

**EFFECT OF POLLINATORS ON SUNFLOWER SEED YIELD  
(*Helianthus annus* L.) IN MAKUENI DISTRICT, EASTERN  
KENYA.**

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**A thesis submitted in partial fulfilment of the requirements for the award of  
Master of Science degree in Agricultural Resource Management (Crop  
Protection Option), Department of Plant Science and Crop Protection,  
University of Nairobi.**

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## DECLARATION

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

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Date 16/08/2006.

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

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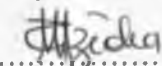
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## DEDICATION

To my parents; Josephine, Jeconiah, husband Stephen and son, Wayne.

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# TABLE OF CONTENTS

	<b>Page</b>
Declaration .....	i
Dedication .....	ii
Acknowledgements.....	iii
Table of contents.....	iv
List of tables.....	vii
List of figures.....	viii
List of Acronyms and Abbreviations.....	ix
Abstract.....	x
 <b>CHAPTER ONE</b>	
<b>Introduction</b>	
1.1 General Introduction .....	1
1.2 Role of pollinators in agriculture, ecosystem and the economy.....	2
1.3 Threats to pollinators.....	3
1.4 Sunflower production in Kenya .....	4
1.5 Constraints to sunflower production in Kenya.....	4
1.6 Justification of the study.....	5
1.7 Objectives of the study.....	6
1.8 Hypotheses of the study .....	6
 <b>CHAPTER TWO</b>	
<b>Literature Review</b>	
2.1 Biology of sunflower ( <i>Helianthus annus</i> L.).....	7
2.2 Distribution of sunflower ( <i>Helianthus annus</i> L.).....	8
2.3 Climatic and edaphic requirements.....	9
2.4 Sunflower production and utilization.....	9
2.5 Sunflower ( <i>Helianthus annus</i> L.) pollination requirements .....	11

2.6 Sunflower ( <i>Helianthus annus L.</i> ) pollinators.....	11
2.7 Role of pollinators in sunflower ( <i>Helianthus annus L.</i> ) production.....	11
2.8 Effects of insecticides use on pollinators and sunflower yield.....	12

**CHAPTER THREE**

**General Materials and Methods**

3.1 Research site. ....	14
3.2 Experimental materials.....	14
3.3 Field establishment.....	15
3.4 Data Analysis.....	15
References.....	16

**CHAPTER FOUR**

**Diversity of sunflower pollinators and their effect on seed yield in Makueni District, Eastern Kenya.**

Abstract.....	20
4.1 Introduction .....	21
4.2 Materials and Methods.....	22
4.3 Results.....	25
4.4 Discussion.....	31
References .....	33

**CHAPTER FIVE**

**Effect of insecticide use on sunflower (*Helianthus annus L.*) seed yield**

Abstract .....	37
5.1 Introduction.....	38
5.2 Materials and Methods.....	39
5.3 Results .....	41
5.4 Discussion.....	45
References.....	45

## CHAPTER SIX

### General discussion, conclusions and recommendations

6.1 General Discussion .....	48
6.2 Conclusions.....	49
6.3 Recommendations .....	49

## LIST OF TABLES

Page

Table 1	Degree of dependence of selected crops on insect pollination. ....	2
Table 2	List of the different sunflower pollinators recorded in Makueni District during the long rains, 2004 and short rains, 2005.....	25
Table 3	Mean number of sunflower pollen dusted from major sunflower pollinators .....	26
Table 4	Mean number of <i>Apis mellifera</i> Linnaeus and non-apis bees during the long rains, 2004 and short rains seasons, 2005.....	27
Table 5	Mean time taken (seconds) by <i>A. mellifera</i> Linnaeus on sunflower during the long rains, 2004 and short rains season, 2005.....	28
Table 6	Mean number of caterpillars, sunflower seed yield during the long rains season, 2004.....	29
Table 7	Mean number of caterpillars, sunflower seed yield during the short rains season, 2005 .....	30
Table 8	Mean sunflower yield during the long rains season, 2004 of different insecticides sprayed at different spray regimes.....	41
Table 9	Mean sunflower yield during the short rains season, 2005 of different insecticides sprayed at different spray regimes.....	43



## **LIST OF ACRONYMS AND ABBREVIATIONS**

**NMK** – National Museums of Kenya

**PCPB** - Pesticides Control Products Board - Kenya.

**Ha**-Hectares

**g**- Grammes

**Cm**- Centimeter

**mm**- millimeter

**%**- Percent

**l**-Litres

**a. i** – active ingredient

## ABSTRACT

A field experiment was carried out twice in the long rains, 2004 and the short rains, 2005 in Makueni District, Eastern Kenya to establish the diversity of sunflower pollinators and their effect on the seed yield. Four treatments were used in a randomized complete block design with plots sizes of 4 × 4 m replicated four times. The treatments included, bagging at night and opening during the day for free accessibility by daytime pollinators, bagging during the day and opening at night for free accessibility by nocturnal pollinators, bagging throughout the flowering period to exclude all pollinators, and no bagging for free access by all pollinators. The pollinators were collected and identified and the honeybees' diurnal behaviour noted. Head diameter, the number of seeds per head, weight of seeds per head, number of deformed seeds per head and the % oil content determined.

A total of 14 insects species were observed visiting sunflower floral heads. Other visitors included, the non-*apis* bees; *Plebeina denoiti*, *Ceratina* sp, *Heriades* sp, *Pseudoanthidium* sp, two (2) species of Diptera namely; *Rhynchomydaea* sp and *Phytomia incisa*, six (6) species of Lepidoptera; *Danaus chrysippus*, *Belenois aurota*, *Junonia oenone*, *Byblia ilithyia*, *Junonia hierta*, *Cephonodes hylas* and one (1) species of coleoptera, *Merylis flavipes*. *Apis mellifera* was the most abundant and important sunflower pollinator recording the highest pollination efficiency index (7606). Peak foraging periods for the honeybees and the non-*apis* pollinators was observed between 10 am and 12 pm. The length of visitation was not significantly different with time of the day. Number of seeds per head and seed weight per head increased by two to three times, and number of deformed seeds reduced by 35 % while the oil content of

seeds per head increased by 66.7 % in the plots exposed to pollinators compared to the plots bagged to exclude pollinators.

Two insecticides namely dimethoate ( Dimethoate 40 % EC) and L-cyhalothrin (Karate 1.75 % EC) were evaluated for their effect on sunflower pollinators and seed yield. Five treatments in a randomized complete block design with plot sizes of 4 × 4 m replicated thrice were used. The treatments were spraying in the morning and evening after flowering for each of the insecticides and a control (untreated). Numbers of foraging honeybees for five days after treatment were noted. The head diameter, number of seeds per head, weight of seeds and the numbers of deformed seeds were recorded.

Untreated plots gave higher numbers of seeds per head, seed weight per head and lower number of deformed seed per head compared to the treated plots. However, the weight of seeds from Dimethoate and Karate treated plots were not significantly different. Insecticides application in the morning had higher number of deformed seeds per head compared to the evening applications. On average seed number per head was reduced by 52 %, seed weight per head by 38 % and the number of deformed seeds per head increased by 63 %.

