

## Research Article

### Pollination Efficiency of Bee Species Pollinating *Coffea arabica* in Kiambu County Kenya

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**Abstract:** Prior to commencement of this study, a survey to identify common bees pollinating *C. arabica* in Kenya was done. *Patellapis zonalictus*, *Apis mellifera* and *Lasioglossum* spp. were identified as the common pollinators of *C. arabica* flowers. Pollination efficiency was analyzed indirectly by assessing pollen deposition on stigmas. Flowers were bagged at bud stage. When the pollinator exclusion bags were removed, the virgin flowers were allowed a single pollinator visit and then the stigmas crushed on a microscope slide and stained using fuchsin dye. The pollen grains deposited on the stigma were counted under a dissecting microscope. The numbers of non coffee pollen grains were also counted to assess pollen purity. Results indicated that *P. zonalictus* and *Lasioglossum* spp. were more efficient pollinators of *C. arabica* than *A. mellifera*. They deposited significantly higher amounts of *C. arabica* pollen grains. The pollen grains also had a significantly higher purity ratio when compared with the pollen grains deposited by *Apis mellifera* ( $p < 0.001$ ).

**Keywords:** *Coffea arabica*, pollen deposition, pollen purity, pollinator efficiency, stigma

## INTRODUCTION

Wild bees and other insects can pollinate many crops but their value for crop pollination has been overlooked for centuries (Klein *et al.*, 2008, 2003a). The importance of wild bees has been overshadowed by the popularity of the well known honey bee *A. mellifera* due to its economic returns through honey production. It is essential to determine the importance of a pollinator species to the plant under investigation since most organisms foraging on plants may not be necessarily the most important pollinators and may not significantly benefit the plant (Spears Jr., 1983).

Flowers must produce their pollen and nectar at different times of the day or seasons for the forager to become continuously active. The flowers must also balance the amount of sugar and water in the nectar, so that on each foraging visit, the bee gets the required energy and water while foraging (Roubik, 2002a, b; Raju and Rao, 2008). A pollinator must visit a flower in such a way and within such a period, that viable pollen is transferred from the anther to the stigma of the same or a different flower (Kevan, 1999).

Flowering plants that benefit from insect pollination produce energy rich nectar and nutrient rich pollen to attract pollinators. While foraging for floral resources, insects unwittingly transfer pollen grains within individual flowers, among flowers of the same

plant and between flowers of different plants (Black *et al.*, 2007). According to Raju and Rao (2008) floral rewards form the criterion of foraging behavior, being either oligolectic (specialists) or polylectic (generalists).

Pollination efficiency of the main bees pollinating *Coffea arabica* had not previously been investigated in Kenya. If an efficient pollinator of *C. arabica* is identified, it might be possible to enhance efforts to conserve it and conserve its habitat so as to increase its population to ensure higher rates of pollination success and higher coffee productivity.

*A. mellifera* has been identified by many studies as the main pollinator of many crops as well as *C. arabica* and this study attempted to compare the efficiency of *A. mellifera* with that of other common bees found foraging on coffee flowers (*P. zonalictus* and *Lasioglossum* spp.). Both the pollen load (on the body of a bee) and pollen load purity (absence of non coffee pollen grains) of pollen deposited on virgin coffee flowers were calculated in order to investigate which bee deposited a lot of coffee or non coffee pollen on virgin coffee stigmas.

