SPATIO-TEMPORAL DELIVERY OF FLORAL RESOURCES IN HIGHLY FRAGMENTED FARMLANDS

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Abstract

Availability of floral resources in farmland has been reported to impact on the presence of diverse pollinators. This is particularly so in tropical fragmented landscapes that have diverse farming activities that are practiced in Kenya. The objective of the study was to determine floral resource deliveries in a highly fragmented landscape across a forest-farm matrix traversing a distance of about 25 km from Mt. Kenya forest edge. This was an ecological study comprised of four sites running from the forest edge towards the farmlands. In each site five farm-plots with a minimum distance of 200m were selected for data collection purposes. A section of the hedge (100m2) and cropped area (1000m2) was used for data collection purposes. Data collected included name of the plant species, whether flowered or not, type of floral resource produced and the number of bees visiting the flowers. Analysis of Variance (ANOVA) was carried out using GENSTAT (Ver. 17) statistical software to compare means of various parameters. Significance was sought at 95% level of confidence limit. Results showed that about 58% of the 142 recorded plant species provided pollen, 33% provided both pollen and nectar and 19% provided nectar. Plants in the Family Asteraceae were the most dominant with over 27% plant species. About 10 plant species were observed flowering all year-round while about 80% of all the plants recorded flowered for more than half a year. Higher bee activity density coincided with intense flowering period. Availability of flowered plants throughout the year assures presence of bees in the farmlands hence increased pollination for plants. Since most farmers do not manage pollination or hire bees for pollination, they must depend on feral bees stressing the importance of flowered plants in the farmlands. It is important for farmers to increase plant diversity and floral density in farmlands to ensure bees are retained for crop pollination.

Key words: Bees, hedge, Plants, pollination, flowering crop

Introduction

Floral resources are substances produced by plant flowers that are utilized by pollinators mainly as a source of nutrition. The popular floral resources sought by bees include pollen, nectar and sometimes oil. Floral resources are important determinants for bee species presence and existence in an area. The variation in the type of vegetation may affect nesting or feeding resources for bees

(Matteson *et al.* 2012) and hence their pollination efficiency. Agricultural systems that provide very little or no floral resources become unattractive to bees for habitation (Decourtye *et al.* 2010). In addition, insufficient nectar and pollen has been reported to affect bee health (Michener, 2007; Vaudo *et al.* 2015) resulting to a decrease in bees available for pollination (Decourtye *et al.,* 2010). Consequently, plants that require pollination in such farmlands produce poorly, affecting family livelihood. It is indicative that bees do not visit flowers for pollination but this occurs incidentally while they are collecting pollen and nectar. Bees require both pollen and nectar for their normal growth and development.

Nectar provides mainly the carbohydrates in form of sugars for energy needed for flight, colony maintenance and a source of vital minerals such as calcium, copper, potassium, magnesium and sodium (Ellis *et al.,* 2010). In addition pollen provides proteins and other nutrients such as fats, minerals and vitamins necessary for brood production and development (Michener, 2000). Pollen produced by stamens attracts pollinators which carries the male gametes from a flower for reproduction. This implies that pollen collected by bees may not be available for pollination. It is the pollen that gets dusted on the body hairs of the bees that get utilized for pollination (Ellis *et al.,* 2010). Different plants produce varying amounts of pollen and nectar. In addition, some plants produce a lot of pollen but no nectar (Ellis *et al.,* 2010). For example in cucurbit flowers, male flowers produce only pollen while female produces pollen and nectar. Likewise there are flowers which produce both pollen and nectar and these forms the majority (Bhalchandra *et al.,* 2014). Nectar is usually located at the base of a flower and has the role of attraction.

Therefore, in order to take care of these nutritional requirements, it is important to protect and intensify floral resources in crop land (Murray *et al.* 2009). This will ensure availability of floral resources for bees even when crops are not in bloom. There have been efforts in protecting wildlife (conservancies and parks) but there has been no attempt in enhancing the presence of pollinating bees in Kenyan farmlands (Kasina *et al.,* 2009a). This probably is due to insufficient studies that could help in understanding how to do this. It may also be due to lack of extension messages on importance of pollinators in farming (Kasina *et al.,* 2009b). In contrast, it has been reported previously that Kenyan farmers do not manage pollination since it is not considered as a key factor in crop production (Kasina *et al.* 2009a). In order to ensure sufficient crop pollination for plants, there is need to conserve the habitats both in agricultural and protected areas.