It was evident that lower yield were attributed to reduced honeybee visits due to pesticide toxicity.

## CHAPTER ONE

### INTRODUCTION

#### 1.1 General introduction

Pollination is the transfer of pollen from the anther to the stigma of the same or another flower of the same species. It precedes seed production in flowering plants with a few exceptions such as the seedless grapes and seedless cucumbers (Free, 1999). Different plants exhibit different types of pollination. Self-pollination occurs in self-fertile plants when pollen is transferred from the anther to the stigma of a flower on the same plant. Cross-pollination occurs when pollen is transferred from another plant of the same species (Free, 1999). Non- self fertile plants must be cross- pollinated if they have to set fruits and seeds. In addition, many plants that are self-fertile will produce better crops if they are cross-pollinated (Maheshwari, 2003) Agents of pollination include wind, water, and animals including man, mammals, birds and insects.

More than 75% of world's major crops and 80% of all angiosperms rely on animal pollinators (Buchmann and Nabhan, 1996; Maheshwari, 2003). Insect pollinators include the various blossom-visiting insects that collect either pollen or nectar or both for their food. These include; honeybees, wildbees, sting less bees, flies, wasps, moths/butterflies, beetles and ants. Bees are the major pollinators, pollinating about 75 % of most cultivated crops (Maheshwari, 2003).

In tropical crop production systems, less attention has been paid to pollinators due to other limiting factors of production such as lack of water, poor soil fertility and pests and diseases. These factors mask the pollinators' effect on sunflower seed yield (Free, 1999). This is unlike

in the highly mechanized agriculture like in U.S.A, where the use of honeybees for pollination has increased (Mc Gregor, 1976). Pollination therefore, forms an integral factor contributing to crop yield other than sound agronomic and crop protection management factors.

### 1.2 Role of pollinators in agriculture, ecosystem and the economy.

Three quarters of the staple crops that feed the world and 90% of all flowering plants rely on pollinators' assistance in cross-pollination. Almost a third of all our food and other wild plants would not exist without pollinators (Maheshwari, 2003). The degree of dependence of crops on insect pollination varies widely with the different crops (Table 1).

**Table 1 Degree of dependence of selected crops on insect pollination.**

Crop	Crop insect dependence	Expected % crop loss estimate
	(Williams, 1994)	(Southwick and Southwick, 1992)
Asparagus	1.0	90
Cabbage seed	1.0	90
Apple	1.0	80
Sunflower	1.0	80
Carrot seed	1.0	60
Avocado	1.0	20
Cucumber	0.9	60
Watermelon	0.7	40
Cotton seed	0.2	30
Soybean	0.1	10

Values 0.1- 1.0 is scale of increasing crop dependence on insect for cross- pollination.

Pollinators interact with flowering plants in keeping a balance of ecosystem services as well as the maintenance and proper functioning of the ecosystem. Pollinators are essential in the reproduction of more than 90 % of flowering plants (Maheshwari, 2003) and are therefore important in many aspects of the ecology of dry land ecosystems as well as in biodiversity conservation. Species diversity facilitates ecosystems diversity, structure and proper functioning (Tepedino, 1979). Kearns *et al.*, (1998) observed that pollinators are very crucial in the functioning of almost all terrestrial ecosystems and are indicators of biodiversity loss. It is therefore evident that without pollinators' service, ecosystems, humans, animals and plants would lose their support of life.

Economic value of animal pollinators to the world agriculture has been estimated to be 200 billion US dollars per year (Maheshwari, 2003). In the U.S.A it is estimated that honeybees contribute about 5-14 billion dollars and other pollinators between 4.1-6.7 billion dollars annually (Southwick and Southwick, 1992). However, research on the valuation of the ecosystem service pollinators has not been done in other countries. Honeybees other than aiding in crops pollination provide honey (with high nutritional and medicinal value) and wax. Honey is used by different communities for various purposes namely as sweeteners for foods and drinks, medicine for brewing traditional beer, meal preservative and as source of income. Some species of stingless bees provide honey that is of high medicinal value (Eardley, 2004).

### **1.3 Threats to pollinators**

Pollinators are on the decline due to pesticide use, reduced availability of nectar parasites and habitat destruction (Buchmann and Nabhan, 1996; Kearns *et al.*, 1998). Low crop yields are often attributed to pest, disease attacks and harsh climatic conditions during crop growth e.g. drought, heavy storms, and flooding. Insect pest and disease management is usually equated

with the use of insecticides and fungicides that may coincide with pollinators' visits at flowering. Even appropriately used insecticides may cause inadvertent yield reduction in crops such as sunflower by reducing pollinator populations and visits (Delaplane and Mayer, 2000). Other human impacts on plant pollinator mutualism include fragmentation of habitat, modern agriculture especially monoculture of non-nectar bearing cereals that displace native forage and leads to loss of breeding, nesting and hibernation sites and introduction of exotic honeybee which may out - compete and displace the indigenous bee species (Buchmann and Nabhan, 1996).

#### **1.4 Sunflower production in Kenya**

Kenya's domestic production of edible oils is estimated at 380,000 metric tonnes, which is one-third of its annual demand and spends over 15 billion Kenya shillings on domestic oil imports to meet this demand (CBS, 2004). The range of vegetable oil crops in Kenya include sunflower, cottonseed, soya, groundnuts, rapeseed, bambara nuts, castor, palm oil, sim-sim, maize germ, beans and olives. The total area covered by vegetable oil crops is low and is estimated to be 127,997 hectares with about 7793 hectares under sunflower production yielding about 8129 tonnes in 2003 (MoA, 2003). Major sunflower producing provinces in Kenya are Rift Valley, Western and Nyanza. Sunflower production has been on the increase due to the establishment of the various oil refinery factories (e.g. Kapa, Palmac, Pwani, Bidco). This is essential in meeting the domestic demand for vegetable oil as well as reducing the national total expenditure on vegetable oil importation.

#### **1.5 Constraints to sunflower production in Kenya**

Constraints to sunflower production include irregular and unstable weather conditions, pests and diseases, and inadequate pollinators. The major pests include *Agrotis segetum* sSchiff,

*Agrotis ypsilon* Hfn, and *Plusia orichalcea* F. *Nezara viridula* L. and *Heliiothis armigera*. Sunflower seed yields also greatly reduced by diseases such as Sclerotinia wilt, Downy mildews and Charcoal rot (Anonymous, 2003; Khaemba and Mutinga, 1982).

#### 1.6 Justification of the study

Sunflower is highly dependent on insect pollination and pollinators have been found to increase yield in hybrids varieties. Therefore, increased production of the sunflower seeds cannot be achieved without identification and conservation of sunflower pollinators. Most of the research on sunflower has been on the insects as pests (Khaemba and Mutinga, 1982). Pollinators of most crops and other wild plants are unknown. The loss of these pollinators can cause reduced seed and fruit set, plant extinction as well as reduced crop yield (Kearns *et al.*, 1998). Inappropriate use of insecticides poses a great threat to the pollinators' diversity and pollination service (Delaplane *et al.*, 2000). Studies on diversity of pollinators are important in biodiversity conservation and bee keeping. Influence of flower phenology on the pollinators' visitation is also important in the understanding of plant – pollinators' interaction in the ecosystem. Most studies done on the conservation of plant biodiversity have shown that plant biodiversity depends on the preservation of the pollinator diversity.

