th April 2025; Accepted 19th June 2025; Published 31st July 2025

ABSTRACT

Globally, *Coffea arabica* (Arabica coffee) and *Coffea canephora* (Robusta coffee) are the two coffee varieties grown on commercial scale which have distinct difference in terms of pollination dependencies. Arabica coffee is autogamous (self fertilization) with varying degrees of cross pollination while robusta is allogamous (cross fertilization). In coffee, the main pollinating agents are honey bees and wind, playing a crucial role in fruit setting. Several authors have studied the effect of bee pollination on coffee yield, while the studies on the bee abundance and impact of bee pollination on coffee quality are rather limited. Therefore, the present study aimed to explore further insights on the effect of bee pollination on coffee quality following bee-exclusion experiments besides recording the common bee pollinators prevailing during the blossom season of both arabica and robusta coffee varieties under Indian condition. The results of the present study indicated that seven different bee species *viz., Apis cerana, A.dorsata, A.florea, Tetragonula travancorica, Xylocopa* sp, *Lassioglossus* sp and *Amigella* sp. noticed during the coffee blossom season. *Apis cerana* was the most abundnat bee species found both in arabica and robusta followed by *T. travancorica*. Regarding coffee cup quality, the overall organoleptic score was higher in the bee-pollinated coffees, as compared to non-bee pollinated coffees both in arabica and robusta suggesting bee pollination has a definite role in the improvement of the cup quality.

Keywords: Arabica, Coffee, Cup quality, Honeybee, Pollination, Robusta.

INTRODUCTION

Coffee is predominantly cultivated in the hilly tracts of Western Ghats covering three southern states of India (Karnataka, Kerala and Tamil Nadu). Coffee is a perennial crop belongs to Rubiaceae family and the genus *Coffea*. Though there are more than hundred species of coffee under the *Coffea* genus, only two coffee varieties *viz., C. arabica* and *C. canephora* are cultivated on commercial scale. *C. arabica* is autogamous (self-fertilization) with varying degrees of cross pollination and *C. canephora* is allogamous (cross fertilization). Self-fertilization in robusta coffee is avoided by gametophytic self-incompatibility which is genetically controlled. Robusta has the adaptive advantage in having longer styles compared to arabica which facilitate the cross pollination. Sometimes in arabica, self-pollination occurs before the opening of the flower buds, within the bud itself and the tendency for cross pollination is high in interspecific hybrids between arabica and robusta. Despite the differences on the mode of pollination, both the coffee varieties benefit from bee pollination (Anonymous, 2023).

In India, coffees are grown under silvi-horticultural condition with two-tier shaded condition (temporary shade trees in the first tier and permanent jungle trees in the second tier) unlike in other coffee growing countries where it is grown in open condition (sun coffee). The coffee farming under the silvi-horticultural conditions is a haven for the existence of various flora and fauna. In coffee, bee visitation is common during the blossom season (January to March) irrespective of the coffee varieties and nature of

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pollination (Anonymous, 2023). The fuzzy body and frequent visitation of honey bee for the collection of nectar help to pollinate the flowers.

Bees and plants are co-evolved during the middle cretaceous period (Michener, 1974). More than 70% of the world crops are depending upon animal pollination (Aizen *et al*., 2009) and over 80% of major food crops depend on bees for pollination (Potts, 1983). In addition to agricultural crops, bees play a significant role in pollinating trees, shrubs and wild flowers. Honey bees are essential for maintaining cross pollination in natural settings, which enhances the ecosystem resilience (Axel, 2019). Honey bee provides ecosystem services in terms of pollination which helps to increase the fruit set, and wild bees are well known to increase yield (Chain-Guadarrama *et al*., 2019).

Several authors have studied the influence of bee pollination on crop productivity (Bartomeus *et al*., 2014; Chain-Guadarrama *et al*., 2019; Klein *et al*., 2003a), while few studies have assessed the impact of pollination on chemical and organoleptic attributes of the final produce (Georg *et al*., 2012). Klatt *et al*., (2014) demonstrated bee pollination can influence nutritional and commercial value of crops. As far as coffee is concerned, several authors have reported the effect of bee pollination on yield (Belavadi, 2013; Klein *et al*., 2003ab; Vergara and Badano, 2009). However, report on the influence of bee pollination on coffee quality is rather scanty (Karanja *et al*., 2013; Meireles *et al*., 2022; Natalia *et al*., 2025). Therefore, the current investigation aimed to understand the further insights on the effect of bee pollination on coffee cup quality besides identifying the common bee pollinators prevailing during the blossom season of both arabica and robusta coffee varieties under Indian condition.

