INCREASING KAVUKO COMMUNITY'S APPRECIATION OF BEE CONSERVATION AS A FOOD PRODUCTION AND SECURITY STRATEGY

Patricia Njoki Nzano,

Reg.No: A60/ 80596/2015

(Diploma, Food Science and Technology, Egerton University, BSc, Environmental Conservation and Natural Resource Management, University of Nairobi)

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DECLARATIONS

This thesis is my original work and has not been presented for a degree or any other award in any university.

Patricia Njoki Nzano,

Signed: ………………………………………… Date: ………………………………….

This thesis has been submitted for examination with our approval as university supervisors

Prof. Gideon N.H. Nyamasyo

University of Nairobi and Environmental Consultant,

School of Biological Sciences, Department of Zoology, Chiromo Campus, Nairobi.

Signed: ………………………………………… Date: ………………………………….

Dr. Grace A. Asiko

University of Nairobi and Director, National Beekeeping Institute, Nairobi.

Signed: ………………………………………… Date: ………………………………….

DEDICATION

It is with great awe that I dedicate this work to the only one who gives wisdom – God almighty.

To my husband, Solomon Nzano and our wonderful children; Wakesho and Mwarema. Thank you for being there for me throughout my study period.

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ABBREVIATIONS

B.C	Before Christ
CBD	Convention On Biological Diversity
EU	European Union
FAO	Food and Agriculture Organisation of the United Nations
GEF	Global Environment Facility
GoK	Government of Kenya
MALF	Ministry of Agriculture, Livestock and Fisheries
NMK	National Museums of Kenya
SDG	Sustainable Development Goals
UN	United Nations
UNEP	United Nations Environmental Programme

ABSTRACT

The research project was carried out at a small village in Makueni County, Kenya, where bee keeping has been practiced for a long time. The concern was that bee keeping practice was not linked, at least consciously to food production and security. Bees are pollinators and without pollination, food production would be drastically reduced. This demands the conscious conservation of the pollinators. There was the need to increase the community's awareness and appreciation of bee conservation alongside traditional bee keeping, a strategy to increase the community's food production and security. The objectives were: Establish the population of hives and bee colonies in the Kavuko area, determine the rate of hive colonisation in the area, access the community's level of awareness especially on the relationship between pollination and crop yields and determine the yield differences between pollinated and non- pollinated crops. The methods used include; a general survey within a 2km radius from the Pollen Glory farm, the project's focal point. A questionnaire was used to establish the exact status of each homestead in respect to the hives there, similar to the survey method, a focus group of 30 farmers each having three hives monitored their colonization, the focus group used a face-to-face questionnaire to establish the awareness on value of pollination. This was complemented by setting up a "bee hotel," a structure intended to attract different species of pollinators for guidance on how to conserve pollinators, a standard agronomical field layout was set up to test the yield differences between pollinated and non- pollinated crops. 3 crops, namely, strawberries, beans and tomatoes were planted in randomized block design with 3 replications. A control experiment, where wire mesh cages were used to exclude all pollinators was set up. Regular counts of the flowers and fruits/pods were made and graded for comparison. The results showed that; only one third (27%) of the households had hives and the common hives were traditional log hives (74%). Hive colonization was at 80% of the hives due to local management methods. The farmers (82%) were aware of the process of pollination, its benefits, but, not in relation to food production and security and their decline. They were also (68%) familiar with traditional bee conservation methods. Pollinated strawberries produced a significantly higher percentage (36%) of super grade fruits compared to non-pollinated (32%). The non-pollinated beans produced more pods. The pollinated gave a high flower abortion. Tomatoes production increased with pollinators. It was concluded that honey bees are important pollinators. Quantity and quality were enhanced by honeybee pollinators. It is recommended that; the community should be educated on the need to keep and conserve bees and take advantage of pollination services for quantity and quality. Also leverage on honey and other hive products to be socio economically empowered and combine traditional and modern innovations.

CHAPTER ONE: INTRODUCTION

1.1 Introduction

Food security is of utmost importance in any community for sustained livelihoods. It has been established that food production of most crops is enhanced by the presence of pollinators which must be conserved. In the absence of pollinators food production declines and conservation is at risk because the pollinators depend on the same plants they pollinate for their food as nectar and pollen. Flowering plants, (Angiosperms), play critical role in various natural and agricultural ecosystems, providing food, fibre and shelter for wildlife and human-kind equally. Pollination is a crucial period in the reproductive process of the world's nearly 300,000 species of flowering plants because it is typically required for the production of seeds (Faegri and Pijl, 1966; Free, 1970; Asiko *et al.*, 2007). Pollination increases the quantity and quality of crop and fruit yields (Bradbear, 2009). Many pollinating agents such as the honey bee are involved in pollination on most plants (Free, 1968; Thompson, 1971; Conner and Martain, 1973).

Honey bees need large quantities of nectar and pollen grains as food to reach their young and to visit the flowers regularly in large numbers. To obtain these foods they focus on one species of plant at a time and serve as good pollinators. For this reason, their body type allows them to pollinate flowers of different shapes and sizes. The pollination potential of honeybees is improved because they can be managed to cultivate high pollination. A well-managed colony can hold as many as worker 10,000 bees. The number of colonies can also be enlarged as needed and the colonies can be moved to the most desirable location for pollination purposes.

A forest ecosystem can supply wood, fruits, carbon sequestration, regulate downstream river and comprise important biodiversity. The maintenance of supply for these services hinge on a range of ecological processes as well as pollination. Pollination in the forest has economic importance as has pollination that supports agricultural production.

Foraging rate as well as pollination speed varies among bee species. Solitary bees foraged on extra flowers than social bees but they spend less time per flower visited. Solitary bees visited more coffee trees besides fields, but deposited less pollen, whereas social bees visited fewer trees and coffee fields in the landscape but deposited more pollen on flowers. Pollination efficiency was influenced by land – use intensity, field management systems and habitat types found in the close surroundings (Munyuli, 2013).

Man is the bee's worst enemy mainly because of indiscriminate use of pesticides that kill off numerous thousands of colonies every year. The killing of bees and other pollinating insects in tropical and subtropical regions can be attributed logically on lack of knowledge about correct pesticide application (Thompson, 1971). Local studies on bee domestication and conservation indicated that pollination contributes significantly to food security and household incomes (Oronje *et al.,* 2006, Asiko et al., 2007; Kinuthia, 2007; Martins, 2014). Various authors have too, attested to the importance of pollination in ecosystem processes that support food production and regeneration of plants (Kozin, 1972; Kioko, 2005; Munyuli, 2013). A project was set up in Kavuko area of Makueni County, to assess the population of bee colonies and the impact they have on crop pollination. Makueni County was curved out of Machakos District in 1992 and covers an area of 7,965.8 Km^2 with distinct habitats for both honeybees and stingless bees (RPSUD, 2006) most is semi-arid and occupied by the Kamba people who have traditionally kept bees. The major constraint is the dearth period when few plants flower. Most swarms migrate and few colonies remain is either due to being managed by farmers or being near some water sources (Nzano *et al.,* 2012).

1.2. Statement of the problem

Beekeeping is an old enterprise practised by many communities in Kenya. Most of them keep bees mainly for honey production. Few associate bees with pollination. Research has been carried out in the same area on bee pollination and its effect on quantity and quality of seed and crops. The missing link has been the disconnect of the information and practical aspect in demonstration to the community as an empowerment to food production and peace through the findings. The link between beekeeping and honey production on one hand is well known, but pollination services and food production on the other is not understood by communities. The research was designed to demonstrate the conservation using sisal pulp hives, bee hotel and demonstration of pollination and non-pollination in the quality and quantity of fruits and seeds of strawberries, beans and tomatoes.

1.3. Objective

Bee farmers within the community will be able to conserve honey bees and make use of pollination services for increased crop yields to sustain their livelihoods and conserve their environment in peace.

1.3.1 Specific objectives

i) To establish the population of hives and colonies in Kavuko area of Makueni district.

ii) To determine the rate of hive colonisation in the area.

iii) To assess the community awareness level on the value of pollination in crop production.

iv) To determine the yield differences between pollinated and non- pollinated crops.

1.4. Research questions

i) What is the density of bee colonies in the area?

ii) What is the farmer's awareness of the contribution of pollination to crop yield?

iii) How long does it take for new hives take to be colonised?

iv) Do they have knowledge on traditional methods of honey bee conservations?

v) Does the yield of strawberry, tomatoes and beans vary with the presence of pollinators?

1.5. Justification of the study

The Kavuko community, like most other communities in Kenya have not been explicitly exposed to pollination awareness and the role it plays in food security. The government and NGO'S have made tremendous effort to promote beekeeping as an economic enterprise aimed at improving communities' living standards.

In the past preliminary research was carried out to test the effect of bee pollination for quantity and quality fruit production, with little emphasis on conservation for sustainability.

The research focused on the awareness of conservation of pollinators for biodiversity using bee hotels and demonstration plots to illustrate and appreciate the important role of pollination in quantity and quality crop yield in the ecosystem.

1.6. Limitations of the study

The study was limited to Makueni County

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Certain agricultural practices aimed at increasing production of fruits or seeds by cross-pollination had been known, as long as subsistence agriculture existed. The oldest available mention to pollination concern agricultural practices. A relief at Nimrud dated 1500 B.C, showed two divine, winged creatures, all holding a male inflorescence above a female date palm. There are other pictures expressing the same idea indicating clearly that the Assyrians used artificial pollination to increase date palm production (Faegri, 1966).

Pollination and conservation are intertwined. The Global Environment Facility (GEF) financed a unique five-year project "Conservation & Management of Pollinators for Sustainable Agriculture through an Ecosystem Approach", which was through the United Nations Environment Programme (UNEP), to help safeguard food security through the protection of the key pollinator species. At the United Nations Sustainable Development Summit (2015), world leaders implemented the Agenda 2030 for Sustainable Development, which includes a set of 17 Sustainable Development Goals (SDGs) to end poverty, hunger and fight inequality, injustice and tackle climate change. The Convention that supports conservation of pollinators (Convention on Biological Diversity, CBD) is a multilateral treaty and varied in dimension. The future of ecological habitats depends on rural farmers who need to be engaged as partners in conservation and sustainable use of resources within the ecosystem (Jacobs *et al.*, 1987).

The United Nations recently declared May 20 as World Bee Day (Radhakrishnan, 2017). The resolution, suggested by Slovenia and supported by all EU member states, was adopted unanimously at a November meeting of the UN's Economic and Financial Committee and the decision to introduce a World Bee Day was taken at the general assembly in New York on Dec. 20, 2017.A milestone was achieved in Kenya through GEF/UNEP/FAO – conservation and management of pollinators for sustainable agriculture project development in 2004. A stakeholder meeting in 2004 at the NMK for a project on conservation and management of pollinators for sustainable agriculture, through an ecosystem approach had been accepted for funding by the Global Environmental Facility (GEF) the project was implemented by the UNEP and executed by the FAO. The three principal objectives were to progress and implement tools, methodologies strategies and best management practices for pollinator conservation and sustainable use. The project was to build local, national, regional and global capacities to permit the design, planning and implementation of interventions to mitigate pollinator population declines and establish sustainable pollinator management practices including raising awareness and strengthening prevailing network dedicated to conservation of pollinators. To support the co-ordination and integration of activities related to the conservation and sustainable use of pollinators at the international level to enhance global synergies. (NMK, 2004).

2.2 Pollination as an often unnoticed "ecosystem service"

An ecosystem is a value that is provided for free by healthy environments that the environment offers us with: habitats for people plants and animals, storing and cleaning of water. Provides soils to support plant and animal life and interactions like pollination (Martins, 2014).

Biodiversity conservation and plant species diversity is a significant factor in stabilizing world food supply and it depends on pollinator diversity 67% of plants depend on pollination which causes plant species survival through regeneration. The bees are keystone species because they are among pollination groups with high influence in plant population structure. Rural poverty and land degradation are closely linked. Conserving and utilizing of natural resources through an integrated way will tackle this issue. Economic incentives that integrate conservation with economic enterprises will ease the preserve of poverty. Beekeeping is one such enterprise. (2014, Kigatiira).

2.3 Honeybee species in Africa

Honeybee belong to the genus, Apis, tropical in origin. The African bee races are Apis mellifera intermissa (North African), Apis mellifera lamarckii (North East Africa), Apis melifera unicolor (Madagascar), Apis mellifera jemenitica (North East). Apis mellifela litorea (coastal regions of East Africa), Apis mellifera scutellata (found in the coastal escarpment and most of Africa). Apis mellifera monitcola (in the mountain areas) (Kioko et al. 2007).

Bees are on the whole, well adapted for blossom visits. They have a whole choice of patterns of behaviour, from rather simple ones in parasitic and solitary bees to the very complicated ones of hive-bees and other social bees. Social hymenopters comprise the most versatile, the most active, and, thus, the best- known pollinators. They are more intelligent than other pollinators and able to operate effectively mechanisms that baffle other ones (Faegri, 1966).

Plants have evolved to produce certain morphological structures that influence the type of pollination and maybe structured to allow any of the following types of pollination: Biotic pollination can be either, Entomophily; pollination by insects or Zoolophily; pollination by animals e.g. birds or bats and Abiotic pollination, through Anemophily; pollination by wind, this type of pollination is very common in grasses and, Hydrophilic; pollination by water which occurs in aquatic plants. 80% of all plants are in biotic and 20% abiotic pollination. 98% is by is by wind and 2% is by water as seen through evidence of decline pollination. (Faegre, 1966; Nyamasyo and Nderitu, 2007; Munyuli, 2014).

The concepts of self- and cross- pollination are related to the flower. The two opposites are autogamy, where pollination takes place within one flower and allogamy where pollen from one flower is carried to the stigma of another one. Allogamy maybe further separated according to whether the two flowers are on the same plant, geitonogamy or on different plants, xenogamy. The task necessary of an insect pollinator will depend upon whether the plant species is self-fertile and partially self- pollinating, or self- fertile and not self- pollinating, or self-infertile, and the efficiency per insect visit will differ accordingly. (Faegri, 1966 ; Free,1970).

After landing on a receptive stigma, a pollen grain germinates and a pollen tube progresses, growing through the supporting style to the ovary. Genetic material in the pollen grain moves through the pollen tube to the ovary where it unites with an egg, the female gamete, in a process called fertilization. The fertilized egg develops into a seed, and that process is frequently accompanied by the development of fruit from surrounding tissue (Calderone, 2012).

Scientific experiments and practical experiences have proved that cross-pollination of flowers of entomophilious crops by insects is the most effective and cheapest process of increasing yield. The cost of planned pollination of plants by bees is yearly recovered 15-20 times over through the value of additional crop yield (Kozin ,1976).

Insect pollination may give advantages other than increasing the yield of a crop. An abundance of pollinators sets a greater proportion of early flowers of some crops resulting in an earlier and more uniform crop (Christian, 2010). Insect pollination of other crops increases not only the quantity but also the quality of the fruit (Crane and Walker, 1984; Crane E, 1985; Crane ,1992; Arieh and Arnon, 2000; Arnon and Yossef , 2001; Dafni -et et al, 2005; Asiko, 2007; Bradbear 2009). In strawberry, *Fragaria x Ananassa* Duch., many insects visit its flowers but only bees are effective pollinators, without injuring the flower parts. If wild bees are not plentiful, honeybees should be 'saturated' to increase the yields. In tomatoes, *Solanum lycopersicum* Mill the stigma is receptive before pollen is released and this favours cross pollination. Mechanical vibrators may be used in greenhouses to effect pollination. Natural cross pollination of tomatoes by solitary bees contributes about 2 %. The bumble bee is an excellent pollinator it vibrates its body while clinging underneath the flower, so that the pollen falls on its body. In the bean, *Phaseolus Spp,* self-pollination may take place but cross pollination is frequent (30-40%). Honeybees collect nectar and pollen from the flower. Stripping of the flower by bumble bees facilitate honeybee visits to access pollen. The pollinating potential of a single honeybee colony becomes evident when it is realized that its bees make up to 4 million trips per year and that during each trip an average of about 100 flowers are visited (Free,1970; Mc Gregor, 1976; Crane and Walker, 1984).

Pollination services are several times more beneficial than the production of honey and beeswax. Pollination value is currently estimated at Kenya shillings 3 trillion 890 billion (Faegri and Pijl, 1966; Arieh and Arnon, 2000; Global Meliponiculture, 2006; Grieg-gran, 2010; Kinuthia et al,. 2010). Case studies for nine crops on four continents revealed that agricultural intensification jeopardizes wild bee communities and their stabilizing effect on pollination services at the landscape (Global Meliponiculture 2006).

In Africa pollinators occurring between farms and natural habitats are extremely vulnerable to habitat loss and destruction. Pollination draws a strong and clear link between livelihoods, sustainability and the protection of the environment. It is important to work with farmers to foster an understanding of pollinators and their habitats, which directly contribute to improving food security and alleviation of poverty through increased yields. Conservation and pollination ensure quantity and quality production of healthy seeds and fruits leading to regeneration of plant species, hence maintaining ecosystem services (FAO, 2012; Giannini et al., 2014; Martins, 2014).