Given the importance of pollinators in sunflower production and plant biodiversity conservation, pollination requirement of the different crops and wild plants in Kenya need to be established. This study aims at establishing the diversity of pollinators and their influence on yield and effect of insecticide use on sunflower pollinators in the semi arid regions of Makueni District, Kenya. The findings will help create awareness of importance of pollinators in the region in crop production, ecosystem and biodiversity conservation.



### **1.7 Objectives of the study**

#### **Overall objective**

To assess the effect of pollinators on the yield of sunflower *Helianthus annus* L. in Makueni District, Kenya.

#### **Specific objectives**

- 1.To establish the diversity of sunflower pollinators and their importance on yield.
- 2.To determine the effect of insecticide use on pollinators and sunflower yield.

### **1.8 Hypotheses of the study**

- 1.Flower visitation by pollinators is not important in sunflower pollination.
- 2.Insecticides have no effect on the sunflower pollinators' diversity and yield.

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1 Biology of Sunflower (*Helianthus annuus* L.).

Sunflower belongs to the family Compositae and order Asterales. Sunflower is an annual, erect broad leaf plant with strong taproot and prolific lateral spread of surface roots making it well adapted to the semiarid areas. Plants flower 3 to 4 months after planting and take about 3 1/2 to 6 months from planting to maturity depending on variety and temperature (Schneiter and Miller, 1981). Sunflower growth stages can be described from vegetative to its physiological maturity stage. Vegetative Emergence (VE) is when the seedling has emerged and the first leaf beyond the cotyledons is less than 4 cm long. This is followed by the vegetative stages (i.e. V-1, V-2, V-3, etc.) that are determined by counting the number of true leaves at least 4 cm in length. At the reproductive stages; R-1, the terminal bud forms a miniature floral head rather than a cluster of leaves; R-2, there is immature bud elongation of 0.5 to 2.0 cm above the nearest leaf; R-3, the immature bud elongates more than 2.0 cm above the nearest leaf; R-4, the inflorescence begins to open; R-5, the inflorescence opens completely; R-6, the ray flowers begin to wilt; R-7, the back of the head starts to turn a pale yellow color; R-8, the back of the head is yellow while the bracts remain green. At R-9 the bracts become yellow and brown (physiological maturity) (Schneiter and Miller, 1981). The flowers have conspicuous showy yellow ray florets that attract different kinds of arthropods (Schneiter and Miller, 1981). The anthers are dehiscent and the pollen spills onto the interior of the flower on the first day after flowers open; this is the male stage. On the following day, the styles extends through the interior of the flower and emerges above the anthers and the stigmatic lobes separate and curl towards the style; this is the female stage. The stigma remains receptive for about 15 to 20

days. The opening of all florets of a single head takes between 9 and 15 days depending on the size of the capitulum's and atmospheric conditions (Schneiter and Miller, 1981).

Sunflower pollen is relatively large (25  $\mu\text{m}$  to 35 $\mu\text{m}$ ) and heavy with an outer coating (the exine) covered in sharp spine and a viscous wax forming caked masses. Wind plays a minor role in cross- pollination due to the pollen grain weight and most of the cross- pollination is aided by insects (Freund and Furgala, 1982). Both the pollen and the nectar of sunflower are attractive to various insect pollinators throughout the day and these bees aid in cross-pollination (Freund and Furgala, 1982). If pollination occurs, the florets withers shortly; otherwise may wait as long as 2 weeks for fertilization but seed setting in such florets is greatly reduced even with cross- pollination. Anthesis and maturation of the resulting fertilized achenes is centripetal (Mc Gregor, 1976). Different varieties of sunflower are available. There are closed and open pollinated varieties. Oil seed varieties are usually small in size, black in color with a gray stripe. Non-oilseeds are light in color with some definite white stripes (Putnam *et al.*, 1990).

## **2.2 Distribution of sunflower (*Helianthus annus* L).**

Sunflower (*Helianthus annus* L) is a native of North America. Heiser (1978) found that there are 67 species of *Helianthus* in nature distributed widely across the world. Originally, it was cultivated in Europe towards the 16<sup>th</sup> century for ornamental purposes and was recognized as oil seed in the 19<sup>th</sup> century in Russia (Putnam *et al.*, 1990). Major sunflower producing countries in the world are Russia, USA, Argentina, Ukraine, France, China, India and Spain (Kevin and Bixley, 2001). In Kenya, the crop is grown throughout Kenya but especially in the maize growing areas namely Western, Nyanza and Rift Valley Provinces (MoA, 2003).

### **2.3 Climatic and edaphic requirements**

The sunflower is considered to be a drought tolerant plant and can grow well in areas of 450 mm to 750 mm of rainfall or more per annum. Optimum temperatures for germination are 8 °C-10 °C and for growth is 21°C -26°C (MoA, 2003). In Kenya, it can be grown from sea level up to 2600 m above sea level as it's tolerant to low and high temperatures. However, there is large potential in the country's Arid and Semi Arid Lands (ASAL) and the Coast Province (MoA, 2003).

Sunflower grows in a variety of soil types from sands to clays and a wide range of soil pH's from 5.7 to over 8 but do possess a low salt tolerance and require well-drained soil. Fertility nutrients required by sunflower are nitrogen, phosphorus and occasionally potassium. Nitrogen usually is the first limiting factor for yield. Yield is most sensitive to moisture stress during the flowering and seed fill stages and less sensitive during the vegetative period (Putnam *et al.*, 1990).

### **2.4 Sunflower production and utilization.**

Sunflower is produced in a number of countries with a total of about 21 million hectares under sunflower production. Current world production stands at 36 million metric tones with Argentina producing 35 percent of this production. (Mc New and Bixley, 2001). In Africa, South Africa is the leading sunflower producer with over 400,000 hectares under sunflower yielding 520,000 tonnes per annum (Mc New and Bixley, 2001). In Kenya, sunflower production yields 8129 tonnes of seed per annum (MoA, 2003).

Sunflower cultivation is primarily for its seeds, which yield one of the world's most important sources of edible oil. The oil accounts for 80 % of the value of the sunflower crop. Analysis of seed composition shows that protein comprises 20.8 %; lipid 54.8 %; carbohydrate 18.4 %; ash, 3.9 % (Putnam *et al.*, 1990). Sunflower oil is considered a premium oil because of its light colour, high level of unsaturated fatty acids e.g. linoleic acid, high oxidative stability and high smoke points. Linoleic acid is required for the cell membrane structure, cholesterol transportation in the blood and for prolonged blood clotting. Sunflower oil is also considered healthy oil as it helps to reduce the serum cholesterol levels. The oil is also used for cooking, margarine, salad dressings, baby formula, lubrication, bio-fuel, hydraulic fluids, soaps, illumination and certain types of paints, varnishes and plastics. The press cake /meal left after the oil has been extracted are a valuable animal feed. The cake meal contains 40 % - 50 % proteins, vitamin B2 complex and 5% fat and lack toxic materials (Putnam *et al.*, 1990). Sunflower can also be grown as a cover crop and for green manure or as fertility improvers. The stover contains large proportions of macro elements due to its inefficient use of these elements hence when returned to the soil the stover releases most of these nutrients to the soil on decomposition. Sunflower can also be used as a catch crop in weed control besides mechanical and chemical control measures. This is due to its fast growth and large leaves that form dense canopy shading and smothering the weeds. It can also be used as silage for milk cattle as it contains more fat than other forages (Putman *et al.*, 1990). Some sunflowers are grown as ornamentals, and varieties have been developed with exotic colors.