MATERIALS AND METHODS

Diversity of bees during coffee blossom

The study was conducted for three consecutive years from 2023 to 2025 at Central Coffee Research Institute (CCRI) located at Chikkamagaluru district in Karnataka state. The bee diversity was studied on robusta and arabica varieties at different blocks of coffee research farm in CCRI. The bee visitation was recorded during the active visitation period between 8.00 AM to 6.00 PM (January to March). Plants were selected randomly and observed for 15 min for bee visitation. Three branches from each plant were observed for 15 min. After every 15 min, another plant was taken for observation and hundred plants were observed for a single blossom day. Number of different bee species visiting the flower was recorded by direct count method. The bees were collected individually with utmost care for not to disturb the coffee flowers and pollens. The bees could not identify at the field level were collected and sent for species level identification. The common bees were collected and mounted as voucher specimen at the division of Entomology, CCRI for future reference. Simpsons diversity indices (Simpson, 1949), Shannon-Weiner diversity indices (Shannon, 1948) were used to analyze bee diversity in arabica and robusta coffee.

Pollination and coffee quality

Pollination exclusion experiments were conducted to study the quality attributes of bee- pollinated and non-bee pollinated coffee of both arabica and robusta varieties. Twenty plants were randomly selected and the branches were marked as open (bee-pollinated) and bagged (non-bee pollinated). The berries in all the treatments were allowed to ripe. The fully ripe cherries of both arabica and robusta varieties were harvested separately from each treatment and then pooled. The pooled ripe cherries from each treatment were wet processed as detailed in (Gopinandhan and Shivalingu, 2024). In brief, ripe coffee cherries were pulped to remove the outer skin and the resulting coffee beans usually covered by thin layer of mucilage (mostly consist of sugars and pectin). The mucilage was removed using aqua-washer machine (mucilage remover). The resulting wet coffee beans were soaked in water for about 8 to 10 hours to remove the residual mucilage clinging to the coffee bean (this process known as post-wash soaking). Then, the coffee samples were sun dried until the moisture level in coffee samples reached to 10%. The moisture content in the coffee bean samples was determined by Sinar moisture analyzer (Model: AP 6060, M/s. Sinar Technology, England). The coffee thus obtained is called as parchment coffee. The parchment coffees were de-husked using peeler-cum-polisher machine (Model: PP7/LS-407, M/s. Marshall-Fowler Group, UK) to obtain the raw coffee bean sample (also known as unroasted coffee bean). The raw coffee bean samples were winnowed to remove all the extraneous matters or non-coffee materials and then subjected to size grading using “McKinnon” make grading sieves or screens (M/s. McKinnon Co., Aberdeen, Scotland). The “A” grade bean (6.65 mm) was sent to Coffee Quality Evaluation Division, Bengaluru for cup quality analysis.

RESULTS AND DISCUSSIONS

The bee species and the percentage occurrence of each bee species in arabica and robusta is shown in Fig 1 and 2 respectively. Seven different bee species *viz., Apis cerana, A.dorsata, A.florea, Tetragonula travancorica, Xylocopa* sp. *Lassioglossus* sp. and *Amigella* sp. recorded in arabica flowers while similar bee species noticed even in robusta excepting *Amigella* sp. Bee species includes both social (*A. cerana, A.dorsata, A.florea and T.travancorica*) and solitary bees (*Xylocopa* sp and *Amigella* sp) and majority of the bee species belongs to the family Apidae of the order Hymenoptera.

In the present study, the number of bee species found was seven while other studies have reported differntly. Fletcher (1915) and Smitha *et al.,* (2012) reported the occurrence of eight and sixteen bee species, respectively under Indian condition. Ricketts (2004) reported forty bee species in Coasta Rica, twenty two bee spceies in Panama (Roubik 2002a) and five to seventeen in Mexico (Jha and