Pollination and fertilization are the deciding factors in the fruiting and yield of seed. It takes place most perfectly with the participation of different pollinating insects, of which honeybees are the most important as they can be transferred near the plantations at the time of flowering.

The efficiency of bee pollination is manifested not only through increase in yield, but also by an improvement in crop quality. While visiting thousands of flowers, transferring pollen grains from one flower to another, bees provide the pollen. Because of this the viability and absolute weight of seeds increases and their germination improves. (Kozin, 1976; Kigatiira, 2014).

2.4 Significance of pollination

Almost all crops are obtained from flowering plants and in most of them seed production is essential and all used and most fruit production depend on pollination. Automatic self-pollination occurs; Self-pollination – cross pollination. There are crop plants in all the categories and pollination process is of the utmost importance in agriculture production. (Oronje et al, 2006) Cross pollination is by insects with over 80% by honeybees. In Argentina sunflower yield increased five to six times and the oil content of the seed increased by 25% (Nyamasyo et al., 2005).

Studies in Kenya on strawberry pollination by stingless bees revealed a 14% increase in super quality fruits and 17% increase in class one fruits.

When the pollinators are few this will be indicated by failure of fruits to develop in some species, poor quality of fruits. Some evidences are: Deformed shapes and or undersized fruits e.g. in pumpkins, melons, strawberry. The non-pollinated end does not develop leading to deformity.

The quality of the fruits is insufficient. Insufficiently developed fruits have unpleasant taste e.g. in pawpaw they become bitter. They also lack quality color e.g. melon, the poorly pollinated ones are white-seeded and pink fleshed. They also have poor keeping qualities e.g. they shrivel sooner than later. This is observed on poorly developed/ deformed side that soils quickly.

Poorly pollinated flowers lead to poor seed set and infertile seeds. They fail to develop. Poorly pollinated fruits have fewer seeds e.g., in apple – 3 seeds compared to 8-9 seeds in well-pollinated fruits. Empty spaces in bean seed pods or low yield is an indicator of some plants and crop species propagated by seed. Once there is no pollination the seeds fail to set and hence no means of propagation. Aborted blossoms are usually symptoms of pollination failure (Wambugu, 2007).

Migratory pollinators travel long distances through areas with varied land uses including private and public lands. To protect these migratory corridors, it is crucial to develop local public acceptance of the conservation needs.

2.5 Factors influencing insect pollinators on flowers

Primary attractants (food): These include nectar, pollen, fat, oil etc. the food urge is the background for the overwhelming majority of blossom visits. The work involved presented at one time and on its availability presented at one time.

Secondary attractants: These have a role in advertising the presence of the primary attractants. The ultimate result of that combination is a given pollination unit, to start a reaction chain that leads to pollination.

2.6 Challenges of pollinator declines

The number of managed honeybee colonies showed a steady decline. Some crops are almost exclusively pollinated by honeybees and many crops rely on honeybees for more than 90% of their pollination. Colony loss rates are increasing, it is thought to be caused by a contribution of stressors including loss of natural forage and inadequate diets, mite infestation and diseases, loss of genetic diversity and exposure to certain pesticides. Contributing to these high loss rates is a phenomenon called colony collapse disorder (CCD) which is rapid, unexpected, and catastrophic loss of bees in a hive.

High colony loss placed commercial beekeeping in jeopardy as a viable industry and threatening the crops dependent on honeybee pollination. Viral agents that are impacting honeybee colonies are also now adversely affecting other pollinators e.g. bumble bees and the pollination services they provide. Other pollinator species e.g. monarch butterflies that migrate an iconic natural phenomenon that has an estimated economic value in the billions of dollars has shown decline with imminent risk of failure (Foley, 2015). With evidence of pollinator decline due to climate change, habitat loss, pesticide use and invasive species, Harvard School of Public Researchers decided to look at what would happen in a worst-case scenario if all the pollinator died. The global mortality rate would increase by 2.7% many deaths would be as a result of cancer, diabetes and health disease exacerbated by nutrient losses from lack of fruits, vegetables and nuts. With the reduction of certain crops people would substitute their diets with staples like wheat or other grains; they don’t rely on pollinators as much.

The researchers recognize that trade plays a big role in consumption, which means that wealthier people would still consume scarcer crops now priced higher, while poorer people could not.

2.7 Honeybee as pollinating agents

They have several valuable qualifications for pollination i.e.

- They can be placed in a location – an apiary that has more than one a hive.
- Their bodies are covered by branched hairs which carry excess pollen.
- They feed exclusively on pollen and nectar.
- They collect nectar and pollen in great quantities daily.
- They can be moved to crops needing pollination.

Around 80% of Kenya is suitable for beekeeping which represents the arid and semi-arid areas. Studies have revealed the high potential of beekeeping and its benefits to encourage beekeeping for enhancement and utilization to all alleviate poverty and biodiversity conservation (Kioko *et a l.*, 2007).

The economic effectiveness of bee pollination is characterized not only by the cost evaluation of the additional yield and expenditure, but also by the effect on the cost production of the major product of the bee industry, and the effect on the profitability levels of its production. The economic effectiveness of bee pollination is also characterized by the productivity of the labor of the apiarist (Kozin, 1976).

Pollinators provide a vital connection with nature by supporting human life and subsistence. In Africa pollinators remain primarily insects that travel between farms and natural habitats loss and destruction (Martins, 2014).

Various bees' types are known to occupy different sites in the environment for example, hollow tubes of stems, hollows in the ground, tree trunks, plastic tubes and plastic bottles, hay/grass, wall crevices, ceilings, electric lamp posts among others. These structures attract pollinator colonies as they find them suitable for habitation. They therefore conserve bees within the ecosystem.

There is need for increased awareness on the economic use of pollinating insects including use of pollinators as a business (commercially). This could be done effectively using the current structures in the ministries of:- Agriculture, Livestock; Environment – education (Asiko, 2004). Research study on mango pollination showed that cross – pollination of flowers increases fruit setting. A study includes in 1965 indicated that plants caged without insects set no fruit, while those caged with a bee colony set heavy crop.

CHAPTER THREE: MATERIALS AND METHODS

3.1. Study site

The experiment was set up at Pollen Glory Farm, in Kavuko village in Makueni County. Makueni County was curved out of Machakos District in 1992 and covers an area of 7,965.8 Km^2 with distinct habitats for both honeybees and stingless bees (RPSUD, 2006).

Coordinates: UTM 37M 0308336, 9789486 for Kima area in Eastern Province (Kibwezi) Kavuko is south east of Kima. The locality is classified as Arid and Semi-Arid area (ASAL), which form the larger proportion of Kenya (70%). It is situated 95 Kilometres Southwest of Nairobi and fringes Machakos and greater Makueni Districts. Communities are basically agro-pastoralists, with livestock, particularly the small stock (goats) as the major means of livelihood.

The area occasionally experiences wildlife-livestock conflicts due to resource sharing. Sub-division of land (which to a great extend is ranch area) into smaller parcels for subsistence farming, is a threat to the environmental conservation effort. The annual rainfall is minimal, averaging less than 800 mm. High diurnal and low temperatures at night are the norm.

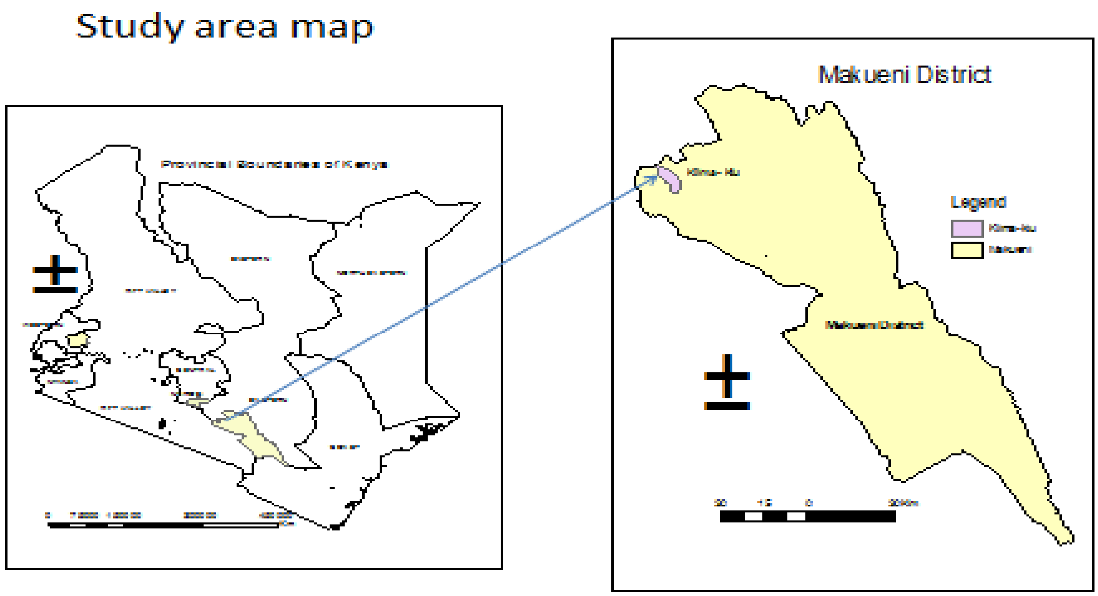

Figure 1: Map of the study area – Drawing, 2011

The research focused on bee conservation, colonization, pollination awareness and crop yields. In each ecological zone there are endemic pollinators adapted to the environment. Today pollinators are faced with the challenge of survival due to environmental degradation leading to habitat loss. The major pollinators, honey bees, are mainly found in rock crevices, hollows of trees, under the ground and in other suitable habitable spaces. A community with existing traditional hives was approached to participate in the research. One of the common traditional hives found in the area, the sisal pulp hive, was incorporated in the research on the basis of bee hive occupancy rate in various farms belonging to a group of 30 members (Farmer Focus Group) each had three hives. The rate of colonization was an indicator to the availability of bee colonies for pollination. The process of pollination was therefore to be sustained by innovatively providing pollinators. A "bee hotel," which is a structure providing different micro-habitats or nesting sites for various bee species was set up within the experimental area. This was to ensure a continuous supply of pollinators to the target plots exposed to pollinators.

It was expected that farmers in the study area would take advantage of bee pollination services to increase crop yields as a food production and security strategy.

Food security is of utmost importance in any community for sustained livelihoods. It has been established that the quantity and quality of food production is enhanced by the presence of pollinators which must be conserved. In the absence of pollinators food production declines and conservation is at risk.

The research site was at Kavuko and Itumbule sub locations of Mukaa Sub County in Makueni County, with the permission of the assistant county commissioner (See appendices). The experimental crops selected for testing were: strawberries, beans and tomatoes, which are high value crops. The beans and tomatoes are common foods of consumption and all give premium returns. The project took approximately six months to complete.

3.2 Survey on hives and colonies

A count of existing hives namely, the traditional log, sisial pulp, box and drum hives the categorising them by type, within a two Kilometer radius of the experimental plot at Pollen Glory Farm was undertaken. The Kavuko community farmer leader – Mr. Simon Kioko was approached to give a list of villages that are within the radius. The villages were visited randomly by picking a homestead along a path that had been chosen as we rode in the villages and farmers responded to prepared face to face structured questionnaires used to capture the desired information (See appendix 1a and b). Only adult individuals or heads of households were chosen as respondents. Villages visited: Kima, Kavuko. Kima Kiu, Kitaingo, Silanga Mbuu, Tuvilane, Marwa A, Marwa B, Mulamini, and Mola

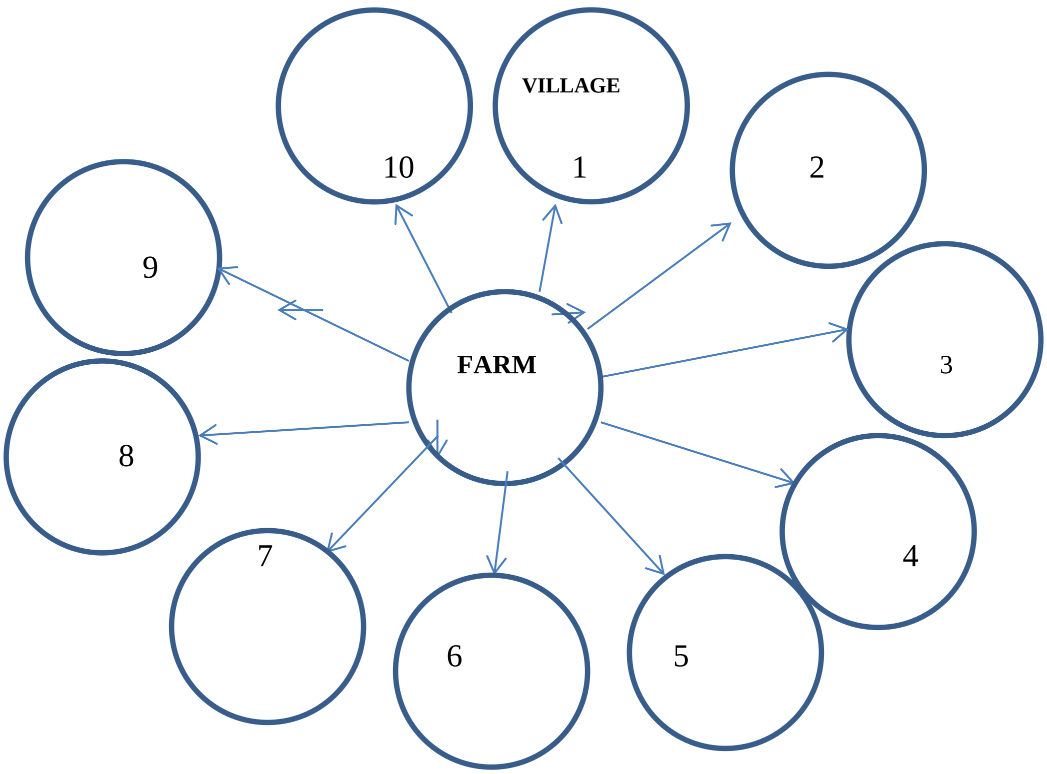

Figure 2: Survey area **Legend:** Villages → 2km radius

Plate 1: Questionnaire filling by respondents in Kavuko village
Photo: (Nzano P, 2016)

3.3 To determine the rate of hive colonisation in the Kavuko area.

A farmer Focus Group was organised consisting of 30 farmers, each farmer had three locally available sisal pulp hives.

Hives were prepared by ensuring that the fluffy fibre in the thickened part of the flower stem was scrapped and made smooth with the aid of a fire flame. Both ends were fitted with lids to allow free entry of bees. They were suspended high on tree branches using rust-proof wires, awaiting bee occupancy. Each farmer took note of the date of hive placement and occupation on a small data sheet provided (See appendix 2).

Plate 2: Focus group hives preparation for placement before bee occupation

Photo: (Nzano P, 2016)

Plate 3: Kavuko Beekeepers focus group with their readily available sisal pulp hive

Photo: (Nzano P, 2016)

3.3.1 Bee hotel

Farmers were shown on how to prepare a bee hotel that could accommodate various species of pollinators within farms and also help stir up creative imaginations on alternative structures for conservation of the pollinators. Occupation is rare during dearth periods in the months of January to march and august to mid-October, it occurs during the flowering season after the rains.

The bee hotel consisted of hollow materials such as tubes plastic tubes, bottomless plastic bottles, hollowed dry hay/grass, concrete, pot, earthen and wooden structures. The structures were to attract pollinators, as well as demonstrate to the farmers on how to prepare suitable alternative habitats (See appendix 3). This is an illustration of how to conserve pollinators within the ecosystem. groups were noted and the reason as to why they kept the bees, what else they knew about bees, the different species and their role in pollination of crops. (See appendix 7).

Plate 4: Bee Hotel model adapted from Martins, 2014.

Photo: (Nzano P, 2016)

Bee hotel set up at Pollen Glory Farm. An illustration of on-farm bee conservation a=wooden box; b=log; c=sisal pulp; d= hay; e= plastic container; f=hollow plastic (hives with plastic parts have been occupied at the national beekeeping institute)

3.4 Assessment of the community awareness on value of pollination

A questionnaire was prepared to elicit responses from individuals in the farmer focus group concerning their level of awareness on pollination in the community. Their gender and age groups (since the practise was traditionally carried out by older men and especially the homestead leaders who passed it onto their son as an inheritance) were noted and the reason as to why they kept the bees, what else they knew about bees, their different species and their role in pollination of crops (See appendix 7).

3.5 Demonstration of crop yield differences between pollinated and non - pollinated crops

It has been noted that small populations of plants could experience reduced pollination as a result of changes in the behavior of pollinators. (Sutherland, 1998).

The aim of this experiment was to demonstrate the effect of pollination on strawberries – (*Fragaria x Ananassa)* beans (*Phaseolus vulgaris)* and tomatoe (*Lycopetsicon esculentum)*.

and replicated three times; some plots were caged using fine wire mesh to exclude pollinators.

