Comparison of Bee Pollinators of Coffee in Organic and Conventional Farms

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Abstract: Kenyan Coffea arabica L. is globally recognised for its high quality and it is used to blend other coffees in the world market. No previous studies in Kenya have identified pollinators of coffee and this necessitated the study. Coffea arabica was thought to be self-pollinated but recent studies have given an indication that it is amphicarpic thus needing pollinator services. This is especially for the self sterile flowers while in self fertile flowers pollination success rate is enhanced. This study assessed the diversity of bee pollinators of coffee in organic and conventional farming system in Kiambu Kenya. Sampling of bees found to evidently carry pollen and interact with anthers was done and these bees were recorded. Sixty three bee species were sampled with organic farm having 60 species and conventional farm 24 species. Bee abundance and diversity between organic and conventional farms differed significantly (t = -2.1227, df = 61, p<0.05). Andrena (sp) possibly a new species was collected. Findings from this study revealed that wild bees other than Apis mellifera are important pollinators of coffee. The wild bees were few in numbers and ways of enhancing their populations should be devised.

Key words: Abundance, coffee, conventional, organic, pollinators, richness

INTRODUCTION

Pollination biology is of great ecological and conservation relevance as changes in plant populations; growth rates, population size and density, and community composition involve reproduction and are an indication of pollination success (Lennartson, 2002). Pollinators are a key to agricultural productivity when all the other factors of production are optimal. There has been a world wide decline of bee populations in the recent past. Factors leading to this population decline include natural phenomena like severe rainy seasons, droughts as well as human-generated hazards such as deforestation and insecticides and pesticides application (Freitas et al, 2004).

Organic farming promotes use of natural means to control pests and weeds. A study by Roschewitz et al. (2005), found that organic farming converts fields into insecticide-free and richer foraging habitats while herbicides reduce the insects’ diversity and diversity of flowering weed species in conventional fields. In homogenous landscapes such as coffee farms, differences in biodiversity between organic and conventional fields may be larger because organic fields compensate for the missing non crop habitats (Bengtsson et al., 2005).

In East Africa there is paucity of data on pollination by bees since very few studies have been done and there is lack of adequate referenced collections as well as bee taxonomists (Gikungu, 2006). However, a few studies have been conducted on economic importance of pollinators to food crop production (Kasina, 2007); bee populations and bee diversity (Gikungu, 2002, 2006) and pollination biology of Citrullus lanatus (Njoroge, 2005). This study focused on the following research questions:

- What are the pollinators of coffee in Kenya?
- Is there a difference in abundance and diversity of bee pollinators in the organic and conventional coffee farms?

MATERIALS AND METHODS

Study area: This study was carried out from October 2005 to April 2008 in Kiambu District which lies between latitudes 0°75’S and 1°20’S of South of Equator and longitudes 36°54’ and 36°85’ East close to Karura forest (G.O.K., 1994; Muchena et al., 2004). The area has privately owned and well managed coffee plantations. Two contrasting farms were selected for the study. They included Paradise Lost which carries out organic farming and Evergreen Farm which is a conventional farm.
Quantification and diversity of bees visiting coffee flower: Documentation of flower visitors paid special attention to discriminate between pollinators and mere flower visitors. Those insects that were found to evidently carry pollen and make contacts with the anthers and the stigma were recorded as pollinators while all the others were recorded as flower visitors (Fausto et al., 2001; Njoroge, 2005).

Two transects (1.5 km each) per site were selected, one in the middle of coffee field and the other 6m from the field edge to minimize edge effect (De Marco and Coelho, 2004; Kremen et al., 2004; Holzschuh et al., 2007). Within these transects four 100 m² plots were randomly selected and permanently marked with wooden sticks and characterized at the same time during this survey (Kremen et al., 2004). Observations of pollinator activity throughout the coffee flowering seasons were done from 07.30 to 17.30 h for 3 days every week. Foraging bee species in the sampling plots were observed and captured under similar weather conditions (Gikungu, 2002). A 10 min observation period was set to document all the pollinators visiting coffee flowers after which they were captured by sweep nets for 30 min. The bee species that were caught were put in killing jars having ethyl acetate to inactivate or kill them (Picker et al., 2004). After each sampling interval the collected bee species were pinned in boxes that were later transferred to laboratory for identification.