Agri-environmental schemes such as the use of flower strips encourages pollinator conservation (Gonigle *et al.* 2016; Uyttenbroeck *et al.* 2016). Hedgerows can be managed to provide forage, nesting sites and source of refuge for bees (Tuell *et al.,* 2008; Tuell and Isaacs, 2010). Previous studies carried out in Kakamega (Mwangi *et al.,* 2012) showed that hedgerows harbor and provide resources for various bees useful in crop production. However, farmers still have no idea on the importance of enhancing bees in their farms (Kasina *et al.,* 2009b). Studies in other countries have shown that hedgerow enhancement with flowering plants may greatly support both native and non-native bees (Carvell *et al.,* 2007; Hopwood, 2008; Batary *et al.,* 2011; Pywell *et al.,* 2011). Therefore this study was done to characterize plants in their natural occurrence in the farmlands bordering a key forestry conservation site in order to come up with a floral calendar of plants that can be used either

singly or in combinations to provide resources for the bees throughout the year.

Materials and Methods

This study was conducted in the farm neighboring North West of Mt. Kenya forest , a span of about 0-30 km from the forest edge, area lying between latitudes 00°01032'N and 00°12316'N; longitudes 37°055711'E and 37°14843'E (Fig. 1). They ranged between 1820 m and 2116 m above sea level with annual rainfall ranging from 450 mm to 750 mm distributed in two seasons: the long rains (March to May) and the short rains (October to December) (Ramser, 2007). The dominant soil type is Luvic Phaozem and chromic luvisols developed from intermediate igneous rocks (Ramser, 2007).

The trial was based on a line transect design with four randomly selected sectors (Katheri, Nyarigino, Gakeu and KHE to represent a gradient from forest edge into the farmland (Fig. 1). For each sector, five farm plots were randomly selected with a minimum gap of 200 m from the nearest plot. Within the farm plot, a 50m x 2m section of hedge was randomly selected for data collection purposes. Additional data was collected on a 50m x 20m area of cultivated area adjacent to the hedge. Data collected included plant identity, flowering situation, the activity density of bees and type of floral resource from each flowering plant. Nectar source was confirmed by the bee behaviour (extension of proboscis into the flowers) and direct observation on the flower. Pollen source was confirmed by presence of pollen on body of the bees as well as physical observation on the flower. Presence of both traits in flowers confirmed source of both floral resources. All unknown plants were carried to the National Museums of Kenya (NMK) for identification. Analysis of Variance (ANOVA) was carried out using GENSTAT (Ver. 17) statistical software to compare means of various parameters. Significance was sought at 95% level of confidence limit.