Vandermeer, 2009, Philpott *et al.,* 2006, Vergara and Badano, 2009). Several authors have reported that *Apis* species (belongs to the family Apidae) are major floral visitors of coffee accounting for over 50% of all visitors (Armas *et al*., 2020; Klein *et al.,* 2003b; Ricketts, 2004). In the current study, though the divseristy indices did not show significant difference in respect of bee species visiting arabica and robusta, the total number of bees visited during the blossom was more in robusta (2072 nos.) compared to arabica (547 nos.). The bee species observed on arabica and robusta coffee varieties displayed differences in composition, abundance, and diversity metrics (Table 1). *Apis cerana* was the most dominant species on both coffee types, comprising 51.01% of the individuals on arabica and 48.99% on Robusta. *T. travancorica* was the second most abundant, with 45.16% on arabica and 45.51% on robusta. Other species, such as *Apis dorsata*, *A. florea*, *Amegilla* sp., *Lassioglossus* sp., and *Xylocopa* sp., were present in lower percentages, showing slight variation between the two coffee types.

Table 1. Diversity of bees species recorded in Indian coffee plantation during blossom season.

Species	**Family**	**Percent Abundance**	
		Arabica	**Robusta**
Apis cerana	Apidae	51.01	48.99
T. travancorica	Apidae	45.16	45.51
A.dorsata	Apidae	1.28	2.03
A.florea	Apidae	0.55	2.94
Amegilla sp	Apidae	0.73	0.00
Lassioglossus sp	Halictidae	0.55	0.14
Xylocopa sp	Xylocopidae	0.73	0.39
	Simpson diversity index	**0.54**	**0.55**
	Shannon diversity index	**0.89**	**0.92**
Evenness	**0.46**	**0.51**	
Richness	**7**	**6**	

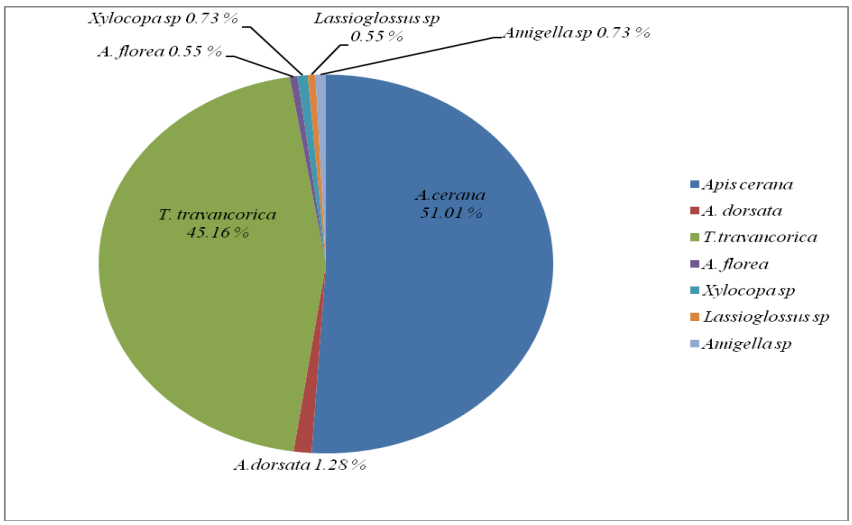

Figure 1. Bee species and percent occurrence of bee species in arabica.

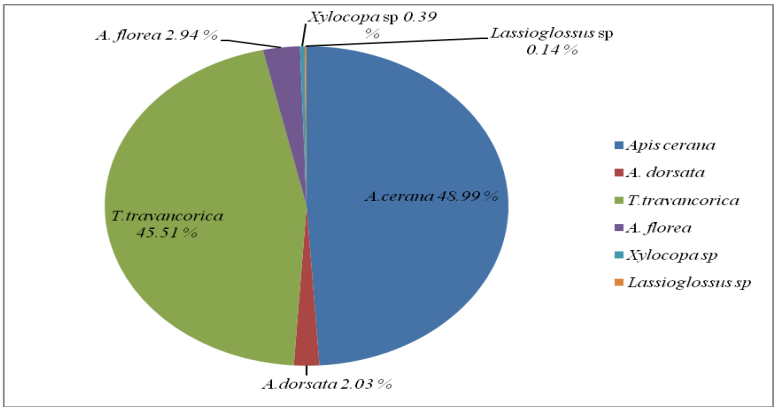

Figure 2. Bee species and percent occurrence of bee species in robusta.