### **2.5 Sunflower (*Helianthus annus L.*) pollination requirements.**

Sunflower pollen is usually heavy hence wind plays a minor role in its cross- pollination (Freund and Furgala, 1982). Hybrid sunflowers are bred to be self-compatible (60% to 90%) while the open – pollinated varieties require cross-pollination to set seed. Hybrid cultivars vary in their dependence on insect pollination. Most hybrids benefit from cross-pollination (up to 50%) but some can achieve full seed set (92%) by self-pollination (Maheshwari, 2003). However, selfing results to low seed set, the seeds are small, the oil content and germination are reduced and production from these seeds is lower than from crossed seeds (Mc Gregor, 1976). Cross – pollination, therefore, becomes advantageous except in self – pollinated varieties like the hybrid sunflower seeds which are usually bred for high self – compatibility.

### **2.6 Sunflower (*Helianthus annus L.*) pollinators.**

Sunflower during flowering is visited by diverse range of insects for example, butterflies, moths, beetles, houseflies, bugs, honeybees, wild bees, thrips and other insect pests. Most of the cross- pollination is by insects with over 80 % being by honeybees (Maheshwari, 2003). *A. dorsata* is the dominating floral visitor to sunflower in India (Arya *et al.*, 1994). In Viamão (Brazil), 96% of the sunflower insect visitors were *A. mellifera* (Hoffmann, 1994). In tropical regions, research has shown that stingless bees are also common visitors to sunflower but are probably rarely important due to their low populations relative to that of honeybees (Radford *et al.*, 1979).

### **2.7 Role of pollinators in sunflower (*Helianthus annus L.*) production.**

Sunflower seed yield in Argentina increased five to six times, and the oil content of the seed increased by 25 % in plots exposed to honeybee colonies as compared to plots isolated from

insects during flowering (Schelotto and Pereyras, 1971). Soares (1977) reported an increase in the sunflower productivity about 98.4%, due to the pollination made by honeybees. Experiments with pollination, developed in Brazil, demonstrated that it is possible to increase the production of several crops. An increase of 82% in sunflower seeds in var. Anhandy, 81% in var. Uruguay and 15% in var. Contisol have been recorded due to honeybee pollination (Moreti *et al.*, 1993). Honeybee pollination can increase seed yield in sunflower by 30% and oil content of seed by 6% in hybrid varieties (Jyoti and Brewer, 1999a).

Research on the number of honeybees per head has shown that each floret should receive 8 to 10 bee visits per flower head (Avertisyan, 1965). However, the exact number of bees needed for maximum pollination has not been determined. Seed set has also been found to be higher in sunflowers nearest to beehives (Furgala, 1954 a). This indicated that, beehives should be well dispersed throughout the field to enhance honeybees' access to sunflower for cross-pollination. Pollinators have also been found to forage longer on flowers that provide more resources and a positive correlation exists between the size of a nectar resource and the number of flowers visited (Krell, 1986). It is therefore evident that, if a sunflower grower wants to obtain maximum yield of high quality, then having high pollinator population in the crop field particularly during blossoming / flowering is essential.

### **2.8 Effect of insecticides use on pollinators and sunflower yield.**

Use of insecticides to manage seed feeding insects may often conflict with pollinator activity. *Agrotis segetum* Schiff, *Agrotis ypsilon* Hfn, *Plusia orichalcea* F. *Nezara viridula* L. and *H.armigera* are major pests of sunflower in Kenya (Khaemba and Mutinga, 1982). Insecticides are toxic to pollinators and have been linked to be one of the causes of decline of honeybees

(Allen- Wardell *et al.*, 1998). Kevan (1975) found that a forest near blueberry fields that was sprayed with Fenitrothion had several dead honeybees, reduced number of foraging honeybees and that the yield of the blue berries reduced. Pankiw and Jay (1992) found that sprayed honeybees colonies gained less weight, collected less pollen and had low hive and foraging bee populations. Dimethoate was found to repel honeybees from apple flowers for at least two days after treatment (Danka *et al.*, 1985). Deltamethrin has been found to affect the homing behaviour of foraging honeybees (Vandame *et al.*, 1995). Bee recovery from the insecticide poisoning is slow due to their low fecundity, hence presents possibility of extinction (Tepedino, 1979). However, there is no documentation of bee resistance to insecticide. Little research has been done to evaluate the effect of insecticides on sunflower pollinators and the subsequent yield. Considering the fact that most growers have not actively adopted honeybees and other pollinator conservation as part of their sunflower production system, effects of insecticide toxicity maybe manifested in the low sunflower seed yields.



## CHAPTER THREE

### GENERAL MATERIALS AND METHODS

#### 3.1 Research site

The research was conducted in Kilome Division within the semi arid areas of Makueni District during the long rains, 2004 and short rains, 2005. The site is along the Nairobi- Mombasa road at an altitude of 1400 m above sea level; latitude of 1°54'S and longitude 37° 40'E. It falls within the Lower Midlands Agro-ecological zone 4 (LM 4). Lower Midlands Agro-ecological zone 4 (LM 4) is a marginal cotton zone with an annual average rainfall of less than 250 mm per annum and annual mean temperature of 21-24°C. This climatic zone is fair for cotton, maize, pigeon peas, sisal and sunflower (Jaetzold and Schimdt, 1982). Makueni District has a high potential for honey production due to the existing multiflora vegetation and warm temperatures that are required by honeybees for their activities.

#### 3.2 Experimental materials

Sunflower hybrid 8998 used in the study was obtained from Kenya Seed Company. This is a variety that is promoted by the Ministry of Agriculture in conjunction with Bidco Oil Refineries Limited. Dimethoate and Karate, which are commonly used insecticides in sunflower production, were used to find out the effect of insecticides on pollinators and yield of sunflower. These insecticides are efficient in pest control but are categorized by the Pesticides and Products Control Board (P.C.P.B) to be toxic to the bees. At flowering the indigenous pollinators in the area visited the sunflower. Standard sweep net of 38 cm wide was used to collect floral visitors from the sunflower crop.

### **3.3 Field establishment.**

Land preparation was done during dry season using hand hoes to open up the virgin land, remove weeds and improve soil aeration. Urea was applied at the rate of 150 kg per hectare. Plots of 4 × 4 m were demarcated and three seeds of the 8998 hybrid planted at a spacing of 60 cm by 30 cm. After germination thinning was done leaving one plant per hole. Weeding was done at 2 and 4 weeks after germination while furrow irrigation was done to supplement rainfall.

Birds were kept away from the crop by bird-scarers. After maturity, the plants were left to dry for harvesting.