These crops were planted in 2m by 2m plots, 15 plants per plot. The soils were standardized in the ratio: 1:4 manure and soil and weeding done by the same person for the three crops. Open irrigation was applied every other day in the evening time to reduce evaporation by the heat of the day for the entire duration of the experiment period. Strawberries (*Fragaria x Ananassa* Duch) were planted 30 cm between lines and 30 cm between rows. Beans (*Phaseolus vulgaris)* Variety: Miezi Mbili Planting instructions: 25 cm in between rows, 30 cm- 35 cm between lines. Tomatoes (Lycopetsicon *esculentum)* these were planted 30 cm between rows and 30 cm between lines.

The blossomed flower/s of each plant, its plant number and plot were recorded twice a week on Tuesdays and Thursdays, at a specified time (11.30 a.m. – 2.30 p.m.) which was my most convenient. As the pod/s and fruit/s got ready for picking they were labeled by giving them the plant number and alphabet letters for example ‘12a’, ‘12b’, ‘12c’, for the plants that had more than one fruit / pod to be picked on that day. To determine quality, the grade for the strawberry fruit was in four categories: Super = Heart shaped, Grade1 symmetrical when cut into half, Grade2 = not symmetrical, Industry = Irregular (see appendix 7),for beans: Super grade: Pod is filled with beans; Grade 1: Pod is lacking a bean; Grade 2: Pod lacking more than one bean; Empty: The pod is lacking well developed beans (see appendix 8) and for the tomatoes Super = well developed, G1= fairly well formed, G2= Damaged, I= decay (see appendix 9. The weight for the fruits and pods were taken using a scientific weighing balance – Scout. Pro (see appendix 10). The data was entered in the appropriate sheets (See appendix 4, 5, 6). This exercise continued for six weeks.

Table 1: Experimental plots layout

BEANS	STRAWBERRIES	STRAWBERRIES
TOMATOES	TOMATOES	BEANS
STRAWBERRIES	BEANS	TOMATOES

Replica I - no pollination, plots caged with fine wire mesh

BEANS	TOMATOES	STRAWBERRIES
STRAWBERRIES	TOMATOES	TOMATOES
BEANS	STRAWBERRIES	BEANS

Replica II: Plots exposed to pollination – control plot

Plate 5: Plots caged in fine wire mesh – no pollination

Photo: (Nzano P, 2016)

Plate 6: Plots exposed for pollination but caged from birds that could eat fruits

Photo: (Nzano P, 2016)

CHAPTER FOUR: RESULTS

4.1 Survey on hives and colonies

i) Farmers with bee hives

From the 102 farmers interviewed, only 29 (28%) of them had a total of 95 hives, an average of 3 hives per homestead and a total of 8 colonies in the study area. The being the dearth season colonies naturally migrate to better environments to return when the rains start in large numbers such that they are all over; in cow sheds, ceilings and of course present hives are readily occupied. Colonies found during the research were managed by having water hoisted high on branches near the colonies they fly far to get the little nectar to sustain, no honey is made in the season.

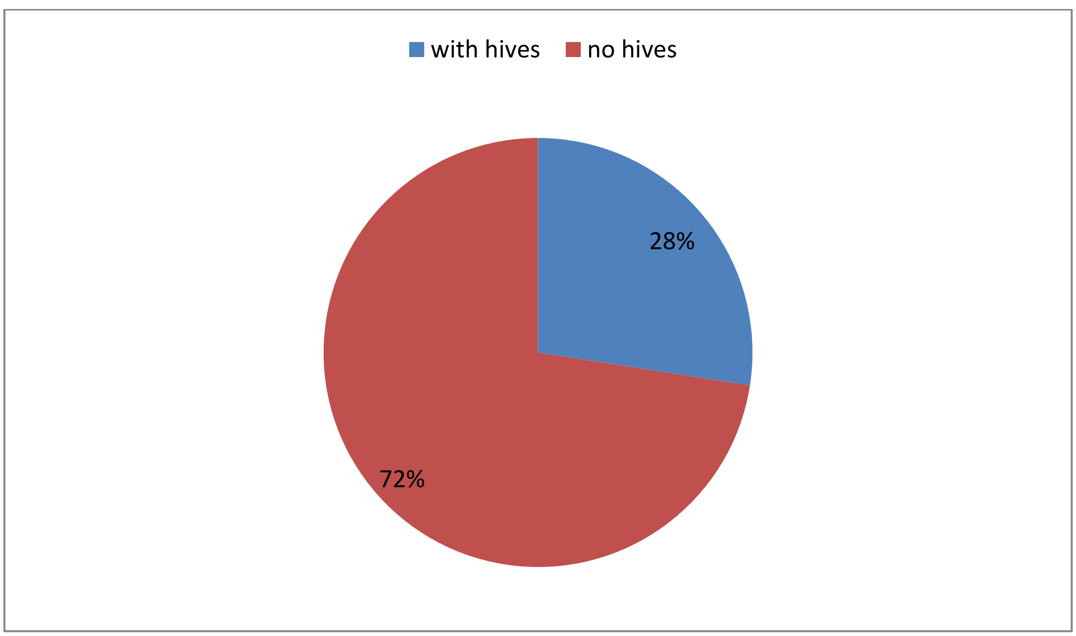

Figure 3: Proportion of farmers in Kavuko community with bee hives.

ii) Hive types

The traditional log hive was the most common - 77 (81.1%), followed by sisal pulp hive - 14 (14.7%), box and drum types of hives were least common at 3 (3.1%) and 1 (1%) respectively.

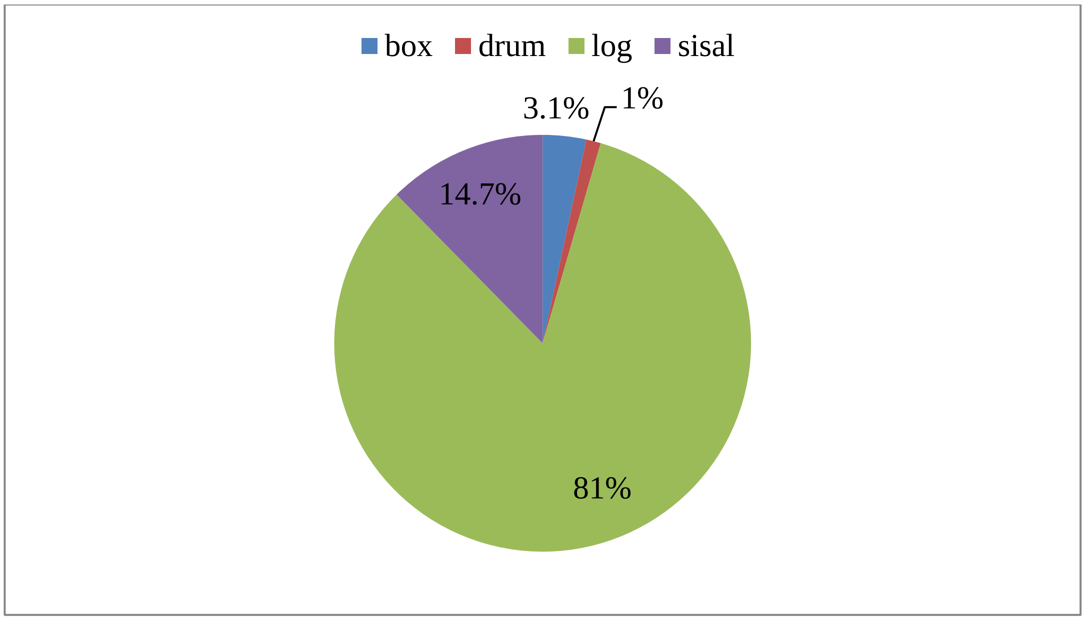

Figure 4: Hive types in Kavuko community

The hives were sourced on – farm initially, due to sub division of land most mature trees that were suitable for hives were young ones or none exist ant and they take long to mature. The sisal pulp hive is faster in growth, well adapted to the climate, easily available seedlings and offers other products like the local sisal ropes and baskets. Box hives are a new technology related to the langstroth hive in design and shape but has top bars without frames. Drum hive is basically a drum that has an entrance for the bees to occupy.

Plate 7: A-Dried sisal stems, B-Log hive, C –Dry tree stem, D- Sisal pulp hive

Plate 8a: Sisal Pulp hive **Plate 8b: Log hive**

Pollen Glory farm, source of material for traditional hives

Photo: (Nzano P, 2016)

iii) Number of Colonies

Since log types of hives were the most common, colonies were mostly found in these hives. This can be shown in the graph below

Table 2: Honey bee colonies

Hive	Log	Sisal	Box	Drum
Colony/ies	7	1	0	0

In a total of 8 colonies that were found, 7were in the log hives and 1 in the sisal type of hives. None were found in Box and drum types of hives respectively

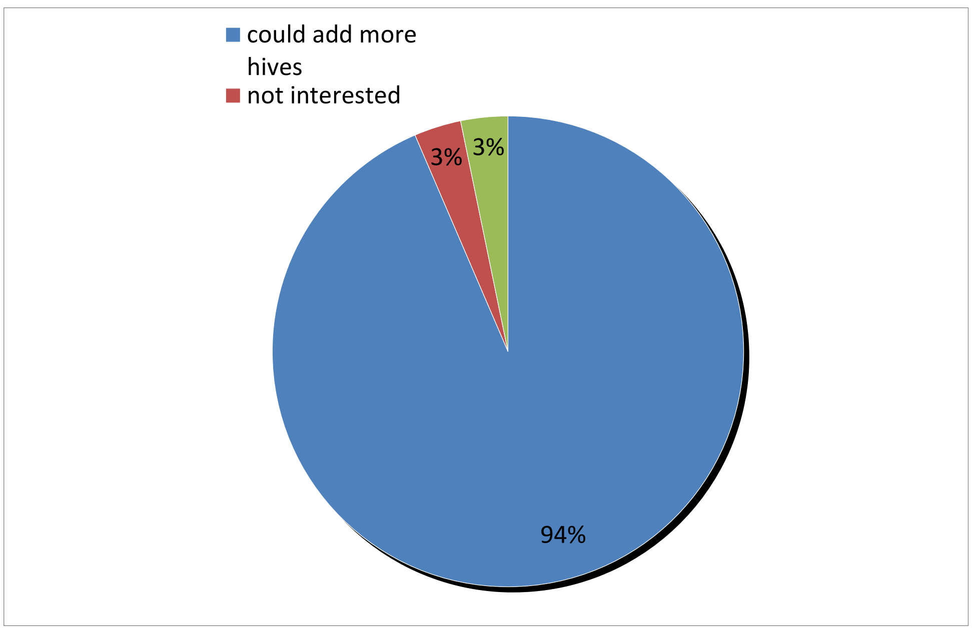

Figure 5: Farmer comments on beekeeping

The results established that 94% of farmers, who owned hives, were interested in additional hives to boost honey production. Only 3% were not interested in adding more hives with a similar percentage not having any interest in bee keeping due to bee phobia. Many hives are inherited from parents that were beekeepers.

4.2 To determine the rate of hive colonisation in the Kavuko area.

Hive occupancy was observed from pre-existing farmers with hives in their 'shambas'. Each of the 30 selected bee farmers was interviewed for hive occupancy details inclusive of date of bee colony occupation. With an average of 3 hives per farmer, the total number of expected hives was 90.

i) **Farmer focus group hive ownership**

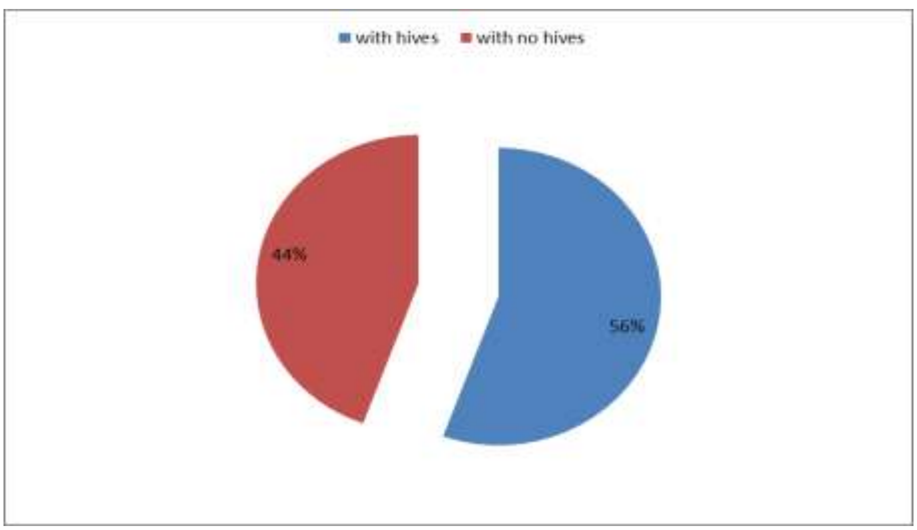

Figure 6: Hive ownership in Kavuko community farmer focus group

In the focus group half of the bee farmers already owned bee hives.

ii) **Hive placement for occupation**

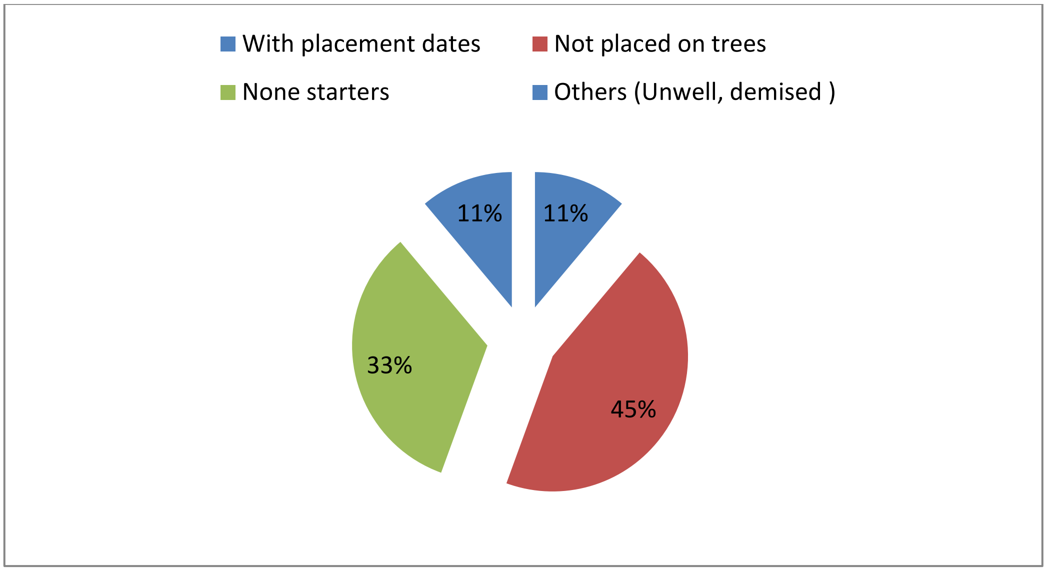

Figure 7: Hive placement by the Kavuko Farmers Focus Group

Figure 7 shows that, only 11% had placement dates and were waiting for hive occupation whereas 45% had not yet placed the hives on trees and were either preparing for placement or anticipating doing so. For the farmers who had no hives, 33% were non-starters and 11% were reportedly unwell or deceased.

Farmers were aware of pollination activities by bees but did not show interest in hive placement due to the seasonal absconding traits. This goes to show that majority did not spend their precious time on an activity that did not promise hive occupation at the time, and there was not a single colony occupation recorded.

This only happens after the long-awaited rains pour and according to the farmers the bees are buzzing everywhere including cattle sheds where they are not needed

4 2.1 Bee hotel

Plate 9: Occupied bee hotel – box hive at Pollen Glory Farm

Photo: (Nzano P, 2016)

The bee hotel used attracted a colony that lasted two days and then migrated. Occupation may take place in the wet reason.