Diversity indices among pollinators indicated that, the Simpson diversity index was slightly higher for robusta (0.55) than for arabica (0.54), indicating a marginally more even distribution of individuals among species in robusta. The Shannon Diversity Index followed a similar trend, with Robusta showing a higher value (0.92) compared to arabica (0.89), further reflecting slightly greater species diversity. Evenness was higher in robusta (0.51) than in arabica (0.46), suggesting that individuals were more evenly distributed across species in robusta. Species richness was slightly greater in arabica (7 species) than in robusta (6 species), indicating a wider variety of pollinators on arabica despite the slightly lower evenness and diversity indices. Overall, arabica coffee plantations hosted a greater number of pollinator species, while robusta plantations exhibited a more even and diverse distribution of the pollinator community. During the initial year of the study, *Apis cerana* colonies were not established at the research farm in CCRI and the most abundant bees recorded during blossom period was *T.travancorica*. Subsequently, apiaries were established and the following year visitaion studies revealed more of *A. cerana* visitation on the flowers. Introduction of *A.cerana* might have caused a sudden decrease in the abundance of *T.travancorica* and the subsequent years the abundance was almost even. Similar kind of observations was reported by Dunning (1886) who observed that the introduction of imported European honey bees and bumble bees displaced the native bees and other pollinators of the native flora. In the current study, *A. dorsata, A. florea* and *Xylocopa* sp. visitation was very less throughout the study period. *A. dorsata* visitation frequency was found to be more in those coffee blocks where coffees are cultivated near to the abandoned jungle area. This observations was also in good agreement with the reports of Klein (2009) and Ricketts (2004) who reported that coffee orchard adjacent to the undisturbed rainforest exhibited more diverse pollinators with high bee visitation rates and consistent fruit set than those coffee orchard farther from the rainforest with single pollinator species. Klein *et al*., (2003$_{ab}$) and Vergara and Badano (2009) opined pollinator diversity is crucial for better fruit set and inturn higher yield in coffee.

Coffee quality

The cup quality of bee-pollinated (open) and non-bee pollinated (bagged) coffee samples revealed that in case of arabica, the bee-pollinated coffee registered comparatively higher cup score (76.75 %) when compared to non-bee-pollinated (75.25 %). The quality characteristics *viz.,* aroma, flavor, acidity, after taste and balance were slightly higher in bee-pollinated coffee while few other quality characteristics *viz.* body, uniformity and sweetness scores were similar in both bee-pollinated and non-bee pollinated coffee (Figure 3).

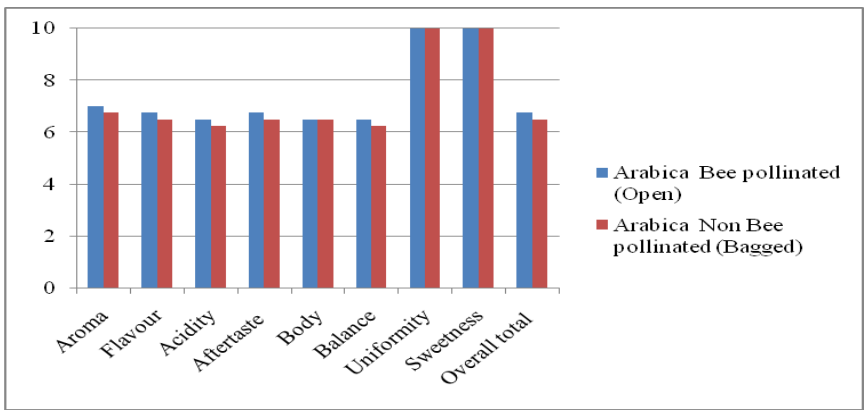

Figure 3. Quality characteristics of bee-pollinated and non-bee-pollinated arabica coffee.