### **3.4 Data Analysis**

Analysis of variance was performed using Genstat Version 8 .1 (PC/Windows XP) 2005, Lawes Agricultural Trust (Rothamsted Experimental Station). Wherever the F-test was significant, Least Significance difference (LSD) test was used to separate the treatment means at 95 % significance level wherever (Ott, 1988).

## References

- Allen-Wardell, G., P. Bernhardt, R. Bitner, A. Burquez, S. Buchmann, J. Cane, P.A. Cox, V. Dalton, P. Feinsinger, M. Ingram, D. Inouye, C.E Jones, K. Kennedy, P. Kevan, H. Koopowitz, R. Medellin, S. Medellin-Morales, and G. P. Nabhan (1998). The potential consequences of pollinator declines on the conservation of biodiversity and stability of food crop yields. *Conservation Biology* 12 (1) 8-17.
- MoA (2003). Crop Development Division Annual Report. Ministry of Agriculture, Kenya.
- CBS (2004). Economic Survey by Central Bureau of Statistics, Ministry of Planning and National Development, Kenya.
- Arya, D. R.; Sihag, R. C.; Yadav, P. R. (1994). Diversity, abundance and foraging activity of insect pollinators of sunflower (*Helianthus annuus* L.) at Hisar (India). *Indian Bee Journal* 56(3/4) : 172-178.
- Avertisyan, G. A. (1965). Bee Polination of Agricultural Crops. *Hi Pchelovodstvo*: 209-248.
- Buchmann, S.L and, Nabhan G.P. (1996). The Forgotten Pollinators. Island Press, Washington, D.C.
- Danka, R.G., Collison, C.H. and Hull, L.A. (1985). Honeybee (Hymenoptera: Apidae) foraging during bloom in dimethoate -treated apple orchards. *Journal of Economic Entomology* 78:1042-1047.
- Delaplane, K.S and Mayer, D.F. (2000). Crop Pollination by bees. CABI, London United Kingdom: 129-132.
- Eardley, C.D., (2004). Taxonomic revision of the African stingless bees (Apoidea: Apidae: Apinae: Meliponi). *African Plant Protection Journal* 10(2): 63-96.
- Free, J. B. (1999). Pollination in the Tropics. *Bee keeping and Development* (51): 6-7.

- Freund, D. E. and B. Furgala (1982). Effect of pollination by insects on the seed set and yield of ten oil seed sunflower cultivars. *American Bee Journal*. 21: 648-652.
- Furgala B. (1954 a). Honeybees increase seed yields of cultivated sunflowers. *Gleanings Bee Culture* 82: 532-534.
- Heiser, C. B., Jr. (1978). Taxonomy of *Helianthus* and Origin of Domesticated sunflower. In: *Sunflower Science and Technology* : 19 : 31-53.
- Hoffmann, M. (1994). Observações sobre a polinização entomófila de *Helianthus annuus* L. em Viamão, Rio Grande do Sul. *An. Soc. Entomol. Bras.*, Londrina, Vol.23,(3): 391-397 .
- Jaetzold and Schmidt, H. (1982). *Farm Management handbook of Kenya, Vol. 11 C: Eastern Province* Ministry of Agriculture and Livestock Development and Marketing; Nairobi.
- Jyoti, J. and G. J. Brewer. (1999 a). Effect of honeybee (Hymenoptera: Apidae) pollination on sunflower hybrids. Proc. 21<sup>st</sup> Sunflower Research Workshop. Nat. Sunflower Assoc. Jan. 14-15, 1999: 103-107.
- Kearns, C.A., D.W. Inouye, and N.M. Waser.(1998). Endangered mutualisms: The conservation of plant-pollinator interactions. *Annual Review of Ecology*: 29: 83-112.
- Kevan G.P., (1975). Forest application of Fenitrothion and its effects on non-apis bees' pollinators (Hymenoptera: Apoidea) of lowbush blueberries (*Vaccinium spp*) in Southern New Brunswick, Canada. *Journal of Biological Conservation*. Vol.7, Issue 4: 301 –309.
- Mc New,K. and Bixley,S.( 2001). Sunflower Production , Uses and Exports. Briefing No. 24 2pp.

- Khaemba ,B.M.and Mutinga, M.J. (1982).Insect pests of sunflower (*Helianthus annuus L.*) in Kenya : In *Insect Sci, Applications* Vol.3,(4) : 281-286,Pergamon Press.
- Krell, R. (1986). A model for estimating pollinator efficiency and pollination requirements. *Am. Bee J.* 126(12): 831-832.
- Maheshwari, J.K., (2003). Endangered Pollinators.In *Environmental Newsletter of ISEB India*.Vol.9 (1).
- McGregor, S. E. (1976). Insect Pollination of Agricultural Crops. "Agricultural Handbook No. 496." U.S Government Printing Office, Washington D.C 411 pp.
- Moreti, A. C. De C. C.; Silva, E. C. E. D; Alves, M. L. T. M. F.; Silva, R. M. B.; Otsuk, I. P., (1993). Initial observations regarding the pollination of sunflower (*Helianthus annuus L.*) by *Apis mellifera L* Pindamonhangaba, São Paulo.
- (1988). An Introduction to statistical methods and data analysis. 3<sup>rd</sup> Edition, PWS- Kent Publishing Company: 441-446.
- Pankiw, T. and Jay, S.C.(1992). Aerially applied ultra- low- volume Malathion effects on colonies of honeybees (hymenopterapp Apoidea) *Journal of Economic Entomology* 85: 692-699.
- Putnam D. H, E.S Ophinger, D.R Hicks, B.Durgan, D.M Noetzel, R.A Meronuck, J.D Doll and E.E Schute, (1990). Sunflower *In Alternative Field Crops Manual*, A3532. Univ. of Wisconsin Ext. 8pp.
- Radford B., Nielson R., Rhodes, J., (1979). Agents of pollination in sunflower crops in the Central Darlingdowns, Queensland. *Aust. J.exp. Agricanim. Hush.*19:565-69.
- Schelotto, B. and Pereyras, N.L.(1971). An Evaluation of the Economic Significance of pollinating sunflower with Bees. *Ciencia y Abejas* 1 (2): 7-25.
- Schneiter, A.A., and J.F. Miller. (1981). Description of Sunflower Growth Stages. *Crop Sci.* 21: 901-903.

- Soares, J. (1977). Como aumentar a produção agrícola utilizando-se abelhas para polinização. *Agroquímica CIBAGEIGY*, v.19, p.4-9, 1982. VRANCEANU, A. V. *El girasol*. Madridpp Mundi-Prensa.
- Southwick, E.E.and Southwick, L.Jr.,(1992) Estimating the economic value of honeybees (Hymenoptera: Apidae) as agricultural pollinators in the United States.*Journal of Economic Entomology* 85: 621-63.
- Tepedino, V.J. (1979). The importance of bees and other insect pollinators in maintaining floral species composition. *Great Basin Naturalist Memoirs* 3: 139-150.
- Vandame, R., Meled, M., Colin, M-E. and Belzunces,L.P.(1995). Alteration of the homing-flight in the honeybees *Apis mellifera* L., exposed to sublethal doses of deltamethrin. *Environmental Toxicity and Chemistry* 14: 855-860.
- Williams, I.H.(1994).The dependence of crop production within the European Union on pollination by honey bees. *Agricultural Zoology Reviews* 6 : 229-257.