## MATERIALS AND METHODS

**Relative pollinator efficiency tests:** The main pollinators of coffee flowers were recorded and identified in a previous study. In the current study,

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flowers were bagged before they opened using fine nylon mesh (10  $\mu$ m). Once the bags were removed; only a single pollinator was allowed to get in. The pollinator was identified in the field when possible or when not sure of the identity captured for later identification. After a single visit to a flower by a pollinator the stigma of the experimental flower was removed with clean forceps and placed in a microscope slide. A drop of basic fuchsin dye was used to stain the pollen grains. Gentle pressure was applied to the top of a cover slip to distribute the pollen grains into a monolayer (Ricketts, 2004). The slides were put in an ice box awaiting transportation to the laboratory (Larsson, 2005). Pollen grains were dyed using fuchsin dye and counted under a compound microscope to determine the number of pollen grains deposited on a virgin stigma. The median rather than the mean pollen deposition per species was used for statistical analysis since previous studies have indicated that it provides a more conservative estimate of pollen deposition per visit (Kremen *et al.*, 2002). Data analysis was done using One Way ANOVA and for separation of multiple responses Dunnett T3 post hoc tests were done (Underworld, 2005).

## RESULTS

Among the collected bee species during this study, the bees that were found to deposit high amounts of pollen on the stigma were *Patellapis (Zonalictus spp.)* followed by *Lasioglossum spp.* The highest level of deposited pure pollen was from *Patellapis (Zonalictus spp.)* while *A. mellifera* had the lowest purity ratio (Fig. 1).

*Lasioglossum spp.* and *Patellapis (Zonalictus spp.)* showed no significant difference ( $p > 0.001$ ) in pollen loads deposited on stigma and pollen purity. However, there were significant differences between *A. mellifera* and *Patellapis (Zonalictus spp.)* ( $p < 0.001$ ) and *A. mellifera* and *Lasioglossum spp.* ( $p < 0.001$ ).

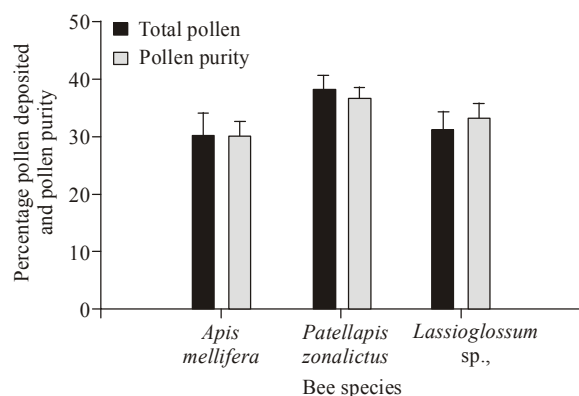


Fig. 1: Pollen deposition rate and pollen purity analysis from main bees pollinating coffee

## DISCUSSION

This study attempted to identify and document the efficiency of different pollinators of coffee flowers. Results on pollen load analysis from the main bees pollinating *C. arabica* shed light to the fact that solitary bee species were the most efficient pollinators of coffee contrary to the common notion that *A. mellifera* is the most important pollinator of *C. arabica* (Greenleaf and Kremen, 2006; Vergara and Badano, 2008).

This study indicates that *Lasioglossum spp.* and *Patellapis zonalictus* were more efficient in pollen transfer than *A. mellifera*. This is because solitary bees are oligolectic thus deposit purer pollen on flowers than the polylectic *A. mellifera* which forages on many flower species. Therefore *A. mellifera* deposits on *C. arabica* flowers pollen grains that are mixed with pollen from other plants. A higher number of pollen grains were deposited by the solitary bees than the social bees.

Previous studies in Brazil have indicated that solitary bees collect pollen from plants of related species or genera and they are also reputed to be efficient pollinators with no known cases of nectar and pollen thieves (Schlindwein, 2004).

These results agree with those of a study carried out in Central Sulawesi (Indonesia) that indicated that the pollination efficiency of solitary bees was significantly higher than that of the social bee species. Similar results were given on *C. canephora* in Indonesia where solitary bees led to 86.5% fruit set while social bees led to 70.4% fruit set (Klein *et al.*, 2003b, c). Higher amounts of pure *C. arabica* pollen deposition, leads to a higher seed set rate (Paschke *et al.*, 2002; Philpott *et al.*, 2006). The results differ with those of Klein *et al.* (2002) whose results indicated that *A. mellifera* has the most important influence on pollination of *C. arabica* and *C. canephora*.

