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Assessment of bee visitation rates on its influence on pod and seed set in beans in Borabu sub-county, Western Kenya

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Abstract
Most agricultural crops rely on pollinators, particularly bees for pollination services. Smallholder farmers in Africa commonly use maize and bean intercropping in order to achieve the optimum yields hence providing them with significant food security and economic impacts. This study sought to assess how bee visitation rates influences pod and seed set in beans in Nyansiongo, Borabu Sub county. One administrative sub location was purposively selected. Three plots were selected at equal 1km distance along a 200m transect laid in that sub location. Three sample plots each of 100m x 100 m were established along transects. Observation of bee visitation rate was done from 0730hrs to 1230hrs. Thirty bean plants were selected randomly. Selected flowers were numbered and marked using a masking tape. Thirty flowers were caged using a stiff net before flowers opened and 30 others were also marked and left open. Mature and dried up pods were harvested for analysis of pod size, weight and number of seeds per pod in the caged and un-cagged pollination treatments. Data obtained were analyzed using one way ANOVA. There was no significant difference between number of pods in closed and open pollination, $p>0.05$. However, there was a significant difference in seed weight of caged and uncaged bean plants, $p<0.05$. There was a significant difference between the caged and uncaged bean plants, $p<0.05$ and seed weight, $p<0.05$. There was an increase in crop quality and yields due to bee pollination. This confirms that bees enhance yield of beans by improving the quality and quantity.

Keywords: Pollination, Apis, beans, yield, cage, smallholder

1. Introduction

Pollination is the process of sexual reproduction in plants, in which the male sexual cell, the pollen grain (a group of cells called gametophyte) is transferred to a female flower of the same species, germinates on receptive stigma and subsequently fertilizes the female gametophyte (ovule). Flowering plants require pollination to produce seed or fruit. Some plants are wind pollinated and others are self-pollinated, but many plant species require animal mediated cross pollination [17].

Studies have shown that plant community composition, pollination syndromes and pollinator types have not been well documented in Africa as compared to other regions in the world [3]. The ecological interactions between plants and pollinators make important contributions to global diversity. Studies by [4, 5] show that nested architecture; plant–pollinator networks reduce competition and increase biodiversity.

Pollinators increases food security and contributes to the improvement of livelihoods and increase of income of some of the world‘s poorest people found mainly in the Sub-Saharan Africa including Kenya [19]. Much as pollinators (bees) are known to pollinate most of the world‘s wild plant species and provide economically valuable pollination services to crops [5], the knowledge of strategies for conservation biology lags far behind other beneficial taxa such as parasitoids and predators [5].

Pollinators are among the biota that are very sensitive to disturbance; particularly to anthropogenic activities (pesticides use, habitat destruction and loss and grazing intensity) and to Intensification in land use systems and to change in farming practices [13, 18]. Bees are important plant pollinators and any decline in numbers or species due to anthropogenic disturbances constitutes a significant threat both to biological diversity and their ecosystem services and to whole agricultural economics [14]. Bees complement each other in pollination. A more diverse bee community provides better pollination service especially in areas where mixed cropping is done, as different pollinators target different flowers. Diversity can help to reduce the risk that may arise due to lack of a pollinator during the critical period of crop flowering. For example, *A. mellifera* are known to abandon flower patches for more suitable ones and in such a case, having other bee species can help counteract the lost honeybee function although this also depends on other crop requirements [8].

2. Materials and Methods

2.1 Description of the Study Area

Nyansiongo Sub-location in Borabu Sub County Nyamira County, Kenya. It is situated at the border of Kisii-Sotik, about 40km south east from Kisii town. It covers an area of 3000ha with the population of 35,413 [7]. The area has rich agricultural soils and receives plenty of rain which is well distributed throughout the year. In the months of January-February dry periods are experienced. More rain is experienced in the month of April with more than 1500mm. Soil type in this area is reddish brown and silt clay. The area consists of a rolling landscape with an altitude of 1850-1950m above sea-level but with some steep conical hills whose tops can have an altitude of 2060m above sea level. Nyansiongo is known for its richness of flora. It consists of both tea as the main cash crop and indigenous trees like acacia and food crops such as bananas, maize, beans and sweet potatoes.