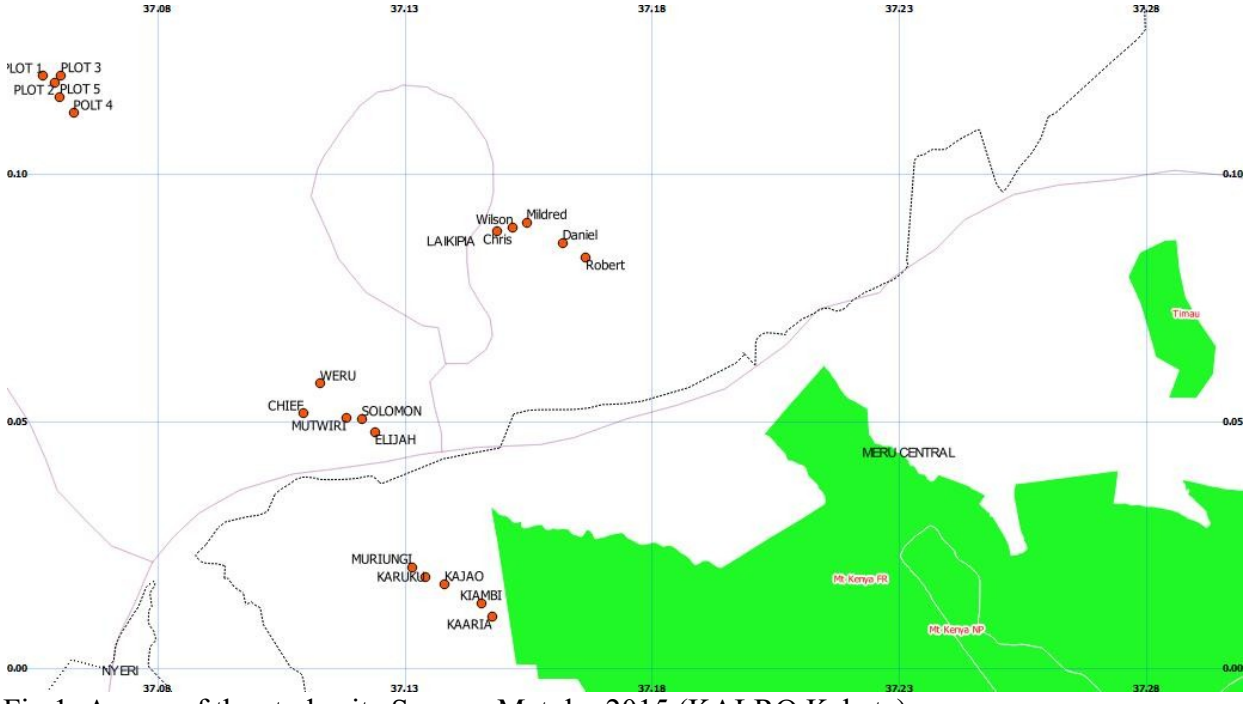

Fig 1. A map of the study site Source: Matolo, 2015 (KALRO Kabete)

Results

A total of 142 plant species representing 42 plant families were recorded in Mt Kenya. The

family Asteraceae recorded the highest number of species (about 27%) in all the study sites followed by Fabaceae and Lamiaceae. About 63% of the all the plant species recorded were weeds, 26% shrubs and 10% trees (Fig 2). The diversity of plant species increased from forest hedge towards the interior of the farmland with the shrubs being the most dominant near the forest hedge and weeds dominating in the interior farmlands (Fig. 2). A highly significant ($P<0.001$) difference in the plant diversity per sector was recorded.

In terms of floral resource provision, 63% of the plants recorded provided pollen, 21% both pollen and nectar while 16% provided nectar (Fig 3). It was also observed that most of the pollen bearing plants flowered more frequently compared to other plants.

Among the flowered plants, *Aspilia mossambicensis, Solanum incanum, Plectranthus barbatus, Achyranthes aspera*, *Lantana trifolia, Tagetes minuta, Sesbania sesban, Bidens pilosa, Ocimum suave* and *Commelina diffusa* bloomed throughout the period of observation of this study (Table 1). A highly significant ($P<0.001$) difference in the number of flowered plants per month was recorded.

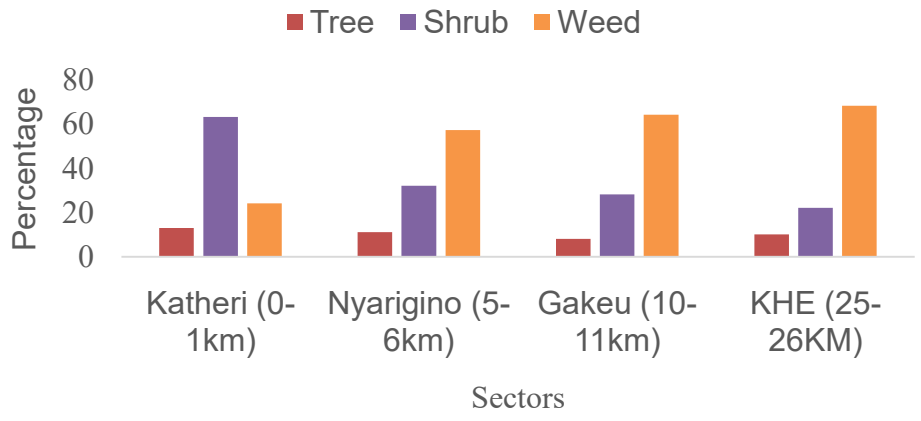

Figure 2. Most commonly occurring plant types in the study sites

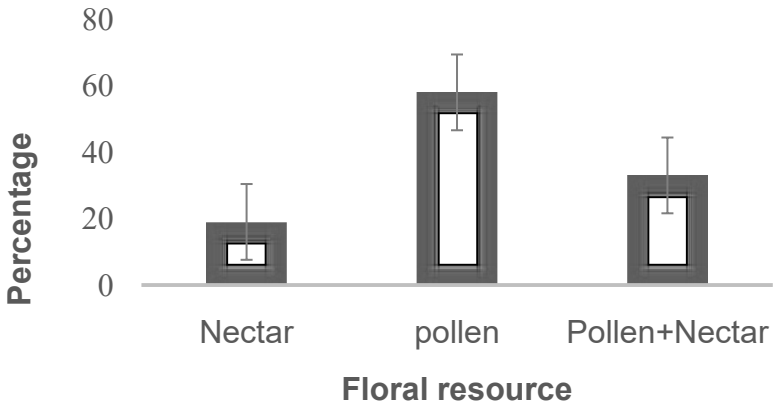

Figure 3. Percentage number of floral resources provided by plants recorded

Table 1. Floral Calendar for hedge plants and the number of bees recorded across the year at Mt Kenya, Sep 2013 to Aug 2014