To supplement the data of bees caught using sweep nets, pan traps of different colours namely; Red, blue, white and yellow (Morandin et al., 2007) were laid alternately at random points within the 100 m² plot in the coffee farms to capture bees that may not have been collected using sweep nets. Each pan trap was filled with 300 mL water and 500 mL odourless detergent. Insects caught in pan traps were transferred into vials containing 70% alcohol by use of forceps for later identification (Gikungu, 2002).

Statistical analysis: Statistical analysis was performed by use of R 2.6.1/Tree Diversity program (Kindt and Coe, 2005). Bee abundance and richness in the two study areas was analysed by use of frequencies, percentages, paired t-test and Renyi’s diversity index measure. Renyi diversity index combines Shannon Weigner and Simpson’s diversity measures with the help of a scale parameter and most importantly, it is extremely sensitive to rare species when the scale parameter is 0. Therefore, it caters for both rare and common species (Magurran, 1988; Kindt and Coe, 2005).

RESULTS

Diversity of bee pollinators of coffee flowers in organic and conventional farms in Kiambu: Sampling was done for 31 months from October 2005 to April 2008 and 9439 bee specimen from 63 species were collected and are deposited at National Museums of Kenya. The Organic farm registered 95.2% (60 species) and the Conventional Farm 24 species which is 38.1% of the total number of species.
species. The organic farm had 59% of the total specimens collected. Bee abundance and diversity between the two farms were significantly different (t = 2.1227, df = 61, p<0.05).

Specimens collected in the two study sites represented five out of six world’s documented bee families namely Apidae, Halictidae, Megachilidae, Andrenidae and Colletidae. The only bee family not sampled in this study was Mellitidae. Family Apidae was the most abundant with 79.1% (45.5% from the Organic Farm and 33.6% from the Conventional Farm) of total bees collected, Halictidae followed with 17.4% (11% from Organic Farm and 6.4% from Conventional Farm) of the total while Colletidae which was sampled from the Organic Farm only had the lowest representation with 0.1% of the total bees sampled. In terms of bee species richness per family, Halictidae had the highest number of species (39%) followed by Apidae (33%). The lowest number of species was from Family Andrenidae and Colletidae each with 3% of the total number of species. Both Colletidae and Andrenidae were absent in the

Bee abundance and richness in various seasons: The highest number of bees 46.5% of the total (26.8% Organic Farm, 19.7% Conventional Farm) were collected during the short rain seasons: October, November and December, followed by long rain seasons: March, April and May (37.1%), with the lowest numbers in the cold season (3.6%): July and August and dry and hot season 2 in September (1.4%) of total bees collected (Fig. 4).

According to Renyi diversity profiles, the highest diversity was recorded during the short rains followed by long rains with the lowest profiles during the dry and hot seasons (Fig. 5). The species richness for the rare species
was comparable across seasons with the short rains season having the highest diversity and dry season in September having the lowest. However, where the common bee species *A. mellifera* predominated, the results were not comparable since the common bees were abundant across all seasons (Fig. 5).

The evenness profile (E-alpha) was calculated to try and separate the diversity across all the seasons. The highest evenness was during the two dry seasons (January, February and September) and the cold season (June to August) an indication that during these seasons, the bees were not diverse. The evenness was comparable for the common species but not the rare species. Bees collected were mainly from the same family with the most common bee species being the most abundant. The most diverse seasons were the short rain season (October, November and December) and long rain season (March, April and May) with both the rare and common species being collected (Fig. 6).

Some bee species in this study (0.37%) of total bees collected were collected in the Organic farm but not in the Conventional farm. *Andrena* sp. 2 was collected at Organic farm and this was the first record of this species in Kenya (Fig. 7).