4.3 Assessment of the community awareness on value of pollination

Questionnaires were prepared and answers drawn from the farmers focus group that monitored their awareness of pollination in the ecosystem by pollinators.

i) Gender

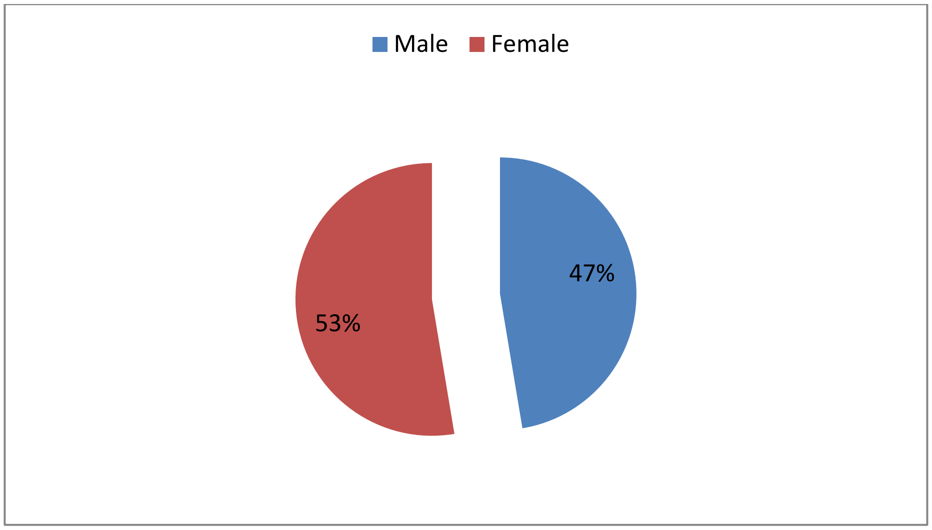

Figure 8: Comparing gender in Kavuko village

On the gender bases 53% were female while 47% were male. The numbers of are slightly statistically different. Females were slightly higher.

ii) Age

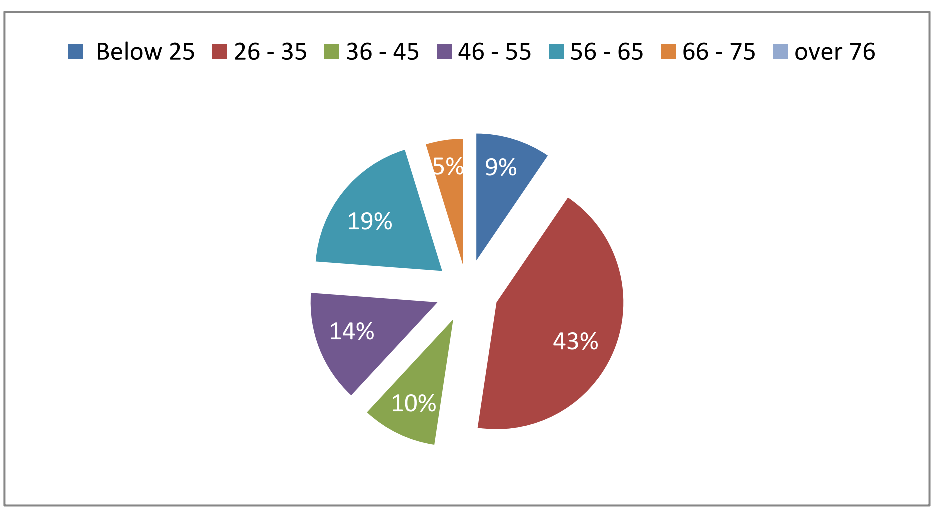

Figure 9: Farmers' age groups in percentage

Majority was aged between 26-35 and none were over 76 years as shown in the chart. The community was made up of youth population at 43%. Most of the beekeepers were of a past generation that makes up 5% of the remaining. This shows that the young generation needs constant follow ups, monitoring and most of all mentors.

iii) Reasons for beekeeping

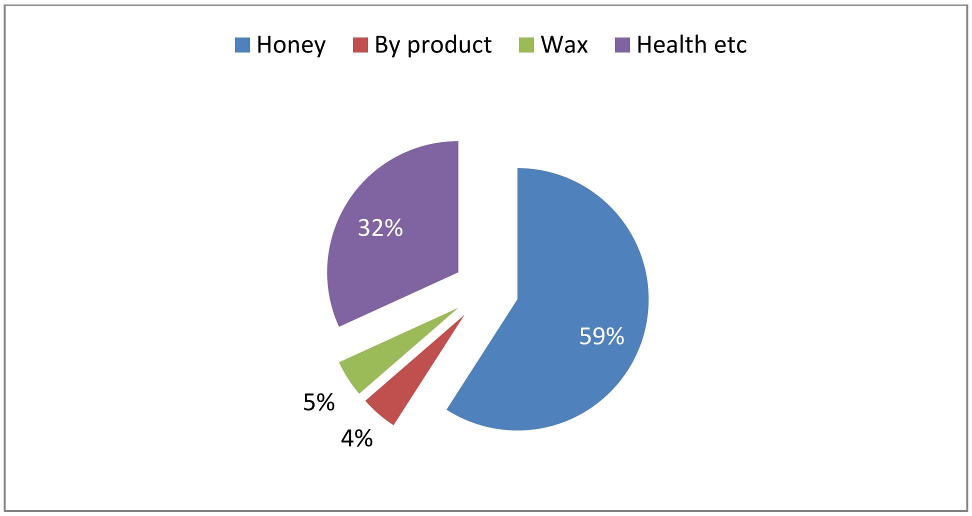

Figure 10: Reasons for bee keeping

The favorite product from beekeeping is honey production, everywhere in the world, accounting for 59%. kept bees because of the honey. The percentage of those that kept bees for wax and other byproducts was 5% and 4%, while the rest, 32%, kept honey bees for traditional medicine and honey wine.

iv) Pollinator types awareness

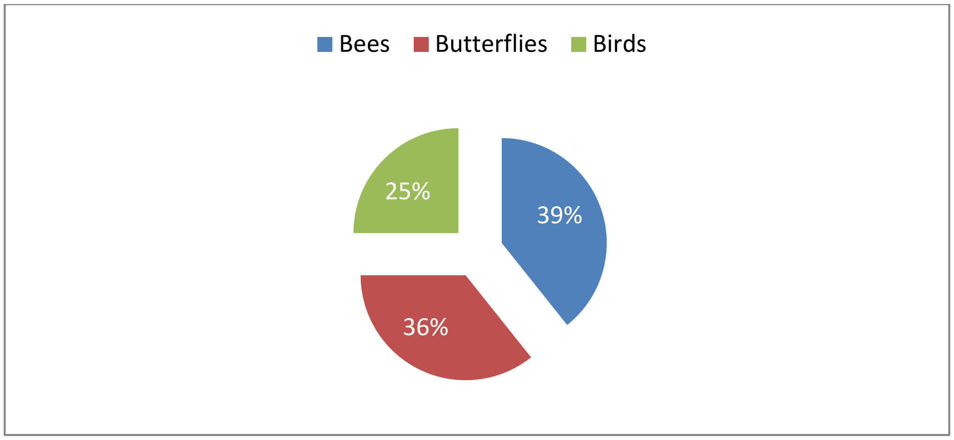

Figure 11: Common types of pollinators in the study area

Respondents were aware of the different types of pollinators in their environment. Some mentioned were honey bees, butterflies' stingless bees, birds among others. This indicated their knowledge of pollination in plants.

Plate 10: Honey bee (*Apis mellifera)* a common pollinator on a cowpea flower

Photo: (Nzano P, 2016)

The common pollinators according to the respondents were honey bees at 39% with birds having the least percentage.

Plate 11: Butterfly (*Acraea sp)* a pollinator

Photo: (Nzano PN, 2016)

Plate 12: Emerald-spotted wood dove (*Turtur chalcospilos*) pollinating Bird

Photo: (Nzano PN, 2016)

iv) Bee species awareness

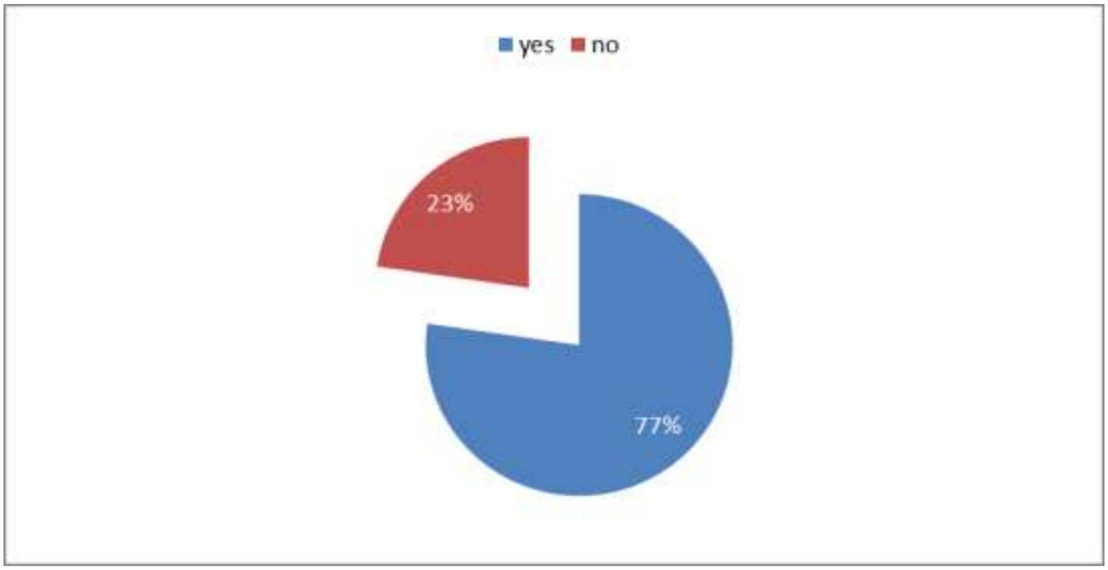

Figure 12: Farmer Focus Group awareness on the different types of bees – stingless and honey bees majority knew the two species which are common in the area.


5mm


10mm

Plate 13a: Stingless bee (*Plebeina hildebrandti)* Plate 13b: **Honey bee (*Apis mellifera)***

Asiko GA, 2012vi)

Knowledge of pollination

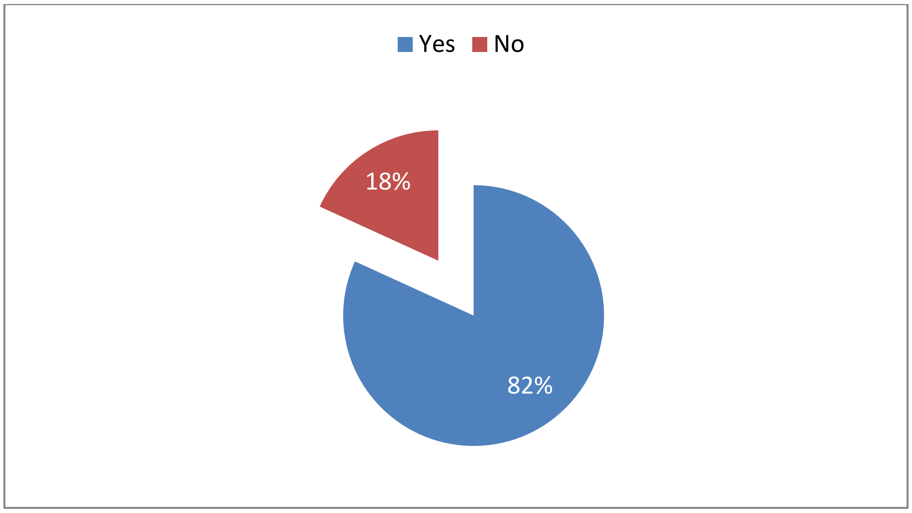

Figure 13: Knowledge of pollination process

Most respondents have been through school and have been empowered to understand pollinators and pollination. 82% of the farmers had the knowledge on pollination while 18% had no idea.

vi) Pollination benefits

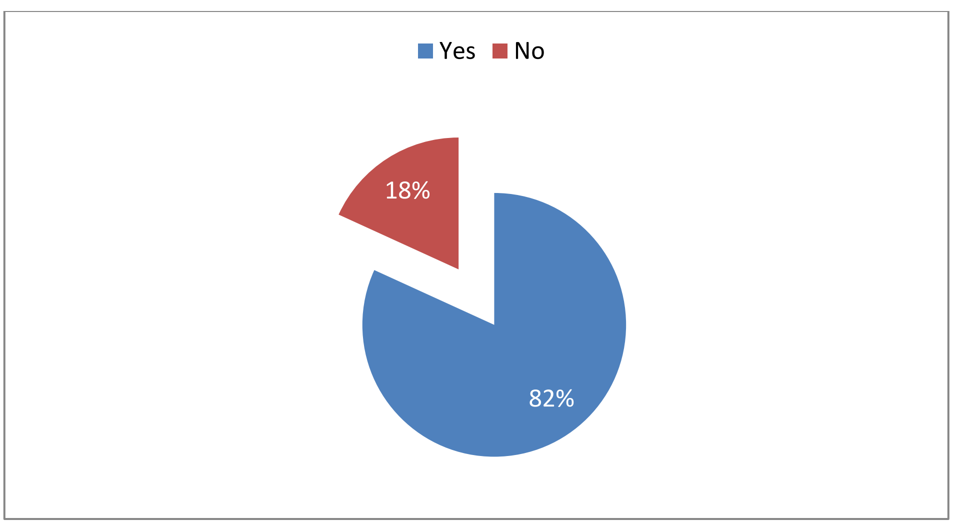

Figure 14: Awareness on the benefits of pollination

The respondents were aware of fruit formation after pollination, but no connection with crop exposure to pollinators for maximum quality and quantity produce while conserving the pollinators.

viii) Pollinator declines

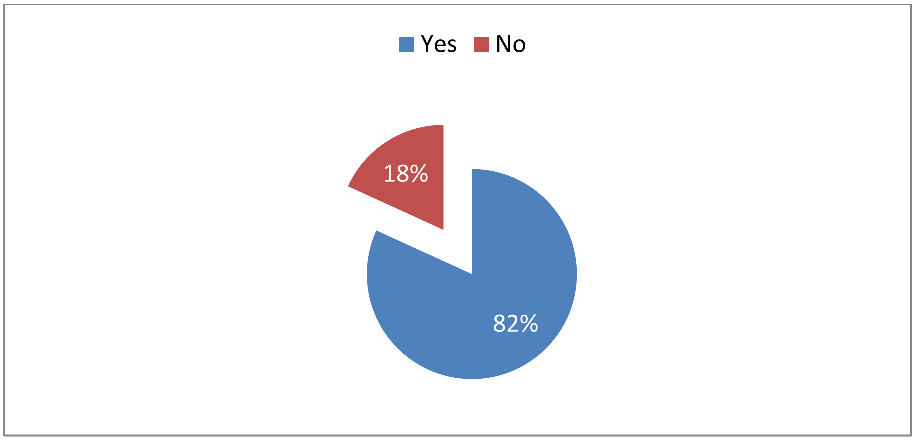

Figure 15: Recognition of the decline of pollinators by farmers

It was found out that 82% of the respondents recognized that pollinators were on the decline while 18% had no idea of the decline. Many expressed concerns over the decrease in number of colonies in the current seasons as compared to previous ones, siting wanton degradation of land and tree destruction by the present generation for charcoal production and now the trees are disappearing leaving questions of what could be the next move.

ix) Traditional bee conservation methods

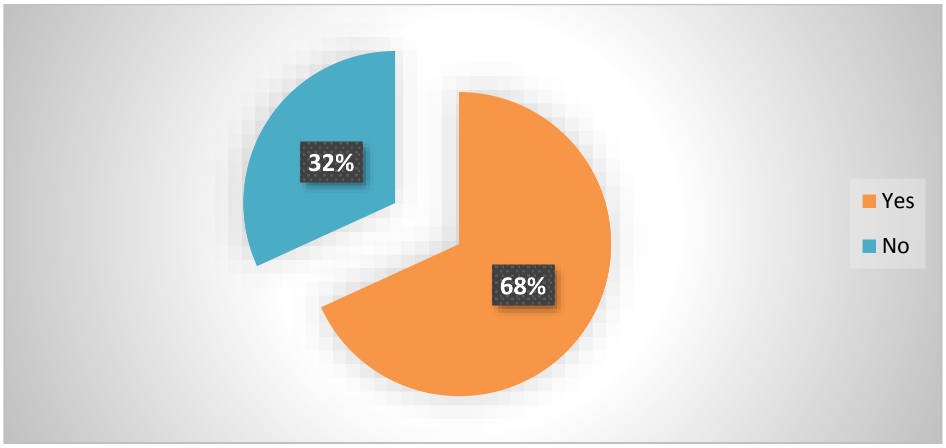

Figure 16: Knowledge on traditional bee conservation methods

Over 60% admitted to knowing traditional methods of bee conservation while 32% had no knowledge. Sheep fat is smeared on the surface of the hives and this causes the bees to become docile saving bees from stinging and also their death due to the tear of the stinging part of their bodies. This way both bees and intruder are kept safe.

X) Interventions for bee conservation

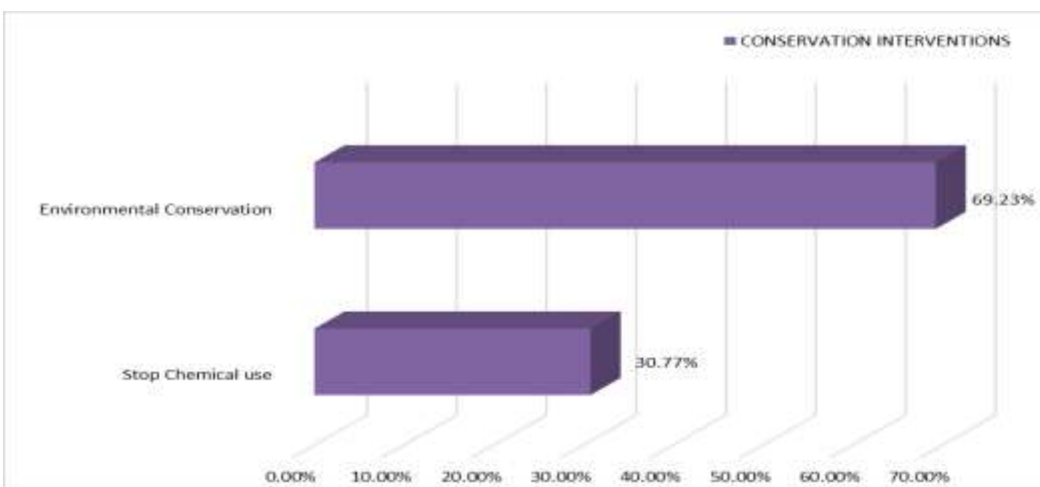

Figure 17: Interventions for bee conservation

The farmers were also interviewed on the methods they thought should be applied in the interventions for bee conservation., 69.23% of the respondents prefer environmental conservation such as afforestation, shamba terracing, improved farming skills like drip irrigation while 30.77% stated the use of chemicals as being the main threat whereby safer alternatives Should be availed through capacity building by cheap and available technologies.