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
347	213	-	177	381	418	269	270	115	134	295	352
Asteraceae (*Achyranthes aspera, Aspilia mosambicensis, Bidens pilosa, Tagetes minuta*), Fabaceaea (*Sesbania sesban*)											
Verbenaceae (*Lanta camara*), Commelinaceae (*Commelina diffusa*), Musaceae (*Musa acuminate)*											
Lamiaceae (*Ocimum suave, Plectranthus barbatus*), Solanaceae (*Solanum incanum*)											
Acanthaceae (*Asystasia gangetica),*									Acanthaceae (*Asystasia gangetica)*		
Acanthaceae *Justicia procumbens),*											*Justicia procumbens*
Asteraceae *(Conyza floribunda)*									Asteraceae *(Conyza floribunda)*		
Asteraceae *(Galinsoga parviflora),* Cupressaceae (*Cupressus lusitanica*)										*Galinsoga parviflora, Cupressus lusitanica*	
Verbenaceae *(Ocimum kilimamdsharicum)*										Verbenaceae *(Ocimum kilimamdsharicum)*	
Fabaceae (*Acacia mearnsii)*					*Acacia mearnsii*						*Acacia mearnsii*
Verbenaceae (*Rotheca myricoides)*									Verbenaceae (*Rotheca myricoides)*		
			Vernonia amygdalina						Asteraceae (*Vernonia amygdalina*)		
						Euphorbiaceae *(Croton megalocarpus)*				Euphorbiaceae *(Croton megalocarpus)*	
				Fabaceae (*Phaseolus vulgaris*)					Fabaceae (*Phaseolus vulgaris*)		
Myrtaceae *(Callistemon ruguloris)*									Myrtaceae (*Callistemon ruguloris)*		
Brassicaceae (*Brassica oleraceae)*					Brassicaceae *Brassica oleraceae*					Brassicaceae (*Brassica oleraceae)*	
				Brassicaceae (*Brassica napus)*				Brassicaceae (*Brassica napus)*			

Key

	Plants that produced pollen as a floral resource
	Plants that produced nectar as a floral resource
	Plants that produced both pollen and nectar as a floral resource
	Number of bee species recorded per month across the year

The bee species diversity recorded was significantly ($P<0.05$) higher in plants offering pollen compared to those offering nectar. Bee-floral interaction was high in plants such as *Plectanthus barbatus* and *Ocimum suave* which provided both pollen and nectar throughout the year. The former provided forage for 15 bee species while the latter supported 13 bee species. Apart from forage, some plants offered nesting sites for bees within the farmlands. These combination of factors were found suitable for selecting the best bee plants in the area (Table 2).

There was a positive correlation between the number of bees present and the number of flowered plants recorded per month. In February when there was a remarkable decline in the number of flowers, a corresponding decline in the number of bees was recorded (Fig 4). Similarly, between May and June an increase in the number of bees was recorded which corresponded to the increased number of flowers (Fig. 4).

Table 2: List of hedgerow plants that would be important for provision of floral resources and nesting sites to bees

Common Name	Scientific Name	Family name	Type of plant	Importance to bees
Indian coleus	*Plectranthus barbatus*	Lamiaceae	Shrub	Nesting and forage
Mtule basil	*Ocimum suave*	Lamiaceae	Shrub	Nesting and forage
Mexican cypress	*Cupressus lusitanica*	Cupressaceae	Tree	Nesting and forage
Asthma weed	*Conyza floribunda*	Asteraceae	Weed	Nesting and forage
Egyptian pea	*Sesbania sesban*	Fabaceae	Shrub	Nesting and forage
Aspilia	*Aspilia mossambicensis*	Asteraceae	Shrub	Nesting and forage
Black jack	*Bidens pilosa*	Asteraceae	Weed	Nesting and forage
Shrub verbena	*Lantana camara*	Verbenaceae	Shrub	Nesting and forage
Avocado	*Persea americana*	Lauraceae	Tree	Nesting and forage
Lamb's quarters	*Chenopodium sp.*	Chenopodiaceae	Shrub	Nesting
Purple top vervain	*Verbena bonariensis*	Verbenaceae	Weed	Nesting
Pencil plant	*Euphorbia tirucalli*	Euphorbiaceae	Shrub	Nesting
Sydney blue gum	*Eucalyptus saligna*	Myrtaceae	Tree	Forage
Cat's claw	*Caesalpinia decapetala*	Fabaceae	Shrub	Forage
Devil's horsewhip	*Achyranthes aaspera*	Amaranthaceae	Weed	Forage
Climbing day flower	*Commelina diffusa*	Commelinaceae	Weed	Forage
Sodom apple	*Solanum incanum*	Solanaceae	Shrub	Forage

