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Rebecca Karanja
Jomo Kenyatta University of Agriculture and …

Grace Njeri Njoroge
Jomo Kenyatta University of Agriculture and …

- Short communication -

BEE INTERACTIONS WITH WILD FLORA AROUND ORGANIC AND CONVENTIONAL COFFEE FARMS IN KIAMBU DISTRICT, CENTRAL KENYA

Rebecca H.N. Karanja[1*], Grace N. Njoroge[1], Mary W. Gikungu[2] & L.E. Newton[3]

[1]*Jomo Kenyatta University of Agriculture and Technology, P.O. Box 62000-00200 Nairobi, Kenya*

[2]*National Museums of Kenya, P.O. Box 40658-0010, Nairobi, Kenya*

[3]*Kenyatta University, P.O. Box 16443, Nairobi, Kenya*

Abstract—Flower scarcity outside coffee flowering periods leads to a decline of pollinators' abundance and diversity possibly through death or migration. The objective of this study was to assess whether other flowering plants within and around coffee farms act as alternative floral resources that may impact on abundance and diversity of pollinators of coffee flowers. Bee pollinators of coffee were assessed and identified for a period of 27 months. Their abundance and diversity were examined within and around organically and conventionally managed coffee farms in Kiambu District in Kenya. This study provides evidence that 42 plant species from 19 families were alternative floral resources for bees that pollinate coffee. Bee pollinators of coffee were observed to visit coffee flowers as well as other flowering plants close by. Significant relationship existed between plant species and bee species richness in the organic farming (R^2=0.5918; P<0.0001) and in conventional farming (R^2=0.6744; P<0.0001). Therefore in coffee monocultures, presence of other flowering plants should be encouraged to support bee pollinators when coffee is not flowering and to enhance abundance and diversity of bees visiting coffee flowers.

Keywords: Bee, conventional farming, interactions, organic farming, pollinators, wild plants

INTRODUCTION

Plant-pollinator interactions have faced increasing threats from man especially through agricultural intensification (Ricketts 2004). Tropical ecosystems are characterized by agroecosystems and there is expanding conversion of natural habitats to agroecosystems. Loss of native habitats within agricultural landscapes may be of particular importance, because crop pollination by wild bee species is provided locally when there are wild plants around cropped areas (Richards 2001). Loss of natural habitats constrains the foraging ranges of bees (Kearns 2001; Richards 2001; Kremen et al., 2002 & Ricketts 2004).

Efforts to conserve biodiversity have been focused primarily on the remaining areas of natural ecosystems. However, only 5% of terrestrial environment is uninhabited and unmanaged. Therefore, most pollinator species that remain in the natural habitats interact with agricultural ecosystems. However, the contribution of management type to these species survival is often ignored, as is the potential value of agroecosystems for conservation (Klein et al. 2002; Power & Flecker 2000).

The repercussions of interrupted plant pollinator relationship are potentially serious (Rathcke & Jules 1993). Plants may experience lower and inferior pollinator visitation and depressed reproductive output in absence of remnant habitat fragments as a result of changes in the pollinator community (Murcia 1996). Pollination studies have revealed that presence of wild habitats enhances pollinator activity in the surrounding agricultural fields. Most pollinators and especially bees need natural plant remnant habitats for foraging purposes, nesting or oviposition, source of water, mating and roosting caves (Roubik 1995; Ricketts 2004).

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*Corresponding author; email: rhugiru@yahoo.com or rkaranja@fsc.jkuat.ac.ke

This study sought to investigate the plants surrounding coffee farms that supply floral resources to pollinators of coffee. Previous pollination studies in Kenya have been carried out on only a few crops e.g. pollination of indigenous crops in Mwingi (Njoroge et al., 2008), pollination of *Citrullus lanatus* (Thunb) Mansf. Nakai (water melon) at Yatta (Njoroge 2005) and bottle guard (*Lagenaria siceraria*) (Morimoto et al. 2004). The economic value of pollinators for crop pollination in Kakamega has also been investigated (Kasina 2007). However, wild floral resources that serve to sustain pollinators outside the flowering period of the crop are not well documented (Njoroge 2005; Morandin et al. 2007; Black et al. 2007).

METHODOLOGY

Study area

This study was carried out for 27 months from October 2005 to December 2007 in Kiambu District which lies between latitudes 0°75' and 1° 20' south of Equator and longitudes 36° 54' and 36° 85' east. The district is adjacent to the northern border of Nairobi and it covers an area of 1324 km^2 with 90% being high agriculture potential land (G.O.K. 1994; Muchena et al. 2004). Two study sites with well managed coffee plantations were selected. The two study sites bordered an indigenous forest. These included an organically (Paradise Lost) and a conventionally (Evergreen) managed farm.