Inadequate deposition of pollen grains may have implications on fruit set of coffee. A study in Chiapas, Mexico, concluded that pollen load affects the size and number of seeds or fruits and there is a probability that it can lead to seed or fruit abortion (Philpott *et al.*, 2006). Pollen purity is important for pollination since high pollen loads with no foreign pollen contamination have been documented to lead to faster pollen tube growth, earlier fertilisation and therefore a longer maturation period and an increase in fruit and seed weight (Philpott *et al.*, 2006; Marques-Souza *et al.*, 2007). Larger pollen loads may also provide plants with higher donor diversity and thus a genetic diversity of pollen. Thus, one possibility in coffee, as in other plants, is that increased coffee pollen diversity from other coffee plants lead to pollen competition, increased pollen vigour and subsequent increase in fruit weight and overall quality (Paschke *et al.*, 2002; Philpott *et al.*, 2006).

*A. mellifera* in this study was found to deposit on coffee flowers pollen from other plant species growing within and around the coffee farms. This may be because after foraging from a plant some pollen grains may remain embedded in the corbiculae even as the bee visits another plant. These findings are in agreement with other findings that pollen loads gathered by honey bees are moistened with regurgitated nectar or honey and packaged in form of small pellets in their corbiculae or pollen baskets situated in the hind legs. During the process of collection and packaging of pollen, contamination of pollen from other sources occur (Chauzat *et al.*, 2006).

Pollinator fidelity has been found to be very important for pollination success (Hanley *et al.*, 2008). *A. mellifera* is a social bee and faced with the pressure to sustain large perennial colonies; these bees are super generalists and cannot afford to specialize on particular plant species (Gikungu, 2006; Danforth, 1999). These findings emphasize the need to enhance other wild bees' population in coffee farms by providing floral resources and favorable nesting sites so as to provide highly efficient pollinators of coffee.

### CONCLUSION

The results of this study points out that solitary bees/wild bees are more efficient in pollen collection and deposition than *A. mellifera*. Therefore, enhancing population of other wild bee species while still maintaining the social bee populations may be very important in coffee fields. This can be done through creation of natural buffers of vegetation that the bees can use when foraging.