Fig 1: Map of Borabu sub County; Adopted from County commissioner office; Nyamira County, scale not shown

2.2 Data Collection

Observation of bee visitation rate was done from 0730hrs to 1230hrs. This was simultaneously done in the 3 study farms at the interval of 20 minutes per sampling. The visitation rate of bees was observed by recording individual flower visitors and number of flowers in the sampled bean plots. A twenty minute observation period was set to record the number of flower visitors per plot (100m x100m) during the flowering period of beans. In each of the 3 samples, data was collected in replicates. Bean plants were labelled differently and only thirty were selected randomly. Selected flowers were numbered and marked using a masking tape [21]. For each bean plant selected, 30 flowers were caged using a stiff net before flowers opened and 30 others were also marked and left open. After three months, the plants were un-caged to record the set fruit (pod) and then re-caged. Once the pods were mature and completely dry, they were harvested. The size and weight of pods and number of seeds per pod was recorded across the different pollination treatments (caged and uncagged) to assess the yield; quality and quantity. The other pods which remained uncaged were left to mature and harvested the pods for yield comparison. The cage and un-caged flowers were used to assess the effects of pollination on the bean yield.

3. Data Analysis

The data obtained was subjected to one way Analysis of variance (ANOVA) at 95% level of accuracy.

4. Results

4.1 Bee Visitation Rates

The highest number of flower visitors were *A. mellifera* at 87% followed by *Meliponula Sp.* 1at 7.8%, *X. Calens* at 5.2% while *X. Sp.* 2 had 0.7%. *X. flavorufa* and *X. Sp.* 3 each had 0.2% while *X. Sp.*1and *M. Sp.* 1 had 0.1% respectively (Appendix 1). The highest frequency of flower visitors, 305 were recorded between 10.00am-11.00am followed by 248 between 11.00am-12.00pm, 244 between 9.00am-10.00am, 105 between 8.00am-9.00am and 90 between 7.00am-8.00am (Figure 2).

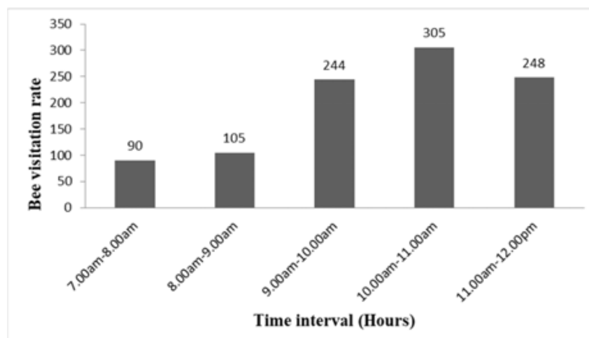

Fig 2: Bee visitation rates

4.2 Bee Visitation Rates on Influence of Pod and Seed Set

There was a difference between plants that were open pollinated (Uncaged) and those that were not visited by bees (caged). Differences were found in the number of pods set per plant, pod weight, seed weight and number of seeds per pod.

4.2.1 Mean Number of Pods per Plant

The mean number of pods per plant obtained from open access to bee pollinated flowers was relatively higher than that obtained from closed pollinated flowers in the replicated treatments (Table 1). However there was no significant difference ($p>0.05$) between the treatments [Appendix 2(i)].

Table 1: Mean number of pods per plant

Treatment 1	Mean Value	Treatment 2(Replication)	Mean Value
Closed flowers	8 (30)	Closed flowers	7.71 (30)
Open flowers	13 (30)	Open flowers	13.94(30)

Number in parentheses represents N value

4.2.2 Average Pod Weight

There was a significant difference in the mean pod weight obtained from closed and open pollinated flowers of the beans ($p<0.05$). Higher weights were recorded for pods obtained from open pollinated flowers in all replicates in the treatments (Table 2) and [Appendix 2(ii)].

Table 2: Mean pod weight (g) per plant

Treatment 1	Mean weight	Treatment2(Replication)	Mean weight
Closed flowers	3.84 (30) ($p>0.05$)	Closed flowers	3.81(30) ($p>0.05$)
Open flowers	6.87 (30) ($p<0.05$)	Open flowers	6.88(30) ($p<0.05$)

Number in parentheses represents N value

4.2.3 Average Seed Number in Pods per Plant

The average number of seeds per pod of the beans obtained from open pollinated flowers was significantly more than self-pollinated flowers in all replicates ($p<0.05$) [Appendix 2(iii)].

Table 3: Average seed number of pods per plant

Treatment 1	Mean Value	Treatment 2(Replication)	Mean Value
Closed pollinated flowers	3.76 (30) ($p>0.05$)	Closed flowers	3.71 (30) ($p>0.05$)
Open pollinated flowers	5.38 (30) ($p<0.05$)	Open flowers	5.44(30) ($p<0.05$)

Number in parentheses represents N value

4.2.4 Average Seed Weight per Pod

Significantly, higher seed weight was recorded for seeds obtained from open pollinated flowers ($p<0.05$) (Table 4). The difference in yield was due to frequent visitation by bees in unbagged beans compared to bagged ones. [Appendix 2(iv)].