## CHAPTER FOUR

### DIVERSITY OF SUNFLOWER POLLINATORS AND THEIR EFFECT ON SEED YIELD IN MAKUENI DISTRICT, EASTERN KENYA

#### Abstract.

A field experiment was carried out in the long rains, 2004 and the short rains, 2005 to establish the diversity of sunflower pollinators and their effect on seed yield in the semi arid areas of Makueni District in Kenya. The treatments included, bagging at night and opening during the day for free accessibility by daytime pollinators, bagging during the day and opening at night for free accessibility by nocturnal pollinators, bagging throughout the flowering period to exclude all pollinators, and no bagging for free access by all pollinators. The pollinators were collected and identified and the honeybee diurnal behaviour noted.

A total of 14 insect species were observed visiting sunflower floral heads. Honeybees, *Apis mellifera* was the most frequent and important pollinator with the highest pollination efficiency index (7606) followed by the non-apis bees; *Plebeina denoiti*, *Ceratina* sp, *Heriades* sp, *Pseudoanthidium* sp. Other visitors though much lower in abundance included, two (2) species of Diptera; *Rhynchomydaea* sp and *Phytomia incisa*, six (6) species of Lepidoptera; *Danaus chrysippus*, *Belenois aurota*, *Junonia oenone*, *Byblia ilithyia*, *Junonia hierta*, *Cephonodes hylas* and one (1) species of coleopteran, *Merylis flavipes*. Peak foraging periods for honeybees and the non-apis visitors was between 10 am and 12 pm. Length of the visit per head was not significantly different at the different time periods of the day. Seed yield; number of seeds and weight of seeds per head increased by two to three times, 35 % reduction in the number of deformed seeds, and 66.7 % increase in the oil content per head in the plots exposed to pollinators compared to the plots bagged to exclude pollinators.

**Key words:** Pollinators diversity, *Apis mellifera*, and pollination efficiency index, seed yield increase.

#### 4.1 Introduction

Sunflower is an annual crop that is propagated by seed only. The world sunflower production is on the increase as the demand for the vegetable oil increases. In Kenya approximately over 7793 hectares is under sunflower production giving 8129 tonnes of seed per annum (MoA, 2003). The pollen is spinney and adapted to be transported by insects principally bees (Freund and Furgala, 1982). Honeybee pollination can increase seed yield in sunflower by 30 % and oil content of seed by 6 % in hybrid varieties (Furgala, 1979; Jyoti and Brewer, 1999a). In *Viamão* (Brazil), 96 % of the sunflower insect visitors were *Apis mellifera* (Hoffmann, 1994). Stingless bees of the sub family melliponinae are also common visitors to sunflower but are probably rarely important for cross - pollination due to low population relative to that of honeybees (Radford *et al.*, 1979). In India, Arya *et al.*, (1994) found a total of 20 insects visiting sunflower floral heads of which 12 bee species were observed and *A. dorsata* was the major pollinator of sunflower. Calmsur and 'O'zbek (1999) found a total of 42 bee species visiting sunflower in Turkey.

Different floral visitors take different time periods depending on the rewards offered by the flower. Kurennio (1957) found that honeybee visit lasted between 5.1 to 6.2 seconds on sunflower flowerhead while LarJrige and Goodman (1974) found that the average of one honeybee per flower head during anthesis could optimize seed set and that visitation time to be between 3 to 187 seconds depending on the size of a nectar resource. However, this is lower than 8 to 10 bee visits per floret proposed by Avertisyan, (1965). Kumar *et al.*, (1994) found the honeybee visit to be between 6 am and 6 pm with peaks between 9 am and 11 am. Sunflower seed yield in Argentina increased five to six times, and the oil content of the seed increased by 25 % in plots exposed to honeybee colonies as compared to plots isolated from



insects during flowering (Schelotto and Pereyras, 1971). Soares (1977) reported an increase in the sunflower productivity about 98.4 %, due to the pollination by honeybees. Experiments with honeybee pollination, developed in Brazil, demonstrated an increase of 82 % in sunflower seeds in var. Anhandy, 81% in var. Uruguay and 5 % in var. Contisol (Moreti *et al.*, 1993). Seed set has been found to be higher in sunflowers nearest to beehives (Furgala, 1954a). This indicated that, beehives should be well dispersed throughout the field to enhance honeybees' access to sunflower fields/plots for cross – pollination. However, the exact number of bees needed for maximum pollination has not been determined. Research on the number of visits for good pollination of sunflower, shows that, each floret should receive 8 to 10 bee visits and that three to five colonies per acre significantly increased yield Furgala (1954a). However, little is known on the pollinators' diversity of sunflower or other crops and the effect on the seed yield of these crops in Kenya.

#### **4.2 Materials and Methods**

A field experiment was conducted twice during the long rains, 2004 and short rains, 2005 in Makueni District, Eastern Kenya. The sunflower hybrid 8998 first planting was initiated on 14<sup>th</sup> November 2004 and the second on 15<sup>th</sup> April 2005. Four treatments were used in a randomized complete block design with plot sizes of 4 × 4 m replicated four times. The treatments were bagging at night and opening during the day for free accessibility by daytime pollinators, bagging during the day and opening at night for free accessibility by nocturnal pollinators, bagging throughout the flowering period to exclude all pollinators, and no bagging for free accessed by all pollinators. Urea was applied at the rate of 150 kgs per hectare at planting. Weeding was done at 2 weeks and 4 weeks after germination while furrow irrigation was done to supplement rainfall.

#### 4.2.1 Sunflower pollinators sampling

Sampling began at flowering and continued for 6 weeks. A standard sweep net of 38cm wide was used to collect pollinators from the sunflower crop. A pollinator was defined as an insect that approaches one or more sunflower heads and contacting the pistil and stamen while imbibing and collecting pollen. Careful observations of the pollinators were made between 8.00 am and 6.00 pm for daytime pollinators and 7.00 pm and 8.00 pm for nocturnal pollinators. Chloroform in cotton wool in a killing jar was used to kill the insects for pinning in insect boxes for further identification at the National Museums of Kenya. Bee species identification was made to the highest taxa possible using the recent identification keys by Michener, 2000. To establish average number of honeybees per flowerhead, numbers of honeybees per plot and the time taken per flower head were recorded between 8 am and 6 pm. Bees other than the honeybees were grouped together as non -apis bees. Total numbers of caterpillars (larval stages of major lepidopteran pests) per treatment were recorded to establish if honeybee visitation reduced the number of lepidopteran pests.

To determine the major sunflower pollinators, pollen from each of the major floral visitors collected were dusted using fuschin glycerine gel, treated with 5 % potassium hydroxide to remove all the organic matter, rinsed with distilled water and glacial acetic acid. The samples were then treated with fresh acetolysis mixture (1 part of  $H_2SO_4$ ; 9 parts of acetic anhydride) and then rinsed with glacial acetic acid, distilled water and alcohol. 50 % glycerol was finally added followed by 100 % glycerol and mounted on slides for identification and counting at the National Museums of Kenya (Palynology Department) using the established method by Faegri and Iversen (1975). Ranking of the pollinators was done using pollination efficiency index, identified as the product of the average flower to insect ratio per visitor species in an hour by the average number of sunflower pollen grains per floral visitor (Vithanage, 1990).