### REFERENCES

- Black, H.S., N. Hodges, M. Vaughan and M. Shepherd, 2007. Pollinators in Natural Areas; a Primer on Habitat Management. Invertebrates Conservation Fact Sheet. The Xerces Society for Invertebrates' Conservation. Retrieved from: www.xerces.org.
- Chauzat, M.P., J.P. Faucon, A.C. Martel, J. Lachaize, N. Cougoule and M. Aubert, 2006. A survey of pesticide residues in pollen loads collected by honey bees in France. J. Econ. Entomol., 99(2): 253-62.
- Danforth, B.N., 1999. Emergence dynamics and bet hedging in a desert bee, *Perdita portalis*. P. Roy. Soc. Lond. B Bio., 266: 1985-1994.
- Gikungu, M.W., 2006. Bee diversity and some aspects of their ecological interactions with plants in a successional tropical community. Ph.D. Thesis, Faculty of Mathematics and Natural Sciences, Bonn University, Nairobi.
- Greenleaf, S.S. and C. Kremen, 2006. Wild bees enhance honey bees' pollination of hybrid sunflower. P. Natl. Acad. Sci. USA, 103: 13890-13895.
- Hanley, M.E., M. Franco, S. Pichon, B. Darvill and D. Goulson, 2008. Breeding system, pollinator choice and variation in pollen quality in British herbaceous plants. Funct. Ecol., 22: 592-598.
- Kevan, P.G., 1999. Pollinators as bioindicators of state of environment: Species, activity and diversity. Agr. Ecosyst. Environ., 74: 373-393.
- Klein, A.M., I. Steffan-Dewenter and T. Tschankrntke, 2003a. Bee pollination and fruit set of *Coffea arabica* L. and *C. canephora* (Rubiaceae). Am. J. Bot., 90(1): 153-157.
- Klein, A.M., I. Steffan-Dewenter and T. Tschankrntke, 2003b. Pollination of *Coffea canephora* in relation to local and regional agroforestry management. J. Appl. Ecol., 40: 837-845.
- Klein, A.M., I. Steffan-Dewenter and T. Tschankrntke, 2003c. Fruit set of highland coffee increases with the diversity of pollinating bees. P. Roy. Soc. Lond. B Bio., 270: 955-961.
- Klein, A.M., I.S. Steffan-Dewenter, D. Buchori and T. Tschankrntke, 2002. Effects of land-use intensity in tropical agroforestry systems on coffee flower-visiting and trap-nesting bees and wasps. Conserv. Biol., 16(4): 1003-1014.
- Klein, A.M., B.E. Vaissiere, J.H. Cane, I. Steffan-Dewenter, S.A. Cunningham, C. Kremen and T. Tschankrntke, 2008. Advances in pollination ecology from tropical plantation crops. Ecology, 89(4): 935-943.
- Kremen, C., J.P. Bugg, N. Nicola, S.A. Smith, R.W. Thorp and N.M. Williams, 2002. Native bees, native plants and crop pollination in California. Fremontia, 30: 1-4.
- Larsson, M., 2005. Higher pollinator effectiveness by specialist than generalist flower visitors of unspecialized *Knautia arvensis* (Dipsasaceae). Oecologia, 146: 394-403.
- Marques-Souzal, A.C., M.L. Aysyl and W.E. Kerrll, 2007. Pollen harvest features of Central Amazonian bee *Scapotrigona fulvicutis* Moure 1964 (Apidae, Meliponinae), in Brazil. Acta Bot. Bras., 21(1): 1-14.
- Paschke, M., C. Abs and B. Schmid, 2002. Effects of population size and pollen diversity on reproductive success and offspring size in narrow endemic *Cochlearia bavarica* (Brassicaceae). Am. J. Bot., 89:1250-1259.
- Philpott, S.M., S. Uno and J. Maldonado, 2006. The importance of ants and high-shade management to coffee pollination and fruit weight in Chiapas, Mexico. Biodivers. Conserv., 15: 487-501.
- Raju, S.J. and P.S. Rao, 2008. Nesting habits, floral resources and foraging ecology of large carpenter bees (*Xylocopalatipes* and *Xylocopa pubescens*). India Curr. 1210 Sci., 90(9): 9-10.
- Ricketts, H.T., 2004. Tropical forests fragments enhance pollinator activity in nearby coffee crops. Conserv. Biol., 18: 1262-1271.

- Roubik, D.W., 2002a. The value of bees to the coffee harvest. *Nature*, 417(13): 708.
- Roubik, D.W., 2002b. Feral African Bees Augment Yield in Neotropical Coffee Yields. In: Kevan, P. and V.L. Imperatriz-Fonseca (Eds.), *Pollinating Bees. The Conservation Link between Agriculture and Nature*. Ministry of Environment, Brasilia, pp: 255-266.
- Schlindwein, C., 2004. Are oligolectic bees always the most effective pollinators? Proceeding of the Brazil Workshop on Solitary Bees: Conservation, Rearing and Management for Pollination. Beberibe, Ceará, April 26-30.
- Spears Jr., E.E., 1983. A direct measure of pollinator effectiveness. *Oecologia*, 57: 196-199.
- Underworld, A.J., 2005. *Experiments in Ecology. Their Logical Interpretation using Analysis of Variance*. Cambridge University Press, NY.
- Vergara, C.H. and E.I. Badano, 2008. Pollinator diversity increases fruit production in Mexican coffee plantations: The importance of rustic management systems. *Agr. Ecosyst. Environ.*, 30(2008): 30.