4.4 Demonstration of crop yield differences between pollinated and non - pollinated crops

Determination of quality and quantity of crop yields in Strawberry, beans, and tomatoes

a) Strawberries

Plate 14: Strawberries in plot no. 6

Photo: (Nzano P, 2016)

i) T -test for strawberries

Statistically the number of fruits produced from pollinated strawberries is significantly higher (2.97±2.647) compared with the number of fruits produced from encaged strawberries (2.92±2.261), t (700) = 0.245, p=0.806

Table 3: T -test for strawberries – Group statistics

Group Statistics					
	Pollinated or not	N	Mean	Std. Deviation	Std. Error Mean
No of fruits	Pollinated	351	2.97	2.647	.141
	Encaged	351	2.92	2.261	.121

Table 4: T -test for strawberries –Independent sample test

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
No of fruits	Equal variances assumed	1.227	.268	.245	700	.806	.046	.186	-.319	.410
	Equal variances not assumed			.245	683.361	.806	.046	.186	-.319	.410

ii) Quantity: Number of flowers and fruits in pollinated strawberries

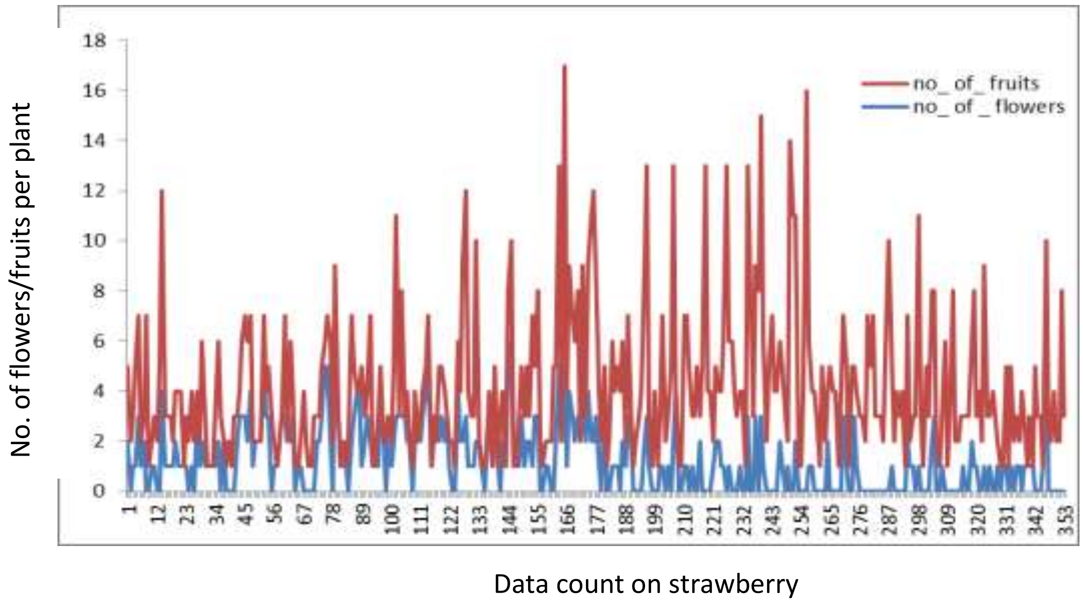

Figure 18: Pollinated strawberries

Figure 19 shows a continuous production of flowers with an average of 2 per plant and a peak production at 5 flowers. There was continuous production with an average of 8 fruits per day and with a peak production of 17 fruits during the data collection period.

iii) Quantity: Number of flowers to number of fruits ratio in pollinated Strawberries

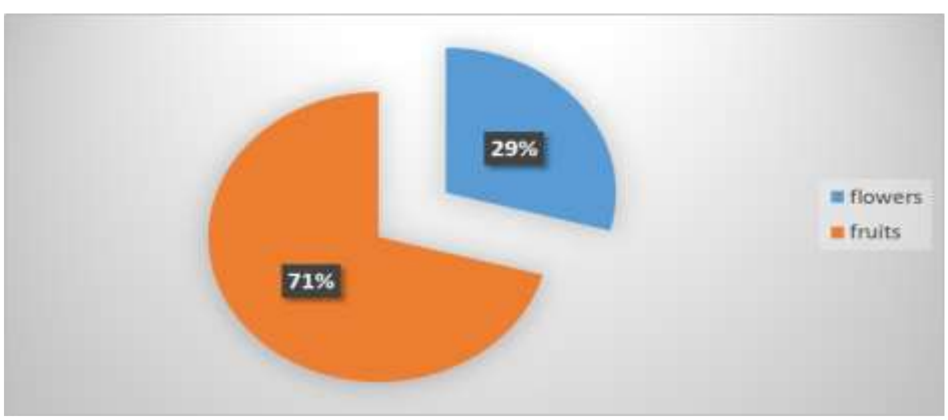

Figure 19: Number of flowers to number of fruit ratio in pollinated strawberry

The effects of pollination in strawberries can also be depicted from the ratio of the number of flowers to number of fruits produced. When pollination occurs, 71% pollinated flowers develop into fruits and only 29% do not.

Ratio is 71: 29

vi) Quantity: Number of flowers and fruits in caged strawberries

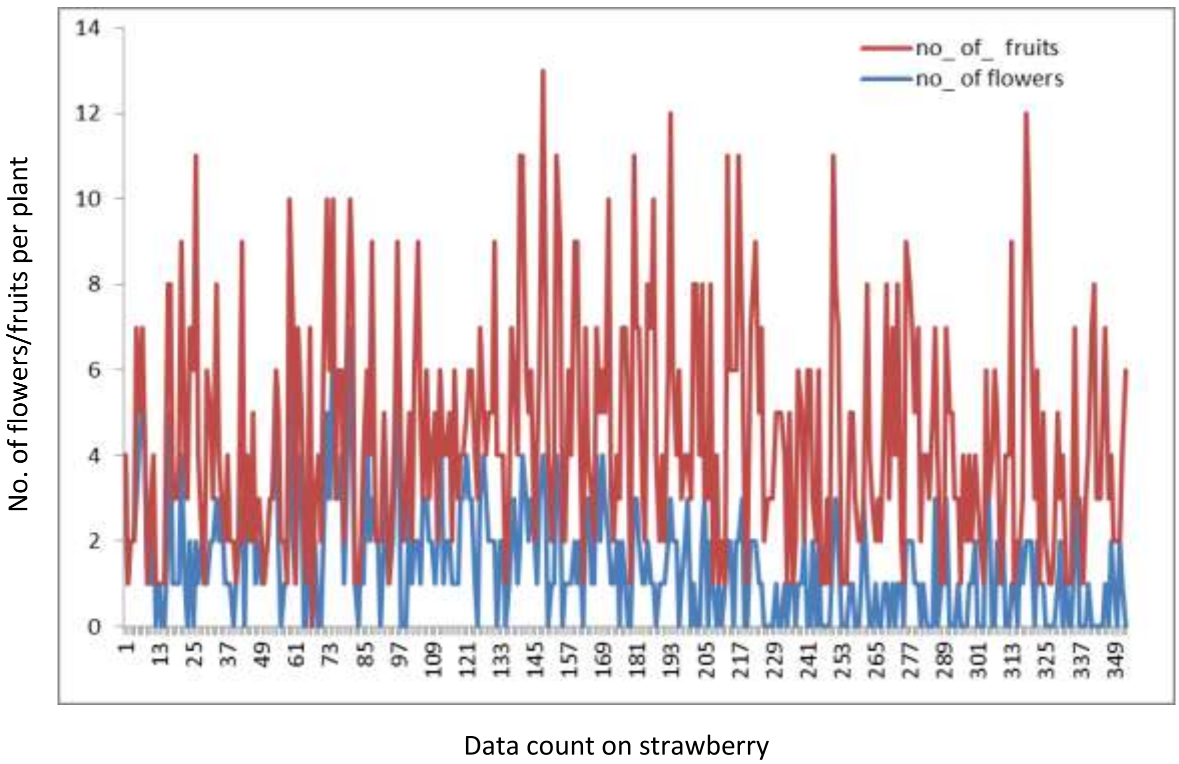

Figure 20: Caged strawberries

Figure 20 shows the continuous production of flowers with an average of 2 flowers per plant and a peak production of 6 flowers.

Fruit production was continuous averaging 7 fruits per picking day and a peak production at 13 fruits per day during the data collection. The compared results show that the pollinated plots had slightly higher produce of flower and fruit than the caged ones.

v) Quantity: Number of flowers to number of fruits ratio in caged strawberries

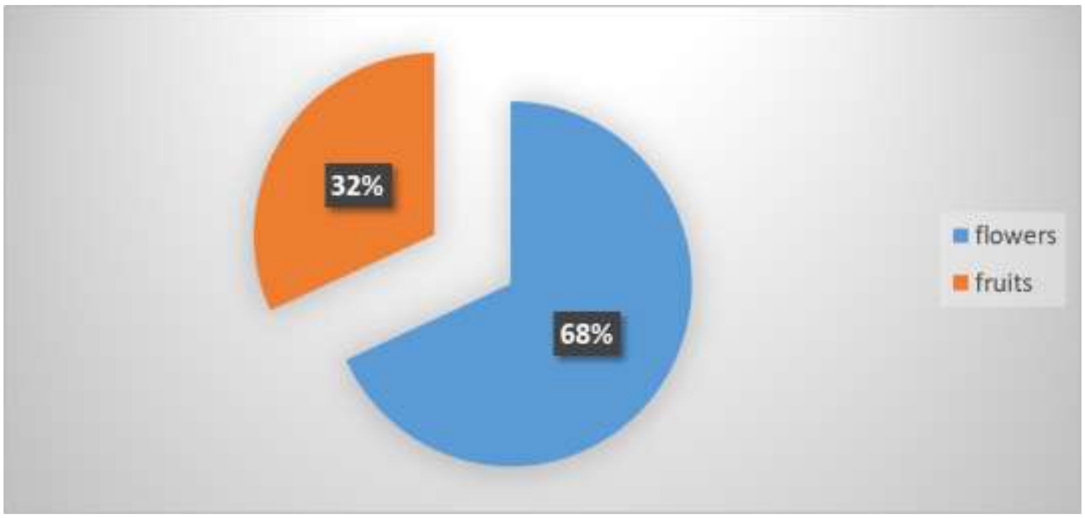

Figure 21: Number of flowers to number of fruit ratio in caged strawberries

Figure 21 shows that of the flowers produced, 68% remained flowers and only 32% developed into fruits. Ratio is 68:32. Immediately after pollination, the petals quickly discolor and drop as the process of fruit formation takes. The results show that the flowers for the pollinated plots gave more fruit than the caged plots. Comparing the ratios, the plots exposed to pollination had high fruit production and the caged had more than half the number of flowers not in fruit.

vi) Strawberry quality assessment

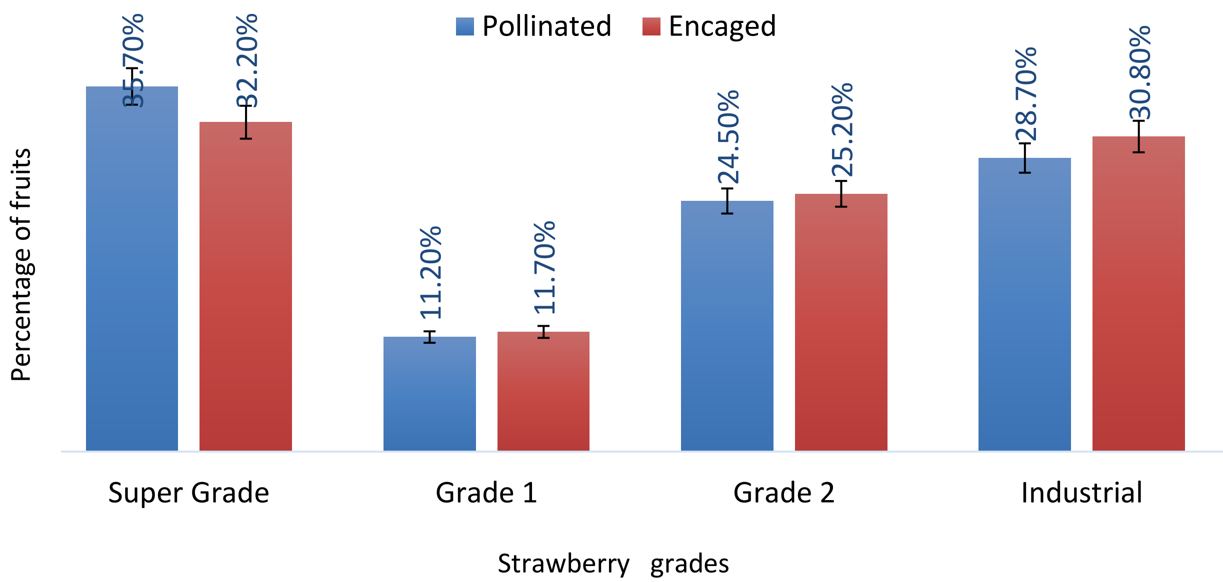

Figure 22: Strawberry quality assessments

Figure 22 shows, the chances of getting super grade quality were 35.7% compared to 32.2% without pollination which is not significant. Industrial quality was easily produced in the absence of pollination at 30.8%, as compared to 28.7% with pollination. Grade 1 was the least of the grades with the caged having slightly higher production with a difference of 0.5%. Grade 2 had the caged quality production slightly higher by a difference of 0.7%.

vii) Quality: Strawberry weight assessment

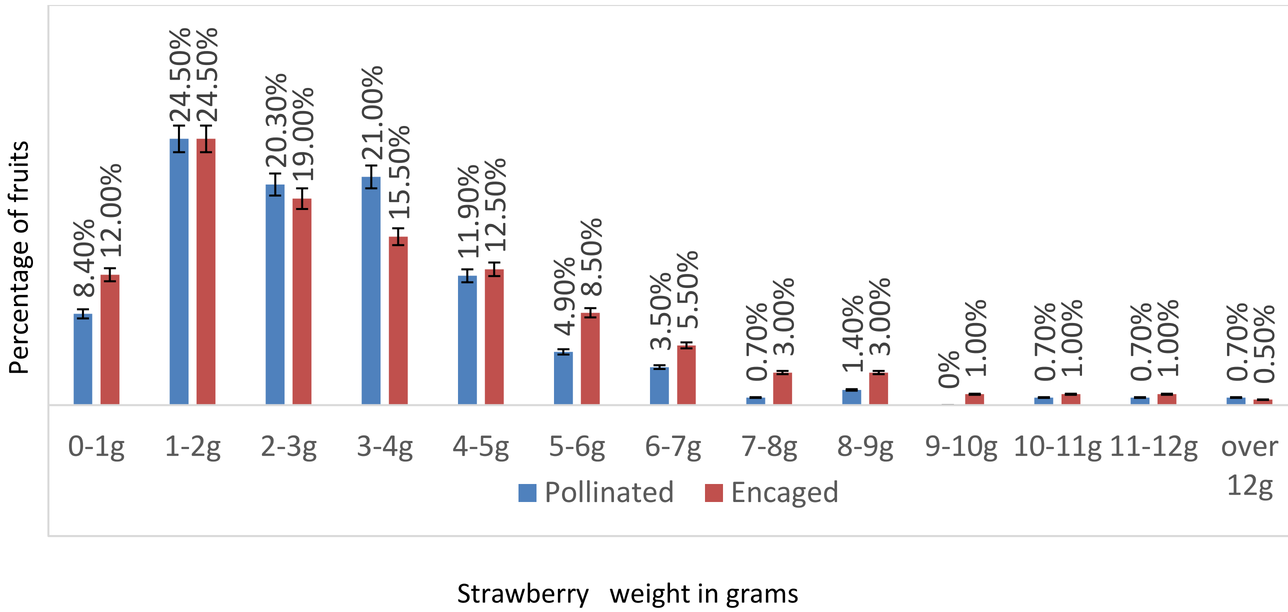

Figure 23: Strawberry weights

The weights of the pollinated and caged are not significantly different as illustrated in all the weight groups, figure 23, there is a peak weight production from 1 gram to 4 grams. Therefore, there is not much of a difference due to the standardized conditions in agronomy.

b) Yield variations in Beans

Plate 15: Encaged beans

Photo: (Nzano P, 2016)

T-test for beans. The group means are statistically different as the significance value is less than 0.05. From the group statistics table, the number of pods from pollinated beans is less than the number of pods produced from encaged beans with the group means of caged beans statistically higher than the group mean of pollinated beans.

From the results, the number of pods produced from caged beans is significantly higher (10.33±7.797) compared to pollinated beans (8.54±7.708), $t(846) = -3.090$, $p=0.00$. This could be due to the delicate nature of the flower which aborts easily. Could it be that pollination and other factors like flower eating attribute to the above phenomenon. Further research could help us understand this.