**DISCUSSION**

This study revealed a high diversity of bees visiting coffee flowers in central Kenya. From literature it is evident that in tropical and temperate areas, Halictidae are the most abundant compared to all the other bees except the honey bees (Michener, 2000). This is an important finding because Halictidae could be important in coffee pollination than the more abundant social bees. The collective role of a species rich bee community is more important than species abundance for pollination success (Klein et al., 2003).

The families that were least abundant and diverse in the study area have also been noted as globally rare. Family Colletidae has been described as the most primitive bee family and they are also few in numbers and most of them are solitary. The family is relatively scarce in the moist sub tropics areas (Michener, 1974). Family Andrenidae is not well represented since in sub-Saharan Africa there are only a few genera and species (Michener, 1974).

*Apis* dominance in the area is due to the fact that *A. mellifera* is a social bee and sociality is often important in that social bees can communicate the presence of resources to their colony and recruit in large numbers to mass flowering crops like coffee (Klein et al., 2008). *A. mellifera* is aggressive in nature and takes advantage of intense nectar flow associated with coffee flowering (Vergara and Badano, 2008). Klein et al., (2008) indicated that *A. mellifera* and solitary bees are the main pollinators of *C. arabica*. Studies conducted in Mexico and Tropical America found that, *A. mellifera* was the most dominant pollinator species in all coffee management systems in terms of abundance accounting for more than 80% of total pollinator assemblages (Roubik, 2002b; Vergara and Badano, 2008).

The short rain season had moderate rain and warm conditions which led to sparse flowering and this encouraged the presence of a diverse number of solitary bee communities (Roubik, 2002b) possibly because they lacked competition from *A. mellifera* which dominate during mass flowering. Members of the species are floral density-dependent and tend to abandon sparsely distributed flowers (Heard, 1994). The results of this study imply that solitary bees could be the main pollinators of coffee during sparse flowering.

During long rains mass flowering led to increased *A. mellifera* which are aggressive bees that lead to a decrease in the solitary bees which are out competed by honeybees due to their aggression (Roubik, 2002a, b). Coffee has been documented to flower after a shower of rain falls following a dry season (Coste, 1992; Roubik, 2002b). The bees collected during the cold season were the least diverse since they were dominated by *A. mellifera*.

Organic farming was found to favour bee abundance and diversity. Conventional farming system may impact on bee diversity due to poisoning by agro-chemicals and lack of other plants that can serve as alternative floral resources and source of refuge when the main crop has been sprayed with agro-chemicals. Other studies have shown that the most serious threat to pollinators in agro-ecosystems is poisoning from pesticides (Tew, 1998; Marshall et al., 2006). Sub-lethal effects of pesticides may have significant impacts on bees and pollination in addition to the more easily observable mortality, disrupting foraging and causing decreased pollination and/or bee reproduction (Morandin et al., 2005).

Bee species that had low populations were sampled in the Organic farm as opposed to the conventional farm, which may indicate that these bees are sensitive to the chemicals used to manage weeds and pests. A study in Germany (North Rhine) found that a higher bee diversity, flower cover and diversity of flowering plants were recorded in organic compared to conventional farms (Holzschuh et al., 2007). Presence of rare bees in the organic farm may be further explained by organic farms being more flora and fauna diversity friendly.

*Andrena* sp. was collected in the Organic farm and suspected to be a new species that has not been previous recorded in Kenya. Some bee species in families Andrenidae and Colletidae were rare but that does not imply that they were not pollinators of coffee. Bee populations as well as diversity are highly variable in time and space and a species that is an unimportant pollinator in one year may be important in the following year (Freitas et al., 2004).
CONCLUSION

This study provides evidence that it’s not only *A. mellifera* that pollinates coffee but other soil solitary bees may play pollination role in varying landscapes and regions. Conventional farming was found to have a negative impact on bee abundance and diversity. Results from this study revealed that organic farming should also be promoted so as to increase the number of pollinators visiting coffee plants. An integrated approach in pest control and habitat management is therefore needed in coffee production systems in order to enhance the delivery of pollination service.

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REFERENCES