The main idea behind organic farming is 'zero impact' on the environment. Organically grown means grown without use of synthetic agrochemicals and inorganic fertilizers for at least three years. Conventional farming systems involve use of whatever means to kill pests and maximize output: It involves use of chemical plant protectants, chemical fertilizers, synthetics and even genetically-modified organisms (Ponte 2002).

Quantification of wild plants visited by bees in coffee farms

Diversity of flowering wild plant species used as floral resources by bees in the organic and conventional farms was recorded. At both sites, 1.5 km transects were laid with 4 plots of 100m^2 placed randomly within each transect. Flowering plants within a coffee plot and those at a 40 m radius from a coffee plot were recorded. Sampling within the coffee plots was done 3 days a week for 27 months. Sampling was done after every hour from 07h30 to 15h30. A ten minutes interval per hour was taken for random walks to record all the plants visited by bees. Ten more minutes per sampling hour were taken to capture the bees. If a plant was visited by a bee species, both the plant and the bee were collected for identification. Voucher specimens of plants were pressed, dried, identified and deposited at Jomo Kenyatta University, Botany Department Herbarium, while the bee specimens were deposited at National Museums of Kenya. Bees were identified and notes made whether their occurrence was on both coffee flowers and other plants. Data analysis on abundance of flowering plant species was done by frequencies and plant richness analysis by Rényi's diversity index was calculated using R 2.6.1 program (Kindt & Coe 2005). Analysis of the relationship between wild plants' floral resources and bee species was analysed using linear regression.

RESULTS AND DISCUSSION

Diversity of wild plants visited by bee pollinators of coffee

A total of 42 plant species represented in 19 plant families were recorded as plants visited by bees in the study area. The organic farm had all the 19 families of plants and 40 species while the conventional farm had 14 families and 25 wild plant species (Appendix 1). The organically managed farm had a higher abundance and richness of both the rare and common plants collected in this study (Tab. 1; Fig. 1).

For the first time in Kenya, this study has documented the important plant families in proximity to coffee farms that provide floral resources to bees when coffee is not flowering or enhance the number of bees visiting coffee flowers (Appendix 1). An important finding in this study is that wild plants act as alternative floral resources for bees visiting coffee flowers. *Bidens pilosa* L., *Galinsoga parviflora* Cav. and *Justicia uncinulata* Oliv. were found to be very common and attracted the highest number of bees. The families Acanthaceae and Asteraceae act as reliable source of floral resources due to their availability throughout the year, and their wide distribution in forest gaps, secondary forests and bushlands (Gikungu 2006).

TABLE 1: Diversity of flowering plant families sampled in the coffee farms

Diversity index	Organic Farm	Conventional
Richness	19 (100%)	14 (73.6)
Shannon index	3.123	2.505

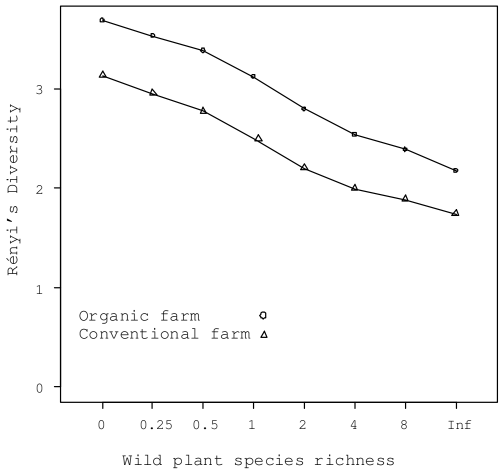

FIG. 1: Rényi wild plants richness profile in the study areas: The value of species richness is on a scale parameter 'alpha' whose value ranges from 0 to infinity. The profile value is the logarithm of species richness. The profile value 0 reflects richness of the rare species in the study while the profile value infinity reflects value of the most abundant species.

When both coffee and surrounding plants were flowering, more bees were sampled from coffee flowers in comparison to when coffee was flowering alone. The abundance and diversity of bees visiting coffee was also higher than those visiting other plant families (Fig. 2). This may be because coffee is a mass flowering plant with dense inflorescences that have a sweet attractive aroma and the flowers produce high amounts of nectar and pollen grains (Klein et al. 2008; Klein et al. 2002; Coste 1992). Studies elsewhere have indicated that bees are likely to visit dense patches of flowering species to minimize on the foraging costs (Hegland & Boeke 2006). The results of this study give evidence that flowering wild plant families enhance bee visits to the surrounding coffee farms.