Table 5: T-test for beans – Group statistics

Group Statistics

	Pollinated or not	N	Mean	Std. Deviation	Std. Error Mean
Total no of pods	Pollinated	256	8.54	7.708	.482
	Encaged	592	10.33	7.797	.320

Table 6: T-test for beans – Independent sample test

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
No of pods	Equal variances assumed	.032	.858	-3.090	846	.002	-1.796	.581	-2.937	-.655
	Equal variances not assumed			-3.104	489.282	.002	-1.796	.579	-2.933	-.659

i) Quantity; Number of flowers and pods in pollinated beans

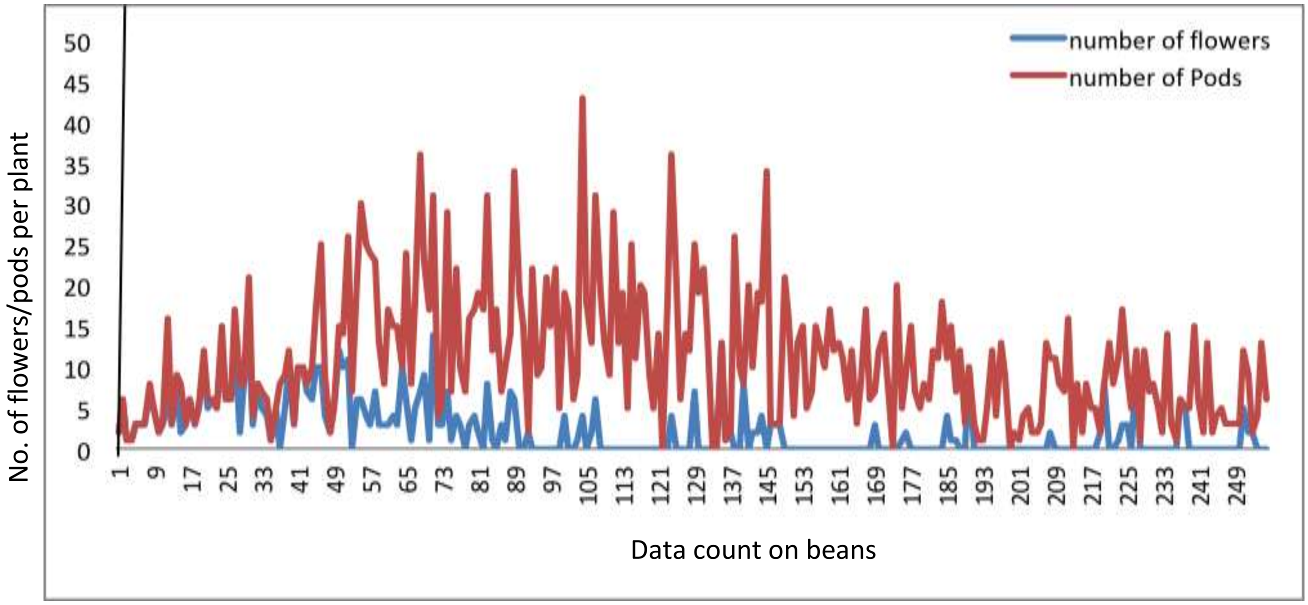

Figure 24: Pollinated beans

The pods in the pollinated plot have an average peak production of 20 pods per plant, with the highest at 43 pods per plant. Each plot had 15 plants

Flower production is more or less continuous with an average of 4 flowers and a peak production at 14 flowers per plant. Pod production shows continuity and a peak production period that does not last long giving the highest production at 43 pods per day.

ii) Bee pollinating bean flower and. bean plant with healthy pods

Plate 16 a: Bean flowers **Plate 16b: Bean pods**

Photo: (Nzano P, 2016)

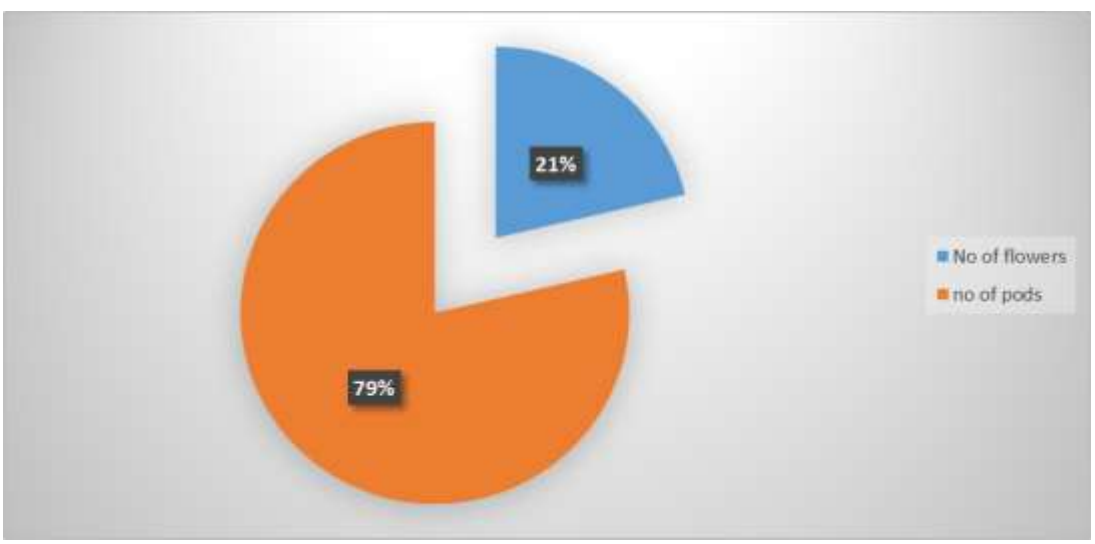

Figure 25: Number of flowers to number of pods ratio in pollinated Beans

The figure 25 shows that 79% of the flowers developed into pods after pollination and 21% were not pollinated. Ratio is 21: 79.

iii) Quantity: Number of flowers and pods in caged beans

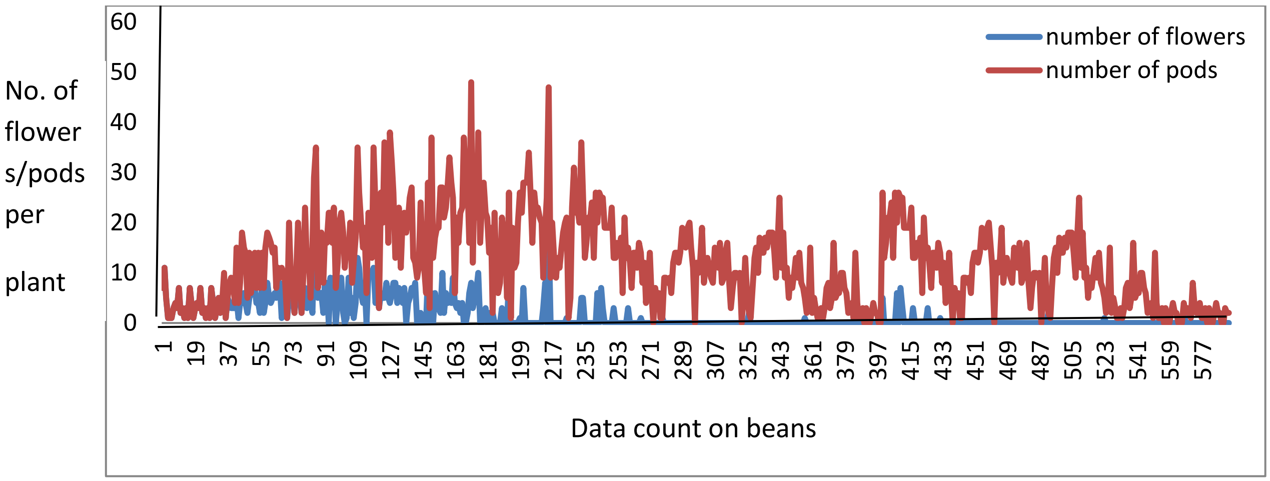

Figure 26: Caged beans

The figure 26 shows that an average of 5 flowers per plant with a peak at 14 are produced only early in the crop cycle and declines later save for a short production in between half of the next cycle. The flower production pattern picks up later and has a short period of peak production and a later show short rise and falls on a descending pattern giving longer period in production of pods. The pods are produced continuously with an average of 25 pods and peak of 49 pods per plant. It has been demonstrated that the caged plots had double the number of data entries was counted meaning the production of the flowers and pods were mote in the caged plots. The flower production was basically the same in both treatments, it is in the caged plots that there was a longer and continuous pattern of pod production with little flower production, whereas, the pollinated plots had the same pattern of pod and flower production until there was a drop-in flower and pod production while the caged continued to produce an average of 19 pods per plant per day with little flowers produced shortly. (579 entries in the caged versus 249 in the pollinated plots.

iv) Quantity: Number of flowers to number of pods ratio in caged Beans

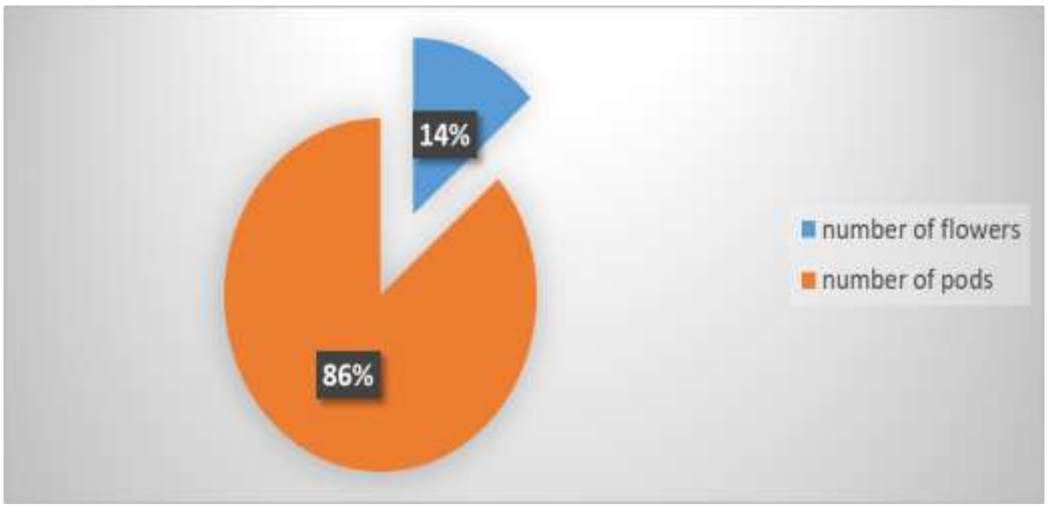

Figure 27: Number of flowers to number of pods ratio in caged Beans

Figure 27 shows 86% of flowers were pollinated and only 14% were let out.

In beans the ratio of the number of pods produced from caged flowers is very high at 86 %, compared to 76% in the pollinated plots.

iv) Quantity: Pod count in beans

Plate 17: Bundled Bean pods each representing a plant from the bean plots

Plate 18a: Bean pod full and well-shaped - pollinated

Plate 18b: Bean pod empty- not pollinated

Photo: (Nzano, P 2016)

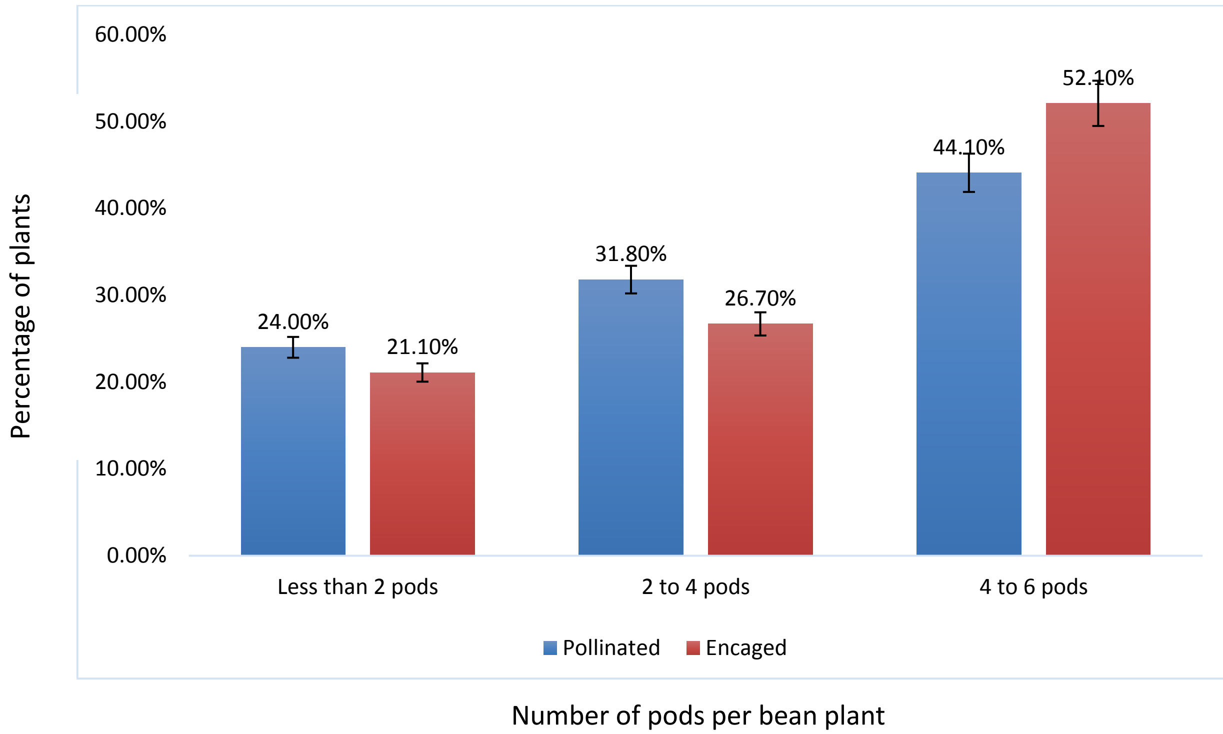

Figure 28: Bean pod count

The number of pods per plant increases in each case, irrespective of the pollination status, whether pollinated or caged. The encaged has a higher percentage of pod counts between 4 to 6 pods while the pollinated have a higher percentage of pod count with pods between 2 to 4.

The production of pods between 4 to 6 per plant illustrated the highest with caged leading in production at 52.10% and for the pollinated and 44.10%. The other pod group clusters illustrate a higher percent in the pollinated plots, the highest with 31.80% and 24.00 %, for less than 4 pods also 26.70% and 21.10% for less than 4 pods in the caged plots. On average the number of pods per plant was higher in the pollinated plots, but more than half was to be found in caged plot. One reason could be flower abortion or a presence of a flower eater in the pollinated plots.

v) **Quality: Pollination and bean weight**

Plate 19: Quality beans on a scientific weighing balance

Photo: (Nzano P, 2016)

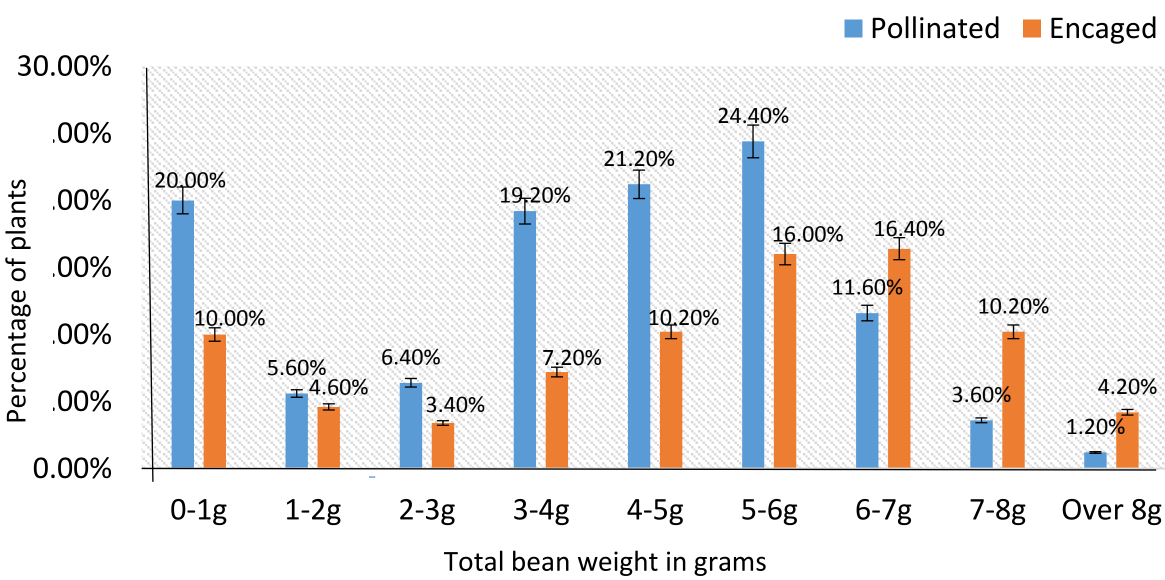

Figure 29: Pollination and total bean weight in single pods

The percentages are based on the total bean weight per pod in the grouping of the weight categories. With pollination, most of the weights of pollinated beans between 0-6g exceed the weight of the beans that were caged. The heaviest beans were found in the pollinated plot with

24.40% for 5g to 6g and 16.40% for 6g to 7g beans. Pollination encourages good tissue production after setting of seed. After 6g there is a down ward production trend for all the plots with the pollinated having the least.