#### 4.2.2 Establishment of effect of pollinators on sunflower seed yield

Pollination cages were built using nylon mosquito netting of 1.4 mm mesh, which allows 80% brightness passage. The cages were mounted some days before flowering (R-4) and were dismantled at the end of the flowering (R-9). A sampling frame of 3 x 2 m each having 10 plants per plot were selected and tagged based on the same flag leaf size. After the physiological maturity, head diameters were measured, harvested and the seeds dried at 129 °C for three hours to moisture content of 12 % and weighed individually. Number of seeds, seed weight, and seed oil percentage per head per treatment plot were recorded. Data from the control was used to establish the levels of self – pollination of the hybrid 8998.

Percentage oil content per head was done in the second season using the alkali extraction method (Rose- Gottlieb process). The seeds were dehulled and ground, then 5g of each sample put into an extraction thimble then placed into the Soxhlet extractor. The sample was then treated with Ammonia and alcohol and the fat extracted with ether-light petroleum mixture. The solvent was then evaporated on a rotary evaporator in an air-oven at 80 °C for one hour, cooled and later weighed. The percent oil content was calculated as a percentage on dry matter basis.

Comparisons between bagging throughout and no bagging were made to determine yield gain from pollinators. Percentage increase in the number of seeds and seed weight due to pollinators was calculated as the difference in the number of seeds and seed weight between bagging throughout treatment and no bagging treatment divided by the bagging throughout yield (number of seeds and seed weight) × 100.

## 4.3 Results

### 4.3.1 Diversity of sunflower pollinators

Fourteen (14) insect pollinator species from seven (7) families and four (4) orders visited sunflower (Table 2).

**Table 2. List of the different sunflower pollinators recorded in Makueni District during long rains, 2004 and short rains, 2005.**

Species name	Order (Family: Sub family)
<i>Rhynchomydaea</i> sp Malloch	Diptera (Muscidae: Muscinae)
<i>Phytomia incisa</i> Wiedemann	Diptera (Syrphidae: Syrphinae)
<i>Merylis flavipes</i> LeConte	Coleoptera (Melyridae: Melyrinae)
<i>Apis mellifera</i> Linnaeus	Hymenoptera (Apidae: Apinae)
<i>Plebeina denoiti</i> Vachal	Hymenoptera (Apidae: Apinae)
<i>Ceratina</i> sp Latreille	Hymenoptera (Apidae: Xylocopinae)
<i>Heriades</i> sp Cresson	Hymenoptera (Megachilidae: Megachilinae)
<i>Pseudoanthidium</i> sp F's Sandanski	Hymenoptera (Megachilidae: Megachilinae)
<i>Danaus chrysi:us</i> Linnaeus	Lepidoptera (Nymphalidae: Danainae)
<i>Belenois aurota</i> Fabricius	Lepidoptera (Nymphalidae: Pierinae)
<i>Junonia oenone</i> Linnaeus	Lepidoptera (Nymphalidae: Nymphalinae)
<i>Byblia ilithyia</i> Drury	Lepidoptera (Nymphalidae: Nymphalinae)
<i>Junonia hierta</i> Trimen	Lepidoptera (Nymphalidae: Nymphalinae)
<i>Cephonodes hylas</i> Walker	Lepidoptera (Sphingidae: Macroglossinae)

Of the specimens collected honeybees *Apis mellifera* Linnaeus had the highest number of pollen grains collected from their bodies followed by the non- Apis bees. No sunflower pollen was dusted from *Merylis flavipes* L., *Ceratina* sp., *Dannus chryssipus* L., *Belenois aurata* F., *Junonia oenone* L., *Byblia ilithia* D., *Junonia hierta* T., *Cephonodes hylas* W., and *Phytomia incisa* W. Other than sunflower pollen, phaseolus pollen grains were also dusted from the *Apis mellifera* and the non- apis bees. (Table 3).

**Table 3. Mean number of sunflower pollen dusted from major sunflower pollinators.**

Species	Average number of sunflower pollen on species body	Other pollen apart from sunflower	% Sunflower pollen on species body	Average number of flower to insect ratio per hour	Pollination efficiency Index
<i>Apis mellifera</i>					
Linnaeus	1667	38	97.7	146: 32	7606
Non-apis bees	9	40	18	146: 20	66
<i>Rhynchomydaea</i>					
sp Malloch	4	1	80	146: 15	39
<i>Merylis flavipes</i>					
LeConte	0	1	0	146: 10	0

Observed insects varied in the number of flowers visits and the duration of their visits. *Apis mellifera* Linnaeus had the highest number of flower visits for the flowering period ( $P \leq 0.05$ ) compared to non-apis bees which had lower number of visits ( $P \leq 0.05$ ) (Table 4).

Variations in the number of *A. mellifera* and the non-apis bees with time of the day in the long rains, 2004 and short rains, 2005 seasons were significantly different ( $P \leq 0.05$ ). In both seasons higher populations of *A. mellifera* and non-apis bees were recorded at 10 am and 12 pm with

8.00 am and 6.00 p m having the lowest populations. However, there was high percentage for co-efficient of variation due to the diurnal differences in the number of pollinators (Table 4).

**Table 4. Mean number of *Apis mellifera* Linnaeus and non-apis bees during the long rains, 2004 and short rains, 2005.**

Time of the day	Long rains season, 2004		Short rains season, 2005	
	<i>Apis mellifera</i> L.	Non-apis bees	<i>Apis mellifera</i> L.	Non-apis bees
8.00 am	19 bc	3b	7b	2b
10.00 am	30a	5b	28a	23a
12.00 am	28 a b	10a	35a	23a
2.00 pm	26 a b c	10a	35a	24a
4.00 pm	17 c d	3b	32a	19a
6.00 pm	14 d	2b	16b	4b
<b>GM</b>	<b>22</b>	<b>5</b>	<b>25.3</b>	<b>15.8</b>
<b>P value</b>	<b>&lt;0.001</b>	<b>&lt;0.001</b>	<b>&lt;0.001</b>	<b>&lt;0.001</b>
<b>LSD</b>	<b>10</b>	<b>5</b>	<b>11</b>	<b>13</b>
<b>CV (%)</b>	<b>90.3</b>	<b>156.6</b>	<b>74.7</b>	<b>143.9</b>

Means followed by the same letter(s) in the same column are not significantly different using LSD test at 5 % level of significance.

Time taken on the flower head by *Apis mellifera* was not significantly different ( $P=0.879$ ;  $P=0.73$ ) in both the long rains, 2004 and short rains, 2005 (Table 5). Each flowerhead received one honeybee visit per day for 6 weeks after flowering. *A. mellifera* were noted visiting the flower bracts from 2 p.m collecting nectar .