Correlation between bee species and wild plants floral resources diversity

Wild plant floral resources richness has a positive impact on bee richness in conventional farming. Higher bee abundance and diversity were recorded where there was high plant species diversity (Fig. 3). The relationship between plant species richness and bee diversity in the conventional farming was highly significant (R^2=0.6744; P<0.0001). In this study, bees found visiting coffee flowers were also noted visiting other flowering plant species surrounding the coffee farm.

In organic farming, bee diversity was found to increase with an increase in wild plants floral resources diversity (Fig. 3). The relationship between other plants near coffee farms and bee diversity was highly significant with bees visiting coffee flowers also visiting flowers of other plant species (R^2=0.5918; P<0.0001).

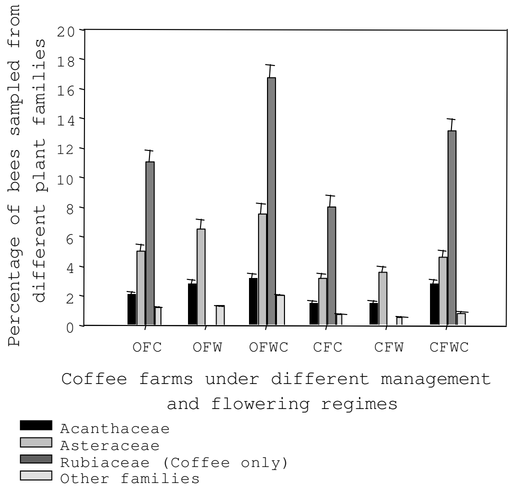

FIG. 2: Bee abundance in major plant families in coffee farms under different management practices at different seasons. Key: OFC - Coffee flowering alone in Organic farm, OFW - Organic farm with weeds flowering alone, OFWC - Both weeds and coffee flowering in the organic farm, CFC - Coffee flowering alone in Conventional Farm, CFW - Weeds flowering alone in Conventional Farm, CFWC - Both weeds and coffee flowering in Conventional farm

The above findings are important because they give an indication that absence of other flowering plants when coffee is not flowering may lead to a loss of bees and compromise pollinator visitors in subsequent seasons when coffee is flowering. Pollinators have been found to be noticeably less diverse and less numerous when natural habitats are either highly fragmented or completely absent (Richards 2001). A study in England showed that species richness of the fauna in field boundaries and crop centres was significantly greater in boundaries of margins sown with diverse plant species. Analysis of total bees caught showed highly significant positive effects of sown margins. Overall diversity of bees was lower in the field centres where the 6m margin strips were absent (Marshal et al. 2006).