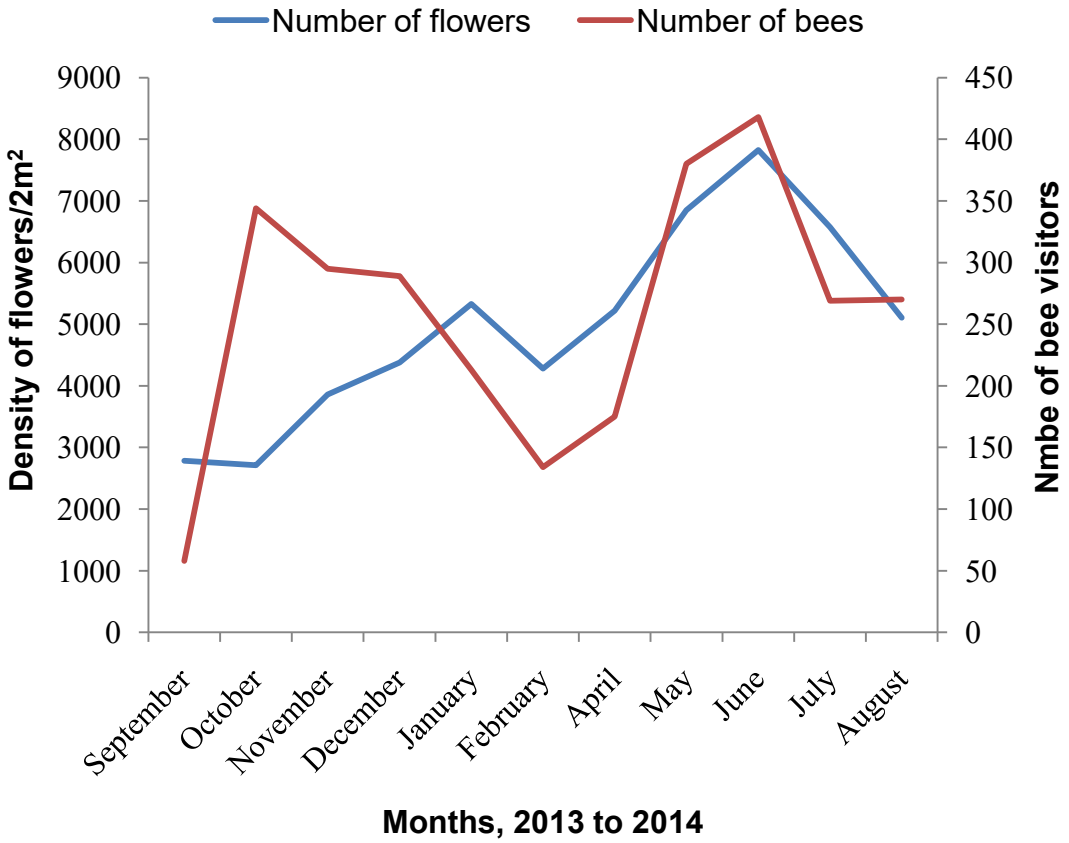

Figure 4. Temporal changes in density of flowers and bee activity density per month, September 2013 to August 2014

Discussion

Weeds account for the majority of all the observed plants and was also recorded throughout the year. The family Asteraceae (e.g Aspilia, Asthma weed and black jack) was highly preferred by bees as a source of forage compared to other families. Studies at Kakamega showed that weeds especially Asteraceae and Acanthaceae have a wide distribution especially in forests and bushlands (Gikungu, 2006). Similarly, in the highlands of Ethiopia, these herbaceous plants were found to be higher compared to other plants and were major contributors of nectar to bees (Wubie *et al.* 2014). Previous studies by studies by Karanja *et al.* (2010) in Kiambu County, Kenya, indicated that plants in Asteraceae family highly provided floral resources for bees when coffee was not flowering. Elsewhere wild plants especially weeds were found to be an important source of floral resources for bees (Requier *et al.* 2015), even in the absence of flowered crops.