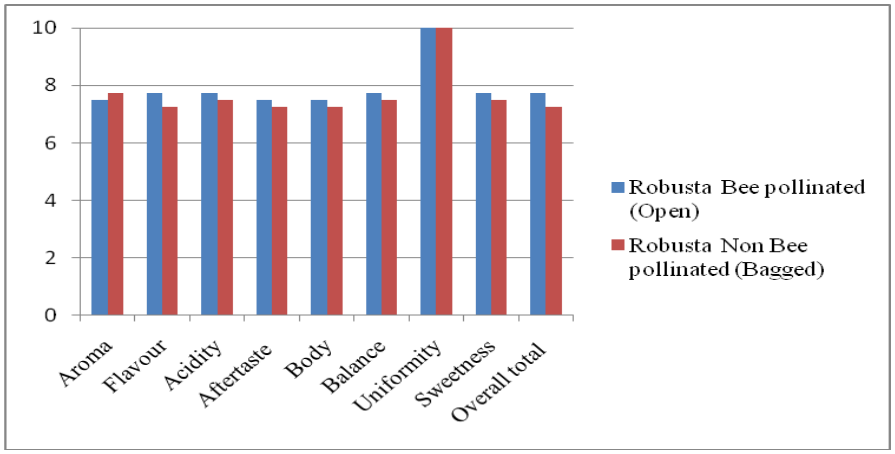

Figure 4. Quality characteristics of bee-pollinated and non-bee-pollinated robusta coffee.

Similar trend was observed even in case of robusta coffee samples (bee-pollinated coffee-81.25%; non-bee pollinated coffee-79.25%). Further, quality attributes such as flavor, acidity, after taste, body, balance and sweetness scores were in higher for bee-pollinated coffee. Aroma was slightly higher in non-bee pollinated coffee and coffees from both the treatments scored similar value for uniformity (Figure 4). The cup quality results observed in the present study was in good agreement with the reports of Karanja *et al*., (2013) and Natalia (2025) who reported that bee-pollinated coffees scored better cup quality rating as compared to non-bee pollinated. Meireles *et al*., (2022) reported that bee-pollinated coffees recorded significant levels of pyrazines, pyrroles, pyridines, alcohols, phenols and sulfur which are precursor molecules for the formation of various quality attributes such as flavour, sweetness and acidity.

Besides coffee, several authors have reported the bee pollinated crops improved both crop quality and cup quality parameters. Bee-pollinated strawberry can reduce malformations, improve commercial grade, and increase shelf life (Atmowidi *et al*., 2022, Georg *et al*., 2012; Klatt *et al*., 2014). Pollination by bees and other insects has been shown to improve physical properties like shape, firmness and chemical properties like acidity and moisture in apple, macadamia, oil seed rape, buckwheat, and tomato crops (Bartomeus *et al*., 2014; Garratt *et al*., 2014; Bashir *et al*., 2018; Samnegård *et al*., 2019; K¨amper *et al*., 2021). Blue berries pollinated by wild bees increased crop quality in terms of uniformity of berries (Nicholson and Ricketts, 2019; Martínez-Salinas *et al*., 2022). Stavert *et al*., (2020) opined that adequate pollination and quality of pollen grains are seems to be crucial factors for the plant's reproduction processes and final quality of the produce.

CONCLUSION

The results of the current study clearly indicated that bee-pollinated coffees registered comparatively higher quality score than the non-bee pollinated coffee in both arabica and robusta varieties. Further, the present study provided information regarding the bee species associated in two differently pollinated coffee species under Indian condition. To conclude the results of the current study underscores the importance of maintaining the bee communities within the coffee plantation for not only improving the yield but also the coffee quality.

ACKNOWLEDGEMENT

The authors extend gratitude to Dr. M. Senthilkumar, Director of Research, CCRI and Dr. J.S. Nagaraj, Joint Director of Research, CCRI for their constant support extended during the study. Further we are grateful to Dr. T. Jobiraj, Associate Professor, Govt. College, Kodenchery, Calicut, Kerala state for the taxonomical identification of bee species. We are also grateful to the Dr. I.M. Mandappa, Dr. Ramya Mohan and Dr. Hari Om (Coffee Quality Specialists), Coffee Quality Evaluation Division, Coffee Board, Head Office, Bengaluru for the cup quality analysis. We are also thankful to Mr. T. Yoganand, and Dr. H.G. Rashmi (Young Professionals) for the field and laboratory assistance during the study.

CONFLICT OF INTERESTS

The authors declare no conflict of interest

ETHICS APPROVAL

Not applicable

AI TOOL DECLARATION

The authors declares that no AI and related tools are used to write the scientific content of this manuscript.

DATA AVAILABILITY

Data will be available on request

REFERENCES

Aizen, M. A., Garibaldi, L. A., Cunningham, S. A., & Klein, A. M. (2009). How much does agriculture depend on pollinators? Lessons from long-term trends in crop production. *Annals of Botany, 103*(9), 1579–1588. https://doi.org/10.1093/aob/mcp076.