Table 4: Mean seed weight (g) per pod per plant

Treatment 1	Mean weight	Treatment 2(Replication)	Mean weight
Closed flowers	0.72 (30) ($p>0.05$)	Closed flowers	0.69(30) ($p>0.05$)
Open flowers	1.32 (30) ($p<0.05$)	Open flowers	1.35(30) ($p<0.05$)

Number in parentheses represents N value.

4.2.5 The Dependence of the Bean Crop on Bee Pollination

The dependence of the bean crop on bee pollination was determined (Table 5). This was done by comparing the yield from bee pollinated flowers (open flowers) with those which had been denied bee visits (closed flowers). Dependence can be expressed as;

$$Pdr = \frac{Y_{ub} - Y_b}{Y_{ub}} + qcv$$

where *pdr* is the pollination dependence ratio of a crop; *ub Y* is the yield (6,875kg/acre) from closed flowers (with unlimited access by bees or from hand-pollinated flowers, whichever is higher); *b Y* is the yield (3,825kg/acre) from closed flowers (not accessed by bees); *qcv* is a quality coefficient value that represents the value addition due to a better quality after bee pollination. The *qcv* equals 0.1 in case there is quality improvement or 0.0 if there is no quality enhancement.

Table 5: Dependence of bean crop on bee production

Pda	*Qcv*	*Pdr*
0.44	0.1	0.54

Pda-pollination dependence amount; *qcv*-quality coefficient value; *pdr*-pollination dependence ratio

5. Discussion

5.1 Bee Visitation Rates

The results revealed that most bee species peak foraging time was at 1000hrs to1100hrs. This might be attributed to variations in temperature, dew, light and amount of floral resources of the beans. These results concur with the study by [11] who reported that variations in weather conditions during bloom of a crop affect abundance activities of insect pollinators. Similarly, [2] in Cameroon reported that foraging activities of *A. mellifera adansonii* on flowers of *P. vulgaris* were influenced by climatic conditions and availability of nectar. [20] made similar observations in cucumber in Western Kenya. This is also in agreement with [19] who found that honeybees (*A. mellifera*) were the most abundant insect pollinators in Peshawar.

5.1.1 Influence of Bee Visitation Rates on Number of Pods

There was an increase in number of pods in uncaged beans compared to caged bean plants. These results are in line with those of [3] who recorded significant increase in the number of pods set in open pollinated (uncaged) plants compared to those closed (caged) for self-pollination. These findings are also in agreement with those obtained by [1] who observed that the numbers of pods obtained from cross-pollination (open flowers) were higher than those obtained by selfing (closed flowers) and therefore pollination by bees made an impact on the number of developed seeds as well.

5.1.2 Influence of Bee Visitation Rates on Pod Weight

The pod weight and size depends on the number of developed seeds. Seeds usually initiate development of mesoderm, hence the more the seeds, the more 'flesh', and thus weight. In this study, the number of developed seeds was found to positively correlate with the pod weight [Appendix 2(ii and iii)]. Seed production follows successful pollen deposition in the stigma and subsequent pollen tube germination. Bees were responsible for the pollination, and the more pollen deposited, the higher the likelihood of fertilization of more ovules, resulting in an increased number of seeds and thus, better pollinated flowers produced a higher fruit weight. These findings agrees with a related study conducted by [16, 19] which reported that cross pollinated beans were heavier in weight than those resulted from self-pollination.

5.1.3 Bee Visitation Rates on Influence of Seed Number
Seed production is due to successful pollen deposition in the stigma and subsequent pollen tube germination in a flower. Bees (*A. mellifera*) were responsible for the pollination, and the more the pollen deposited, the higher the likelihood of fertilization of more ovules, which brings about increased number of seeds. The results show that the mean number of seeds was lower than the maximum attainable in the un-caged flowers, which implies that bee pollination of the bean crop in the study area was not sufficient. This is in agreement with a study carried out by [10] which described the role of bee pollinators in enhancement of coffee yields, crop production and quality. Similar findings were obtained in a related study conducted by [22], who observed that cross-pollinated apple flowers resulted into higher seed set. Additionally, [1, 23] found a significant positive impact on the seed yield of broad bean (*V. faba).* They further observed that the numbers of pods as well as the seed yield obtained by cross-pollination were higher than those obtained by selfing.