The chart also illustrates a cycle pattern for weight production.

vi) Quality: Pollination and bean grades

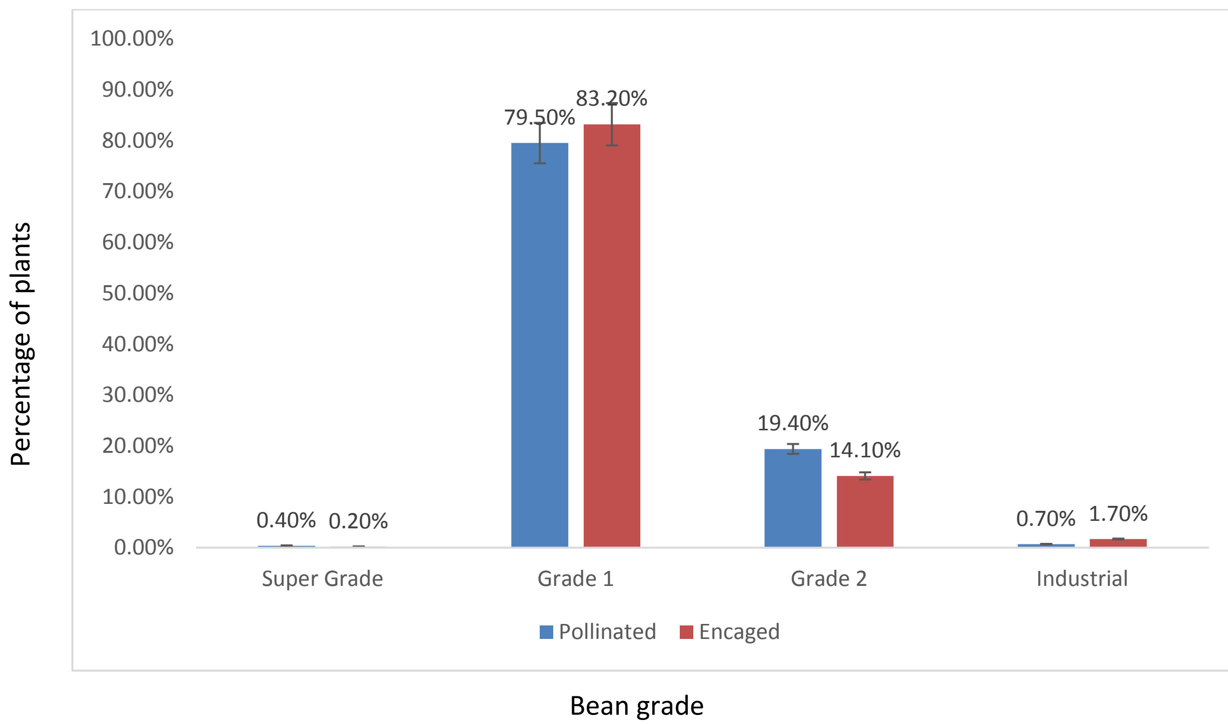

Figure 30: Bean quality assessments

The chart shows Grade 1 dominating the quality by having 83.20% for the caged and 79.50% for the pollinated as total number of beans per grade. This shows us most pods lacked a bean to fill up a pod giving super grade. Grade 2 has a small percentage, 19.40% for the pollinated and 14.10% for the caged. Super grade and empty grade are negligible, having below 2%.

Nevertheless, Super grade of the pollinated has twice that of the caged, while the empty pods display a higher percent in the caged.

c) Yield variations in Tomato

Bee pollination plays a critical role in tomato production.

Plate 20: Plot 12 showing pollinated tomato crop

Photo: (Nzano P, 2016)

(i) T-test for Tomatoes

The group means show statistically significant differences because the significance value is less than 0.05. From the group statistics table, it is clear that the number tomato fruits produced as a result of pollination are higher than the number of fruits produced from caged tomatoes.

From the results, the number of fruits produced from pollinated tomatoes is significantly higher (4.15±5.387) compared to un-pollinated, caged tomatoes (0.95±2.697), t (376) =4.588, p=0.000

Table 7: T-test for Tomatoes - Group statistics

Group Statistics					
	Pollinated or not	N	Mean	Std. Deviation	Std. Error Mean
No of fruits	pollinated	315	4.15	5.387	.304
	Encaged	63	.95	2.697	.340

Table 8: T-test for Tomatoes- Independent sample test

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	d f	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
No of fruits	Equal variances assumed	20.612	.000	4.588	376	.000	3.194	.696	1.825	4.562
	Equal variances not assumed			7.010	178.081	.000	3.194	.456	2.295	4.093

ii) Quantity: Number of flowers and fruits in pollinated tomato plots

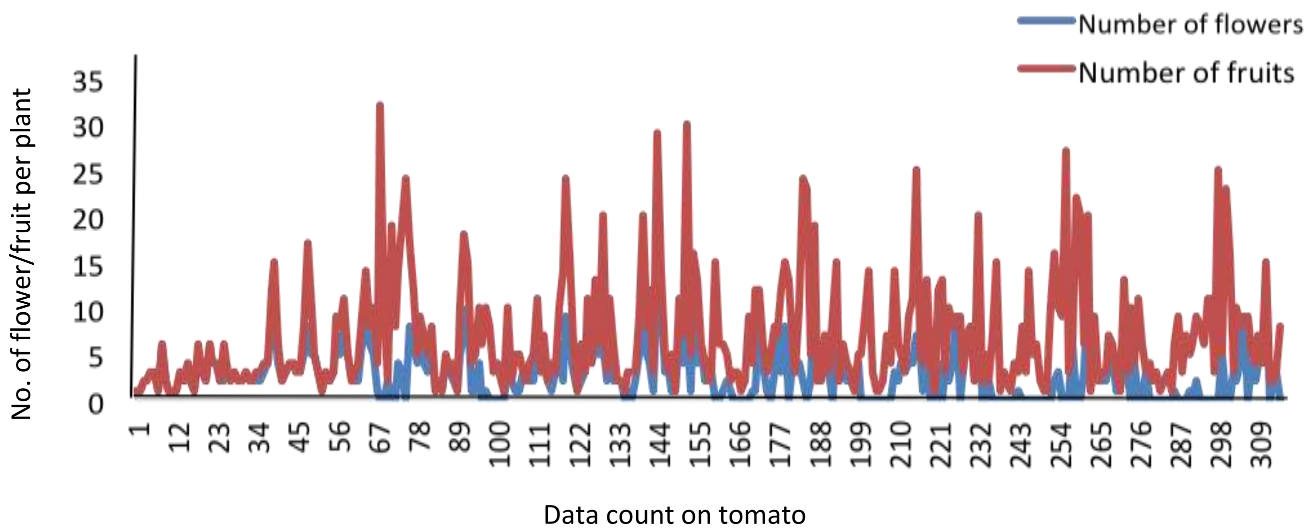

Figure 31: Pollinated Tomatoes.

Figure 31 illustrates a continuous flower production, with a peak of 13 flowers per plant and an average of 5 flowers. Fruit production increases with flower production. The recorded average was 10 fruits per plant with a peak production of 33 fruits per plant.

iii) Quantity: Number of flowers to number of fruits ratio in pollinated tomatoes

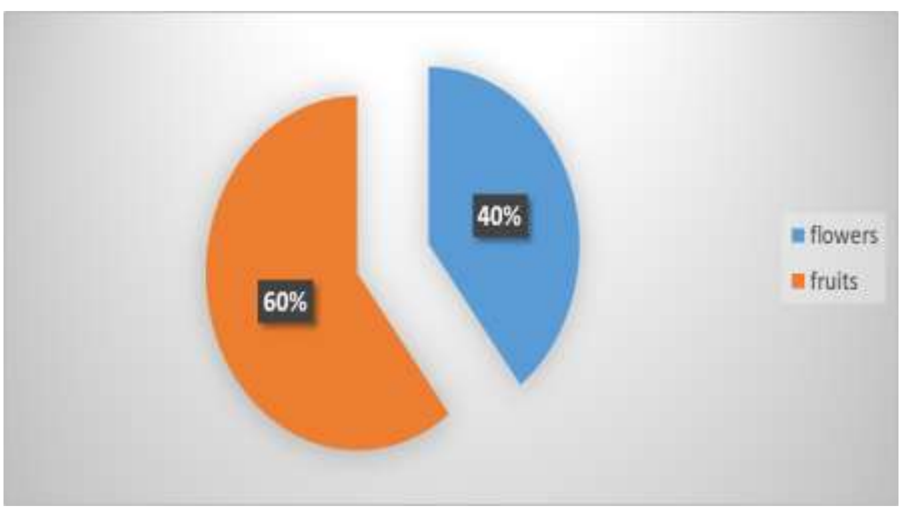

Figure 32: Number of flowers to number of fruits ratio in pollinated tomatoes

The chart illustrates a positive increase in fruit production as a result of bee pollination. Ratio is 60:40 fruit and flower respectively.

iv) Quantity: Number of flowers to number of fruits in non-pollinated tomato plot

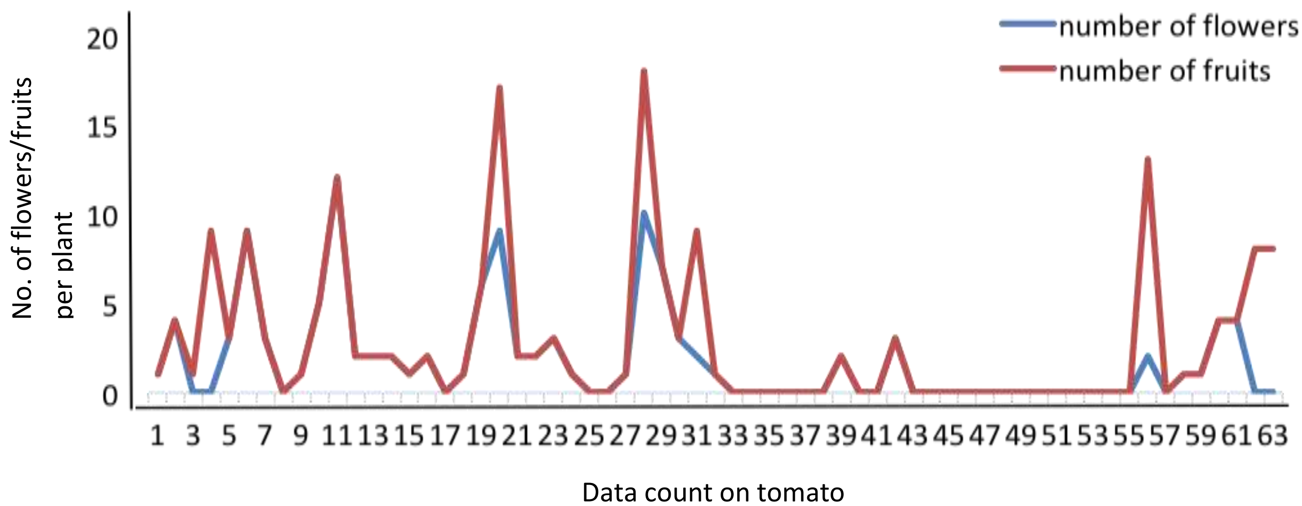

Figure 33: Caged tomatoes

The average production of flowers was 2 per plant, with a peak count of 11 flowers. The average number of fruits produced was 8 per plant, with a peak production of 18 fruits. From the chart, the number of fruits and flowers are greatly reduced compared to the data from the pollinated plot which indicates the reverse. This could be due to the aspect of self-pollination which is evident in tomatoes Ref. Crane and Walker, 1984.

v) Quantity; Number of flowers to number of fruits, ratio in non-pollinated tomato plot

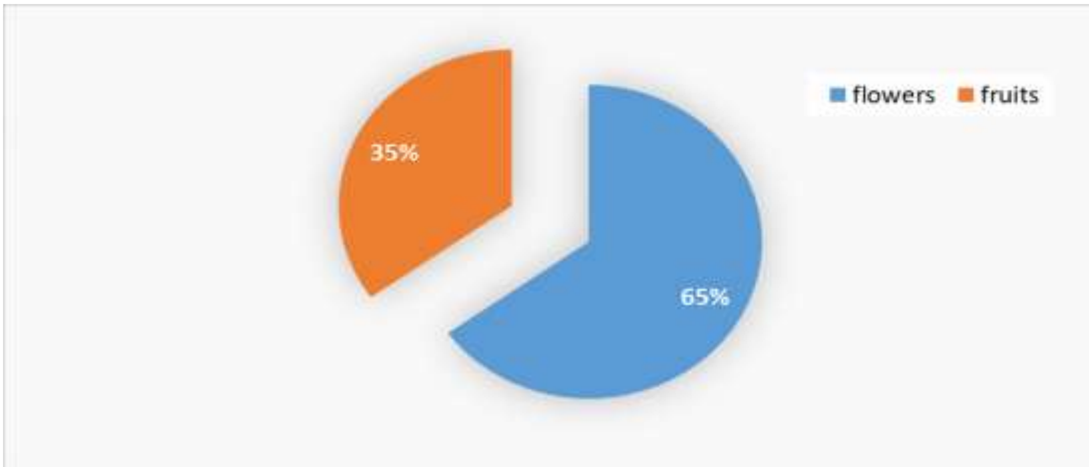

Figure 34: Number of flowers to number of fruits ratio in caged tomatoes

Figure 34 shows a large percentage of flowers and less fruits in the ratio of 2:1 ratio, flower and fruit respectively. Flowers were produced but little pollination took place.

Not only are the flowers and fruits few, the data count is also less, 63, compared to 309 in the pollinated crop plots.

Plate 21a: Tomato plant in flower

Plate 21b:Tomato plant with fruits

Photo: (Nzano N, 2016)

vi) Quality: Weight of Tomatoes

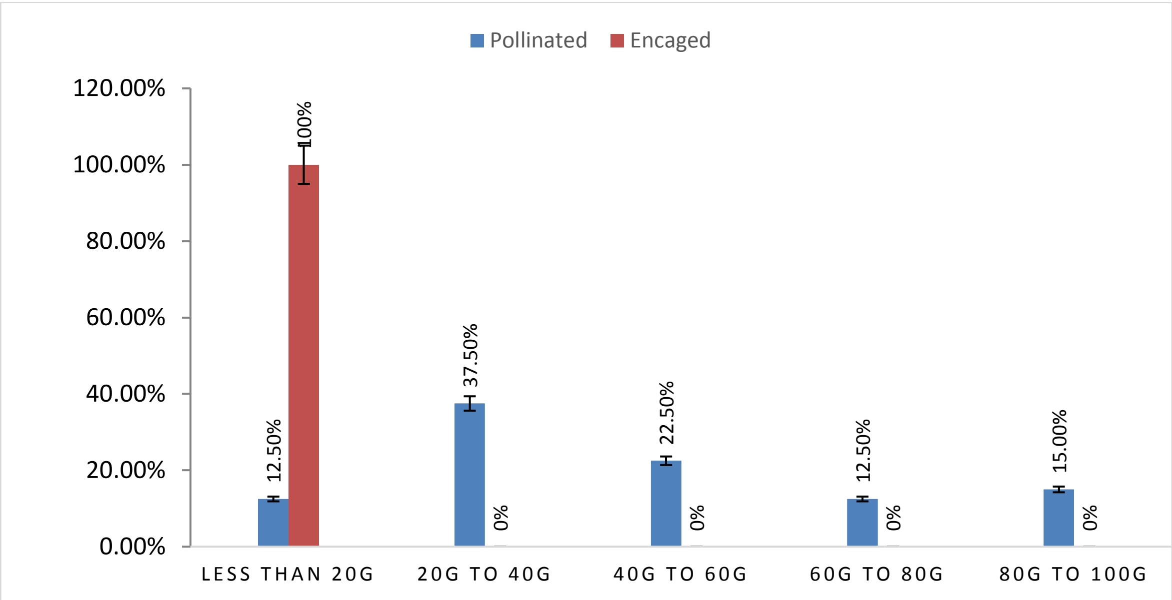

Figure 35: Tomato fruit weight

All the fruits in the none pollinated plots weighed less than 20g. The rest of the categories had nil number of fruits signifying the importance and dependence on bee pollination in tomatoes. The pollinated plots had a maximum weight percentage of 37.5% in the 20 to 40g category whereas the maximum weight category of 80 to 100g had 15% of the total fruits, in this experiment.

vii) Tomato qualities

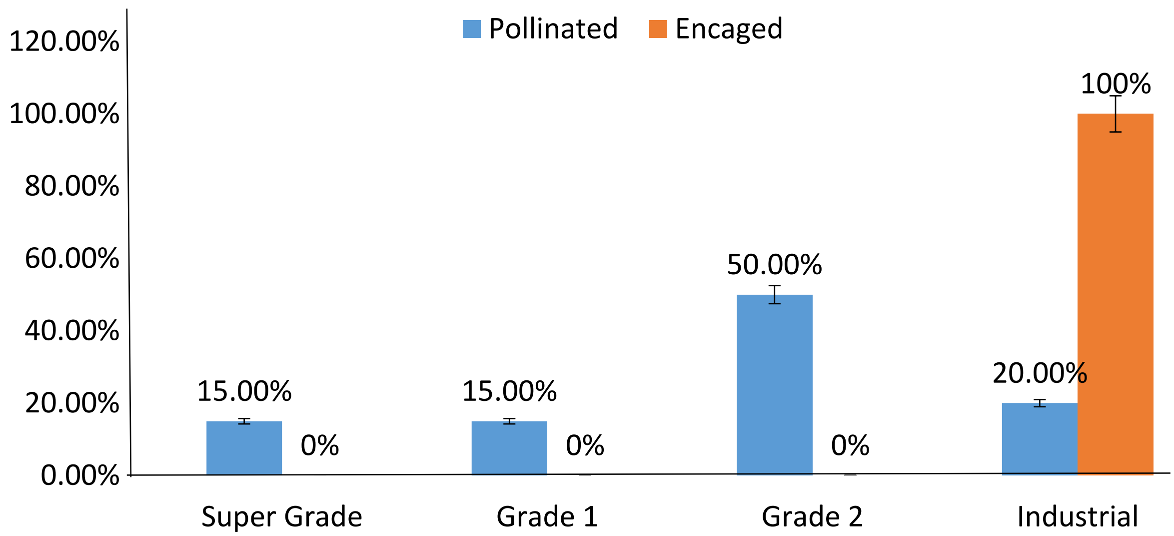

Figure 36: Quality assessments in Tomatoes

Figure 36 shows that lack of pollinators greatly lower the quality of the tomato. To get the best grades in tomatoes, pollination is also a key player producing Super, Grade 1 and Grade 2. Encaged tomatoes produce 100% industrial quality fruits.