Sectors nearest to the forest had a higher plant diversity comprising more of trees than other plants species. Being near to the forest, the climate was cooler hence able to support more woody plants compared to other sectors. In addition, forests are less interfered with compared to the farmlands. Similar studies in Mexico showed that the density of plants was higher near to the forests than away from it (Muniz-Castro *et al.* 2006). Nearer the farmlands more weeds and shrubs were recorded compared to the trees probably due to the anthropogenic activities resulting in clearance of habitats for farming.

Most bee species visited plants for pollen provision but a significant number preferred a plant that could offer both pollen and nectar. In California, bees were found to have greater preference for plants in Asteraceae family as a source of both pollen and nectar, and Lamiaceae family as a source of nectar (Frankie *et al.* 2009). Plants providing sufficient quantities of both nectar and pollen may be more frequently visited which result to their effective pollination. For crops, it will translate to higher yields and thus more benefits to farmers. The overall abundance of bees in a particular habitat is positively correlated to the number of floral resources present (Potts *et al.* 2003; Fisher, K (2016); Mensah *et al.* 2017). Therefore agro ecosystem located nearer well managed habitat such as hedgerows host higher species richness of bees than those that are bare.

Generally, plants vary in the amount of nectar and pollen that they produce. Some plants produce a lot of pollen but no nectar (Ellis *et al.* 2010). Similarly, some bees visit certain plants for nectar only while other bees like *Lasioglossum imitatus* collect pollen from only one plant species during a single flight (Polidori *et al.* 2009) which may be attributed to floral constancy. Therefore it is important for crop producers and land owners to protect and enhance flowering plants around their farms (Murray *et al.* 2009) so as to ensure that both pollen and nectar are available for bees (Potts *et al.* 2005) even in absence of flowered crops. It is also necessary to know the floral composition of plants because they have an impact on bee diversity and abundance (Matteson *et al.* 2012).

Weeds such as *Bidens pilosa* (Asteraceae), *Justicia procumbens* and *Asystasia gagentica* (Acanthaceae) and shrubs such as *Plectranthus barbatus* (Lamiaceae) which are usually ignored, were found to harbor a number of bee species and also found to flower throughout the year, in this study. Hedgerows harboured most plant and bee species possibly because they had minimal disturbance compared to the cropped area. Therefore more weeds and shrubs which were targets for bees were able to thrive more and the number of bees visiting was higher compared to the crop. In absence of flowered crops, hedgerows provided floral resources to bees throughout the year confirming earlier studies on their importance as a source of forage and nesting sites for bees (Corbit *et al.* 1999; Tuell *et al.* 2008; Mwangi *et al.* 2012). Martins (2014), also indicated that hedgerows does not only provide pollinators with nectar and pollen, but also habitat in which they can nest and thrive. Bhalchandra *et al.* (2014) reported that wild plants especially herbs and shrubs were highly visited by bees especially if the crops were not flowered.

In recent times, hedgerows have provided a potential avenue for managing pollinators in the farmlands; a more than 40% net benefit after sales of crops was demonstrated as a result of non-Apis bees in Kakamega (Kasina *et al.* 2009). Previous studies in Kakamega (Mwangi *et al.* 2012) showed that hedgerows harbor and provide resources for several bee species. Studies in other countries have shown that hedgerow enhancement with flowering plants may greatly support both native and non-native bees (Carvell *et al.* 2007; Hopwood, 2008; Batary *et al.* 2011; Pywell *et al.* 2011). Therefore, hedgerows can be managed to provide forage, nesting sites and source of refuge for bees (Tuell *et al.* 2008; Tuell & Isaacs, 2010).

Conclusion

Some plants are capable of providing floral resources to bees throughout the year especially if used in combination with other suitable ones. Hedgerows provide better environmental conditions for the survival of these plants because of less disturbances compared to the crop. Hedgerow also provide

safe avenues for bee species due to availability of floral resources, better nesting facilities and shelter from high temperatures. Therefore, farmers should maintain an integrated hedgerow planting system in the farmlands which maintains interconnection between the farmland and natural protected habitats. This will ensure that pollination provision is enhanced throughout hence greater and better crop yields.

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