Armas-Quiñonez, G., Ayala-Barajas, R., Avendaño-Mendoza, C., Lindig-Cisneros, R., & del-Val, E. (2020). Bee diversity in secondary forests and coffee plantations in a transition between foothills and highlands in the Guatemalan Pacific Coast. *PeerJ, 8*, e9257. https://doi.org/10.7717/peerj.9257.

Atmowidi, T., Prawasti, T. S., Rianti, P., Prasojo, F. A., & Pradipta, N. B. (2022). Stingless bee pollination increases fruit formation of strawberry (Fragaria x annanassa Duch) and melon (Cucumis melo L.). *Tropical Life Sciences Research, 33*(1), 43–54.

Axel, D., Cédric, A., Le, C. Y., & Mickaël, H. (2019). Toward the protection of bees and pollination under global change: Present and future perspectives in a challenging applied science. *Current Opinion in Insect Science, 35*, 123–131.

Bartomeus, I., Potts, S. G., Steffan-Dewenter, I., Vaissière, B. E., Woyciechowski, M., Krewenka, K. M., & Bommarco, R. (2014). Contribution of insect pollinators to crop yield and quality varies with agricultural intensification. *PeerJ, 1*, e328. https://doi.org/10.7717/peerj.328.

Bashir, M. A., Alvi, A. M., Khan, K. A., Rehmani, M. I. A., Ansari, M. J., Atta, S., & Tariq, M. (2018). Role of pollination in yield and physicochemical properties of tomatoes (Lycopersicon esculentum). *Saudi Journal of Biological Sciences, 25*(7), 1291–1297. https://doi.org/10.1016/j.sjbs.2017.10.00

Belavadi, V. V., & Ganeshaiah, K. N. (2013). Report of NICRA project on effects of climate change on pollinator populations. *Insect Pollination Manual*, University of Agricultural Sciences, Bangalore.

Chain-Guadarrama, A., Martínez-Salinas, A., Aristizábal, N., & Ricketts, T. H. (2019). Ecosystem services by birds and bees to coffee in a changing climate: A review of coffee berry borer control and pollination. *Agriculture, Ecosystems & Environment, 280*, 53–67. https://doi.org/10.1016/j.agee.2019.04.011.

Dunning, J. W. (1886). The importation of humble bees into New Zealand. *Transactions of the Royal Entomological Society of London, 6*, 32–34.

Fletcher, T. B. (1915). Bees and the fertilisation of coffee. *Madras Bulletin, 4*, 3.

Garratt, M. P. D., Breeze, T. D., Jenner, N., Polce, C., Biesmeijer, J. C., & Potts, S. G. (2014). Avoiding a bad apple: Insect pollination enhances fruit quality and economic value. *Agriculture, Ecosystems & Environment, 184*, 34–40. https://doi.org/10.1016/j.agee.2013.10.032.

Georg, A., Maj, R., & Smith, H. G. (2012). Organic farming improves pollination success in strawberries. *PLOS ONE, 7*(2), e31599. https://doi.org/10.1371/journal.pone.0031599

Gopinandhan, T. N., & Shivalingu, B. R. (2024). Assessment of genetic divergence for bean traits in Coffea arabica germplasm. *Indian Journal of Plant Genetic Resources, 37*(3), 513–517.

Jha, S., & Vandermeer, J. H. (2009). Contrasting bee foraging in response to resource scale and local habitat management. *Oikos, 118*, 1174–1180.

Kämper, W., Trueman, S. J., Ogbourne, S. M., & Wallace, H. M. (2021). Pollination services in a macadamia cultivar depend on across-orchard transport of cross pollen. *Journal of Applied Ecology, 58*(11), 2529–2539. https://doi.org/10.1111/1365-2664.14002.

Karanja, R. H. N., Njoroge, G. N., Kihoro, J. M., Gikungu, M. W., & Newton, L. E. (2013). The role of bee pollinators in improving berry weight and coffee cup quality. *Asian Journal of Agricultural Sciences, 5*, 52–55. https://doi.org/10.19026/ajas.5.4841.

Klatt, B. K., Holzschuh, A., Westphal, C., Clough, Y., Smit, I., Pawelzik, E., & Tscharntke, T. (2014). Bee pollination improves crop quality, shelf life and commercial value. *Proceedings of the Royal Society B: Biological Sciences, 281*, 20132440. https://doi.org/10.1098/rspb.2013.2440.