5.1.4 Bee Visitation Rates on Influence on Bean Seed Weight
Seed formation is due to effective pollen deposition in the stigma and subsequent pollen tube germination. Bees (*A. mellifera*) were responsible for the pollination, and the more pollen deposited, the higher the chances of fertilization of more ovules, which leads to increased number of seeds with more weight in uncaged flowers compared to the caged flowers. These results concurs with those obtained by [9] who found out that cross-pollinated common beans by *A. mellifera* resulted in increased seed weight and nutrition improvement of the dry harvested seeds.

5.1.5 Dependence of Bean Crop on Bee Pollination
Bean crops were found to gain from pollination when yields between caged and uncaged flowers were compared. There are few studies world-wide on the dependence of this crop on bee pollination. In Kenya more so Kakamega studies done by [6] showed that an increase in crop yield in beans ranging from 25% to more than 99% is due to bee pollination. Thus, although some crops can produce without bee pollination, presence of bees is important to increase yields, and hence, food security and income. Similarly, bee pollination is essential for reproduction in other crops. Generally, previous studies have noted that bee pollination does not result in a significant increase in pod numbers, but the number and weight of seeds in a pod do increase [9, 22].
The caged and un-caged flowers enabled the assessment of the effects of bee pollination on crop yields. The caged flowers were assumed to have had non-bee pollination while there was a strong possibility that the un-caged flowers were visited by bees. However, the dependence of the crops on bees for their reproduction varies. Usually, hand pollination should provide the highest attainable yield as a result of cross-pollination, which can also be achieved if the number of effective bee pollinators is adequate. Generally, without bees, a crop can only produce with assistance from man or by chance if visited by nectar thieves [15]. According to [23], the pollination dependence ratio due to bee pollination is close to 1.0 this study obtained a bee pollination dependence ratio of 0.40. The ratio shows the extent of expression of contribution of bees to the harvestable yield of the crop.

6. Conclusion
The findings of this study have revealed that flower pollinators are important in pod set of bean crops and therefore, there is a need to conserve the populations of non-Apis bees, especially, *Xylocopa* and *Megachilidae* in order to enhance bean production. Bean crops depended greatly on bee pollination for their yield in this study. The seed weight per pod obtained from open flowers was higher than that obtained from closed flowers, implying that cross pollination is quite important.

6.1 Conflict of Interest
"The author(s) declare(s) that there is no conflict of interest."
There was no role of the funding sponsors in the design of the study; in the collection, analyses or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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Appendix 1: Bees visitation rate

Name of bee		Time in the day					Total	Percentage (%)
		7.00-8.00	8.00-9.00	9.00-10.00	10.00-11.00	11.00-12.00		
1	*Apis mellifera*	77	81	203	264	225	850	87.0
2	*Xylocopa calens*	2	-	14	27	9	52	5.2
3	*Xylocopa flavorufa*	-	-	2	-	-	2	0.2
4	*Xylocopa Sp.1*	-	-	1	-	-	1	0.1
5	*Xylocopa Sp. 2*	-	1	2	-	4	7	0.7
6	*Xylocopa Sp. 3*	1	-	1	-	-	2	0.2
7	*Meliponula Sp. 1*	10	23	21	14	9	77	7.8
8	*Megachilida Sp. 1*	-	-	-	-	1	1	0.1
Total		90	105	244	305	248	992	100

Appendix 2: Statistical Analysis Output
(i) Number of pods per plant

		Paired Differences					T	Df	Sig. (2 tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Open– closed	-5.61500	.86974	.61500	-13.42932	2.19932	-9.130	1	.069

(ii) Average pod weight per plant

Unbagged-Bagged					
	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	.027	9	.003	2.924	.022
Within Groups	.021	20	.001		
Total	.048	29			

(iii) Average number of seeds per pod

Unbagged-Bagged					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.001	3	.000	3.758	.023
Within Groups	.001	26	.000		
Total	.002	29			

(iv) Seed weight per pod

Unbagged-Bagged					
	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	.002	4	.000	3.551	.020
Within Groups	.003	25	.000		
Total	.005	29			

(v) Number of bees between plot 1 and 3(from the forest edge into Nyansiongo farmland)

		Paired Differences					t	df	Sig. (2 tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	P1 – P2	-77.0000	16.52271	9.53939	-118.0469	-35.95531	-8.072	2	0.015

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