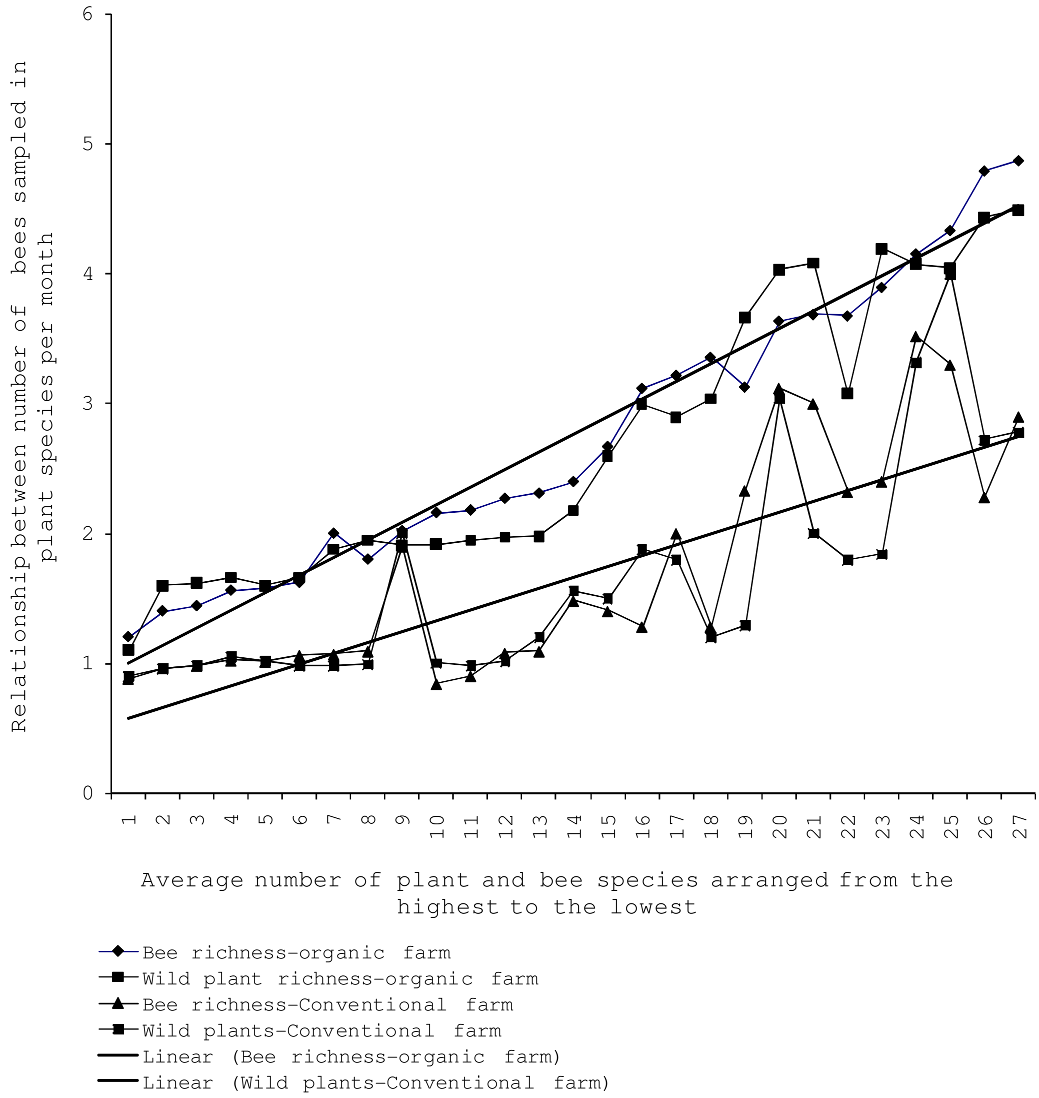

FIG. 3: Relationship between wild plants floral resources and bee richness in an organic and a conventional farm

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APPENDIX

APPENDIX 1: Wild plant species visited by bees in coffee farms

Plant family	Plant species	Present in Organic Farm	Present in conventional farm
Acanthaceae	*Asystasia schimperi* T.Anderson	√	√
	Justicia uncinulata Oliv.ex C.B. Clarke	√	√
Amaranthaceae	*Amaranthus hybridus* L.	√	√
	Amaranthus graecizans L.	√	-
Commelinaceae	*Commelina benghalensis* L.	√	√
Compositae	*Ageratum conyzoides* L.	√	-
	Bidens pilosa L.	√	√
	Conzya schimperi L.	√	√
	Conzya bonariensis L	√	√
	Erlangea cordifolia (Benth.) S. Moore	√	-
	Galinsoga parviflora Cav.	√	√
	Sencis diosmifolius L	√	-
	Sonchus exauriculatus (Oliv. & Hiern) O. Hoffm.	√	√
	Sonchus oleraceus L.	√	√
	Sonchus schweinfurthi L.	√	-
	Tagetes minuta L	√	√
Cruciferae	*Raphanus raphanistrum* L.	√	-
Euphorbiaceae	*Euphorbia hirta* L.	√	-
Graminae	*Dactyloctenium aegyptium*	√	-
	Digitalia velutina (Forssk.) P. Beauv.	√	√
	Digitaria abysinnica (Hochst. ex A. Rich.) Stapf	√	√
	Pennisetum clandestinum (Hochst. ex Chiov.) Chiov.	√	√
	Setaria Verticillata (L.) P. Beauv.	√	-
Labiatae	*Plectranthus barbatus* L.	√	-
	Plectranthus lonuginosus L.	-	√
Leguminosae	*Physeolus vulgaris* L.	√	√
Malvaceae	*Sida cuneifolia* A.Gray.	√	√
	Sida rhombifolia L.	√	-
Oxalidaceae	*Oxalis latifolia* Kunth.	√	√
	Oxalis corniculata L.	√	√
Papilionaceae	*Indigofera spicata* Forssk.	√	√
Papilionoideae	*Rhynchosia elegans* A.Rich	√	-
Polygonaceae	*Polygonum convolvulus* L.	-	√
	Oxygonum sinuatum (Meisn.) Dammer.	√	√
Portulacaceae	*Portulaca oleracea* L.	√	-
Rubiaceae	*Richardia brasiliensis* Gomez	√	-
	Rubia cordifolia L.	√	√
Solanaceae	*Cestrum aurantiacum* Lindl.	√	-
	Solanum nigrum L.	√	√
	Solanum tuberosum L.	√	√
Verbenaceae	*Lantana camara* L.	√	-
Zygophyllaceae	*Tribulus terrestris* L.	√	-