Klein, A. M. (2009). Nearby rainforest promotes coffee pollination by increasing spatio-temporal stability in bee species richness. *Forest Ecology and Management, 258*, 1838–1845. https://doi.org/10.1016/j.foreco.2009.05.005.

Klein, A. M., Steffan-Dewenter, I., & Tscharntke, T. (2003a). Fruit set of highland coffee increases with the diversity of pollinating bees. *Proceedings of the Royal Society B, 270*, 955–961. https://doi.org/10.1098/rspb.2002.2306.

Klein, A. M., Steffan-Dewenter, I., & Tscharntke, T. (2003b). Pollination of Coffea canephora in relation to local and regional agroforestry management. *Journal of Applied Ecology, 40*, 837–845. https://doi.org/10.1046/j.1365-2664.2003.00847.x.

Martínez-Salinas, A., Chain-Guadarrama, A., Aristizabal, N., Vilchez-Mendoza, S., Cerda, R., & Ricketts, T. H. (2022). Interacting pest control and pollination services in coffee systems. *Proceedings of the National Academy of Sciences, 119*(15), e2119959119. https://doi.org/10.1073/pnas.2119959119

Meireles, D. A. L., Valdez, A. S. B., Boroski, M., Augusto, S. C., & Toci, A. T. (2022). Effects of pollination on the composition of volatile compounds in Coffea arabica L. *Journal of the Science of Food and Agriculture, 102*(11), 4955–4960. https://doi.org/10.1002/jsfa.11769.

Michener, C. D. (1974). *The social behaviour of the bees: A comparative study*. Harvard University Press.

Nicholson, C. C., & Ricketts, T. H. (2019). Wild pollinators improve production, uniformity, and timing of blueberry crops. *Agriculture, Ecosystems & Environment, 272*, 29–37. https://doi.org/10.1016/j.agee.2018.10.018

Philpott, S. M., Perfecto, I., & Vandermeer, J. (2006). Effects of management intensity and season on arboreal ant diversity and abundance in coffee agroecosystems. *Biodiversity and Conservation, 15*, 139–155.

Potts, S. G., Pyke, G. H. J., & Balzer, L. (1983). The effects of the introduced honeybee (Apis mellifera) on Australian native bees. *Hawkesbury Agricultural College, NSW*, 18–22.

Ricketts, T. H. (2004). Tropical forest fragments enhance pollinator activity in nearby coffee crops. *Conservation Biology, 18*, 1262–1271.

Ricketts, T. H., Daily, G. C., Ehrlich, P. R., & Michener, C. D. (2004). Economic value of tropical forest to coffee production. *Proceedings of the National Academy of Sciences, 101*, 12579–12582. https://doi.org/10.1073/pnas.0405147101.

Roubik, D. W. (2002). Feral African bees augment neotropical coffee yield. In P. G. Kevan & V. L. Imperatriz-Fonseca (Eds.), *Pollinating bees: The conservation link between agriculture and nature* (pp. 255–266). Ministry of Environment.

Samnegård, U., Hambäck, P. A., & Smith, H. G. (2019). Pollination treatment affects fruit set and modifies marketable and storable fruit quality of commercial apples. *Royal Society Open Science, 6*(12), 190326. https://doi.org/10.1098/rsos.190326.

Shannon, C. E. (1948). A mathematical theory of communication. *The Bell System Technical Journal, 27*, 379–423.

Simpson, E. H. (1949). Measurement of diversity. *Nature, 163*, 688. http://dx.doi.org/10.1038/163688a0.

Smitha, K., Kushalappa, C., Shaanker, R. U., & Ghazoul, J. (2012). Status of pollinators and their efficiency in coffee fruit set in a fragmented landscape mosaic in South India. *Basic and Applied Ecology, 13*(3), 277–285. https://doi.org/10.1016/j.baae.2012.03.007

Stavert, J. R., Bailey, C., Kirkland, L., & Rader, R. (2020). Pollen tube growth from multiple pollinator visits more accurately quantifies pollinator performance and plant reproduction. *Scientific Reports, 10*(1), 1–9. https://doi.org/10.1038/s41598-020-73637-5.

Vergara, C. H., & Badano, E. I. (2009). Pollinator diversity increases fruit production in Mexican coffee plantations: The importance of rustic management systems. *Agriculture, Ecosystems & Environment, 129*, 117–123. https://doi.org/10.1016/j.agee.2008.08.001.