Half of the tomato crop is grade 2, implying damage by pests, diseases or insufficient number of pollinators resulting in deformities in fruit shape. Super and grade one were lower than expected, 15%.

4.5 Analytical Model

A linear regression model was applied to establish the connection between the number of fruits produced and the number of flowers. The relationship equation is represented in the linear equation below.

$$Y = \alpha + \beta X$$

Where;

- Y= the number of fruits.
- α = Constant Term: This is the mean of the number of fruits produced when independent variables are constant,
- β= Beta coefficient measures the changes in dependent variable caused by the changes in independent variables(pollination)
- X=Number of flowers

Table 9: Dependent variable: No of fruits / pods

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Correlations		
		B	Std. Error	α	T	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part
1	(Constant)	3.662	.362		10.118	.000	2.950	4.373			
	No of Flowers	-.019	.096	-.010	-.196	.845	-.207	.169	-.010	-.010	-.010

a. Dependent Variable: No of fruits/Pods

The model of this study was:

$Y=\alpha+\beta X$

Therefore, from the regression result, the estimated model is given below

$Y = -0.10+3.662X$

From the regression analysis above, a positive beta coefficient is obtained showing that there's a positive correlation between the number of flowers and the number of fruits. Pollination causes a positive change in the number of fruits produced hence showing the importance of pollination in increasing the number of fruits in crops.

CHAPTER FIVE: DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1. Discussion

The Kavuko community in Makueni County represents the arid/semi-arid ecological zone in Kenya whose majority land cover is 75% of the same zone type (MALF Strategic plan, 2016).

House hold survey data revealed that farmers for the season the research was conducted did not show much interest for keeping honey bees for reasons related to the then weather conditions which were dire except for the few farmers that practiced beekeeping management practices and sustained the few colonies providing water in small containers hoisted high up near the hives.

Only a quarter of the farmer populations are beekeepers. The long dry spells could be a contributing factor implying absence of overlapping flowering periods. Major flowering tree plants include acacia tortilis, sisal, and mango among other trees and shrubs which might not flower in the long dry spells therefore discouraging most farmers. The vegetation in the area provides readily available material for making the hives therefore trees and sisal plants that are suitable for beekeeping are used (Martins, 2014). Due to the high number of log hives the colony occupation rates favored the same trend seen.

Kavuko farmers for the research season conducted did not show much interest for keeping honey bees for reasons related to the then weather conditions which were very dire except for the farmers that practiced beekeeping management practices and sustained the few colonies providing water in small containers hoisted high up near the hives otherwise they would have absconded with the rest for better habitats (Kigatiira, 2014). The majority expressed keen interest to own and increase their hives for honey production. They needed further information on the management of bees and constant follow up because majority of the younger generation in the population is constantly moving out of the vicinity in search of better livelihood activities.

The conservation of pollinators draws conflicts between farmers and the communities since pollinators cannot be contained in a given environment. Where these issues arise, the existing laws and policy in place shall be applied accordingly (UNCHE, 1972). Of the 30 farmers that had hives, only 11% had placement dates and were waiting for hive occupation whereas 45% had not yet placed the hives on trees and were either preparing for placement or anticipating doing so. For the farmers who had no hives, 33% were non-starters and 11% were reportedly unwell or deceased. Farmers participated in the decision to partake conservation of the pollinators demonstrating Environmental Governance and fulfilment of Environmental rights (saflii.org, 2008).

Farmers were aware of pollination activities by bees but did not show interest in hive placement due to the seasonal absconding traits of the bee colonies. This goes to show that majority did not spend their precious time on an activity that did not promise hive occupation at the time, and there was not a single colony occupation recorded (Kigatiira, 2014). This only happens after the long-awaited rains pour and according to the farmers the bees are buzzing everywhere including cattle sheds where they are not needed. Every ecological zone has its merits and demerits. The materials for bee occupancy may vary as the resources of the particular zone provide depending on the climate the colonies will abscond especially if the material is not suitable.

Communities the world over have from time immemorial used various materials and sites to encourage bee occupancy influenced by the specific ecological zones and their valuable resources, it is common knowledge that bees have been known to occupy one hive and reject another for reasons not clear yet (Martins, 2014). It is important to use the right resource material for the colony to accept to occupy. Plant related materials – one of them wood, is most suitable for high temperature areas. Soil used to make earthen hives, rock, concrete, metal pipes among others have been occupied as bee habitats on some in the most unexpected places.

Makueni being a semi- arid, temperatures averages 30^{o} C. When the season lacks rain, the vegetation cannot sustain the bee colonies and therefore they migrate. Most heads of the homestead are absent due to commitments or occupation elsewhere leaving their female counterparts in the homestead. The middle age, 46 – 55 years constitute only 14%. This is the active group that has settled in their occupation and has the time to do beekeeping. This could indicate that half the population is bound to have less knowledge on bee keeping as they are focused on other promising career fields and activities of early stages of life.

Bee farmers rely on knowledge at hand and especially the one passed down the generations- Traditional Knowledge. There is need for new knowledge, technology, demonstrations and follow ups to empower them. There are obviously more types of pollinators in the environment e.g. Bats, flies, Beetles, among others, but not as noticeable as the ones pointed out. As the farmers awareness is stirred up their knowledge will improve and therefore the appreciation of pollinators (Martins, 2014). The area has always had beekeeping as a traditional activity for harvesting honey for consumption as food, medicine and local brew, only that it has been overtaken with time by new found activities and occupation that bring income faster and with certainty. Most were able to get the knowledge on pollination from the schools they attended, as majority were youth and therefore empowered with the knowledge. As discussed, knowledge has been passed on about the benefits of the same. The population growth, the subdivision of land, climate change and environmental degradation are some of the contributing factors to decline of pollinators. The older generation had applied the practice to the knowledge of the majority. Farmers need to be enlightened about the correct use of chemicals in their farms and the consequences of their use in the short and long term, or better alternative uses altogether.

The use of chemicals should be controlled (Kigatiira, 2014; Martins, 2014). Environmental education, awareness, equity, action programs, democracy, pollution and justice go hand in hand with environmental rights found in arenas like International bill of Rights, Regional human rights law and Domestic constitution (UNCHE, 1972)

The methodology applied in the experiment is locally applicable, empowering and opens platforms for policy making attaining a beginning of resource governance (JASS, 2018)

Yield variations in strawberries: The pollen Glory Farm was used as an excellent platform to usher the community to environmental governance through the various groups, government institutions and external organizations like the Ministry of Environment and the United Nations Environmental Programs; With programs aimed at community empowerment in the changing environment generating value through food security (Bradbear, 2009; JASS 2018), and participation in ecological restoration and improved livelihoods through beekeeping.

Pollination plays a key role in increasing the number of fruits produced in strawberry. This is seen in the graphs. Many insects visit strawberry flowers but only bees are effective pollinators, without injuring the flower parts. If wild bees are not plentiful, honeybees should be ‘saturated’ to increase yields, since they are not particularly attracted to strawberry flower, in the presence of other more attractive flowers, (Mc Gregor, 1976).

The pollinated strawberry fruits were significantly nuemrous in number and of a higher quality with 80% super grade, compared to the none pollinated, whose fruits were few with the majority, 60% in the industry category. The results concurred with free, Bradbear and Martins observtions (Free, 1968; Brabdbear, 2009 and Martins, 2014).

Yield variations in Beans: Bean flowers are delicate from what was observed in the field. They have a peak production period that does not last very long. Pod production for the pollinated plot is continuous but on a decreasing trend after the peak period. The encaged beans chart shows a short production period that settles to peaks averaging 19 pods before the finale drop. In the encaged plot the number of pods is visibly higher and this could be attributed to latter peak production before the final drop. The pods in the encaged plot have a peak production of above 25 pods for most of the data as compared to the pollinated plot at 20 pods. Majority of bean plants produced 4 to 6 pods with the encaged having the highest. In the encaged plot the number of pods is visibly higher and this could be attributed to peaks averaging 19 pods before the finale drop. The beans produced more pods when encaged, due to self-pollination (Crane and Walker, 1984).

The encaged illustrate better grade quality production. This result shows most of the pollinated pods are not completely bean filled. Indication of lack of complete pollination due to an absent pollinating agent (Free, 1970; Mc Gregor, 1976; Crane and Walker, 1984). In temperate regions, the bumble bee is used due to its vigorous vibration beneth the flowers, striping it open to expose pollen for other polinators, bees. At pollen glory, the stingless bee, with its strong bitting mandibles would do the stipping. Alternatively, the carpenter bee with the same mode of action as the bumble bee would open the bean flower and pollinate, exposing the flower to other bee pollinators as noted by (Crane and Walker, 1984).

Higher pod weights are achieved when the beans are encaged. The quality of beans harvested with reference to availability of pollinating bees was significant to a small extend. There was a higher percentage of the possibility of production of super grade quality with availability of pollination compared to without. It was also observed that there was more than half difference between the industrial grade with and without pollination, with lack of pollination having more of the percentage.

Yield variations in Tomato: Pollination also plays a key role in improving the quality of produce in terms of grading and fruit weights. This is evidenced in tomatoes with pollinated tomatoes producing maximum weights of up to 100g while their encaged counterparts producing less weights. To get the best grades in tomatoes, pollination is also a key player producing Super, Grade 1 and Grade 2. Encaged tomatoes produce 100% industrial quality fruits. The same also applies to strawberries with higher chances of getting higher fruit qualities and weights when pollinated than when encaged. Pollination was absolutely necessary for the tomato plant.

5.2. Conclusion

1. It was concluded that Pollination was an important process for optimum quantity and quality seed and fruit production, whether self or cross-pollinated, as demonstrated by other researchers. (Free, 1968; Thompson, 1971; Conner and Martain, 1973; Oronge *et al.*, 2006; Asiko *et al.,* 2007; Kinuthia, 2007; Bradbear, 2009 and Martins, 2014).
2. The community should leverage on honey and other hive products to be social economically empowered to uplift their living standards, as reiterated in vision 2030's Economic, Social and Political Pillars of the Kenyan government agenda.
3. The community shall combine both traditional and modern innovations to achieve a harmonious, peaceful and sustainable environment that is conducive for beekeeping.

5.3 Recommendation

1. Invest in semi-arid areas. The ASALs should be restored through tree planting, which was the late Peace Laureate, Prof. Mathaai's legendary passion. she pioneered the Green Belt Movement in Kenya.
2. There should be continuous education and follow-up of the community on the need to keep and conserve pollinators and take advantage of pollination services.
3. They should leverage on honey and other hive products to be socio economically empowered and combine traditional and modern innovations for a harmonious sustainable environment.
4. Plant off- season crops using smart agriculture (caged/green house, drip irrigation for minimum moisture loss and utility, and suitable bee pollinators) to complement and enhance strategic food reserves to reverse the current trend in food shortage and distribution.

5. Emphasis should be laid on pollinator information dissemination through the already existing institutional structures, through Media, Agricultural Training Centers and other approved infrastructure.

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United Nations Conference on the Human Environment, Stockholm, 5-16 June 1972

APPENDICES

Appendix 1: Data sheet to establish the population of bee hives and colonies in the Kavuko area

No	Farmer's name	Type of hive	No. of hives	Bee colony	Year set up	Comments
1		Log		P		
		Kenya top bar hive		A		
		Sisal pulb				
		Others				
2						

Legend: P=Present, A= Absent.

Appendix 1b

Questionnaire on survey of honey bee colonies and hives

1. Gender Male…... Female…….
2. Age groups (years):

   Below 25…., 26 – 35…., 36 – 45…., 46 – 55…., 56 –65…., 66 – 75…., Over76……

3. Why do you keep bees in your farms?
4. Are you aware that there is more than one type of bee?
5. What else do you know about bees?
6. Do you know what pollination is?

7. Which pollinators do you know?
8. Do you know the benefits of pollination?
9. Do you see any decline in bee pollinators?
10. How can you help in stopping this trend?
11. Do you know of any traditional method used in conservation of bees?

Appendix 2: Data sheet for Rate of Hive Occupancy

No	Farmer's name	Hive type	No of hives	Date set up	Date colonised hive					Pollination Link awareness		Comments
										A	NA	
					1	2	3	4	5			
1										x		
2											x	

Legend: A= Aware, NA= not aware

Appendix 3: Data sheet for the Bee Hotel habitat

Bee Hotel Data Sheet				
Date	Day	Time		
Pollinator	Location in hotel	Frequency		
		Rare	Frequent	Most frequent
Honey bee	Br		x	
Stingless bee etc.				

Legend: Gr= grass, Ho = hollow pipe, Br = hole in brick, Pl = plastic pipe, Bo = plastic bottle

Appendix 4: Caged crops (non-pollinated)

<table>
<tr><td colspan="7">Data Sheet no………………….</td></tr>
<tr><td colspan="7">caged crops</td></tr>
<tr><td colspan="7">Date……………………………   Day………………….
Time…………………………….</td></tr>
<tr><td>Crop</td><td>Plot no</td><td>Plant no</td><td>No. of flower/s</td><td>Remark</td><td>No. of fruit/s</td><td>Remark</td></tr>
</table>

Appendix 5: Pollinated crops

<table>
<tr><td colspan="7">Data Sheet no…………..…….</td></tr>
<tr><td colspan="7">Pollinated crops</td></tr>
<tr><td colspan="7">Date……………………..………… Day………………….
Time…………………………….</td></tr>
<tr><td>Crop</td><td>Plot no</td><td>Plant no</td><td>No. of flower/s</td><td>Remark</td><td>No. of fruit/s</td><td>Remark</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Appendix 6: Yield Assessment Data Sheet

Plot no	crop	Crop no	Pod count	Pod Weight (g)	Fruit Count	Fruit weight (g)	Quality				Remarks
							S	G1	G2	I	

Legend: Strawberry fruit: = Super, G1= Grade 1, G2= Grade 2, I= Industry

Super = Heart shaped, G1 symmetrical when cut into half, G2 = not symmetrical, I = Irregular

Bean pod: G1= Pod full and well-shaped - pollinated, G2 = pod empty- not pollinated

Tomato fruit: Super, = well developed, G1= fairly well formed, G2= Damaged, I= decay

Appendix 7: Strawberry qualities used in grading

Super

G1

G2

I

Super = Heart shaped, G1= symmetrical when cut into half, G2 = not symmetrical, I=Industry Irregular

Canadian food inspection agency
http://www.inspection.gc.ca 2018-11-13

Plate 22: Strawberry qualities

Photo: Nzano P, 2016

Appendix 8: Pollination and bean grades

Super Grade1 Grade 2 Empty

Key: Super grade: Pod is filled with beans; Grade 1: Pod is lacking a bean; Grade 2: Pod lacking more than one bean; Empty: The pod is lacking well developed beans

https://www.ams.usda.gov/

United states department of agriculture, Agricultural marketing service. February, 2016

Plate (18): Bean grades

Photo: (Nzano P, 2016)

Appendix 9: Tomato qualities

Super Grade

Grade 1

Grade 2

Industry

Key: Tomato fruit:

Super, = well developed, Grade1= fairly well formed, Grade 2= Damaged, I= Industry

http://webapps.daff.gov.za/

Classes and grading requirements of tomatoes

Plate 22: Quality assessments in Tomatoes

Photo: (Nzano P, 2016)

Appendix 10 : Quality beans weighing on a scientific balance

Plate 25: Quality beans weighing on a scientific balance

Photo: (Nzano P, 2016)