**Table 5 Means of time taken (seconds) by *Apis mellifera* Linnaeus on sunflower during the long rains, 2004 and short rains, 2005.**

Time of the day	Time taken per flowerhead (seconds)	
	Long rains season, 2004	Short rains season, 2005.
8.00 am	125	110
10.00 am	132	118
12.00 am	126	121
2.00 pm	125	108
4.00 pm	128	118
6.00 pm	117	105
<b>GM</b>	<b>125</b>	<b>113</b>
<b>P value</b>	<b>0.897</b>	<b>0.73</b>
<b>CV (%)</b>	<b>35.8</b>	<b>38.7</b>

#### 4. 3.2. Effect of pollinators on lepidopteran larvae, sunflower seed yield and components.

In the long rains season, 2004, head diameter, number of seeds per head, seed weight per head and number of deformed seed per head were significantly different ( $P \leq 0.05$ ). Mean numbers of seed per head for plots only visited by diurnal pollinators and plots where all pollinators freely accessed the flowers were not significantly different ( $P \leq 0.05$ ). However, plots where pollinators were excluded had the lowest number of seeds per head (1253) Open plots had the highest seed weight while plots where pollinators were excluded had the lowest seed weight per head (397.1g). There was a double increase in number of seeds while the number of deformed seeds reduced by 20 % in plots exposed to pollinators compared to plots where pollinators were excluded. The average number of caterpillars was significantly different ( $P \leq 0.05$ ) with plots that pollinators were excluded having the highest (150.2) and open plots having the lowest number of caterpillars (59.5) (Table 6).

**Table 6 Mean number of caterpillars and sunflower seed yield during the long rains, 2004.**

Treatments	Mean number of caterpillars /head	Mean head diameter (cm)	Mean number of seeds /head	Mean number of deformed seeds /head	Mean seed weight /head (g)
Plots bagged at daytime	76.8b	16.1c	1866b	242b	484.1c
Plots bagged at night	74.5b	20.4b	2702a	356a	731.1b
Bagged throughout	150.3a	14.2d	1253c	269b	397.1d
Open Plots	59.5b	22.6a	2650a	224b	853a
GM	90.2	18.32	2118	273	616.5
P value	<0.001	<0.001	<0.001	0.003	<0.001
LSD	24.2	0.9	295.2	73.6	8.22
CV (%)	8.8	11.1	31.6	61.1	3.0

Means followed by the same letter(s) in the same column are not significantly different using LSD test at 5 % level of significance.

In the short rains season 2005, open plots had the highest head diameter (27.5 cm), highest seed weight per head (855g) and the lowest number of deformed seeds per head (145.9). Plots that were bagged throughout had the lowest head diameter (17.2 cm), lower number of seed per head but the highest number of deformed seeds per head. (Table 7). The percentage oil content per head was significantly different ( $P \leq 0.05$ ) with plots freely accessed by all the pollinators recording the highest (44.78 % per head) (Table 7). There was a two to three times increase in number of seeds and seed weight, 49 % reduction in number of deformed seeds, and a 66.5 % increase in oil content in plots exposed to pollinators compared to plots where pollinators were



excluded. The average number of caterpillars was significantly different ( $P \leq 0.05$ ) with plots where pollinators were excluded having the highest (146.5) and plots exposed to all pollinators having the lowest (61.5) (Table 7). Seasonal variation of sunflower seed yield was also noted. The long season rains, 2004 had lower yield compared to the short rains, 2005 sunflower seed yield. Generally, plots exposed to pollinators gave the highest head diameter, seed weight, and number of seeds, % oil content, and lowest number of deformed seeds (Table 7).

**Table 7. Mean number of caterpillars and sunflower seed yield during the short rains season, 2005.**

Treatments	Mean number of caterpillars	Mean head diameter (cm)	Mean number of seeds / head	Mean number of deformed seeds / head	Mean seed weight / head (g)	% Oil content/head
Plots bagged at daytime	80.8b	20.6c	1034b	123.2c	662b	32.9c
Plots bagged at night	77b	24.9b	1418a	159.7b	785a	39.2b
Bagged throughout	146.5a	17.2c	483c	286.2a	413c	26.9d
Open Plots	61.5b	27.5a	1364a	145.9c	855a	44.8a
<b>GM</b>	<b>91.4</b>	<b>22.52</b>	<b>1074</b>	<b>178.7</b>	<b>679</b>	<b>35.9</b>
<b>P value</b>	<b>&lt;0.001</b>	<b>&lt;0.001</b>	<b>&lt;0.001</b>	<b>&lt;0.001</b>	<b>&lt;0.001</b>	<b>&lt;0.001</b>
<b>LSD</b>	<b>27.5</b>	<b>1.2</b>	<b>193.1</b>	<b>27.2</b>	<b>92.9</b>	<b>4.3</b>
<b>CV (%)</b>	<b>18.8</b>	<b>4.9</b>	<b>11.1</b>	<b>5.9</b>	<b>6.6</b>	<b>7.7</b>

Means followed by the same letter(s) in the same column are not significantly different using LSD test at 5% level of significance.

#### 4.4 Discussion

In the experiment to find the diversity of sunflower pollinators *A. mellifera* was the most abundant and important floral visitor. This agrees with other research results of Moreti *et al.*, (1993) and Hoffman (1994 who found out that 80 % of sunflower pollinators' are *A. mellifera* In this study; *A. mellifera* was the most important sunflower pollinator due to high pollen count and the high pollination efficiency index. This is because as a social insect it must provide for the non-foraging individuals in the colony, hence collects more resources when foraging than solitary insects. Non-apis bees were less important sunflower pollinators due to the low sunflower pollen count, pollination efficiency index as well as their few numbers of visits.

The low sunflower pollen count may indicate that they may have visited the sunflower for nectar and not pollen and that they prefer other pollen sources than sunflower pollen. This confirms other findings of Radford *et al.*, (1979) that non-apis bees e.g the stingless bees may visit sunflower but play little role in pollination due to their low population relative to that of honeybees. *M. flavisepta* may have visited the sunflower for mating purposes, nectar and not for pollen. However, the presence of *Phaseolus vulgaris* pollen on the *A. mellifera* and non- Apis bees is an indication that bees visit a variety of plants to satisfy their dietary requirements. Dipteran visitor *Phytomyia incisa* and other lepidopteran visitors; *D. chrysippus*, *B. aurota*, *J. oenone*, *B. ilithyia*, *J. hierta*, *C. hylas* were considered nectar robbers rather than pollinators. On the other hand, *Rhynchomydaea* sp may be a potential pollinator of sunflower (Khaemba and Mutinga, 1982).

Higher populations of and non-apis bees were realized between 10 am and 4pm. This disagrees with findings by Kumar *et al.*, (1994) that *A. mellifera* peaks are between 9am and 11 pm. This indicates that sunflower nectar and pollen may be high between 10 am and 2 pm and

reduces from 4 pm and that *A. mellifera* may have evolved to forage during these times when pollen and nectar production are optimal. This agrees with Waddington (1983) that plants generally only produce nectar and pollen during specific periods of the day and insects have learned to forage when pollen and nectar production are optimal. From the findings of higher populations of *A. mellifera* from 10 am to 12 pm shows that *A. mellifera* may have evolved a control mechanism that enables it visit sunflower when nectar and pollen amounts are high and agrees with findings by Von Frisch (1967) that *Apis mellifera* has an internal clock, which enables it to effectively time its visits to flowers. However, floral visitors were attracted to the sunflower throughout the day as even low populations were recorded at 8.00 am and 6.00 pm. This confirms research findings by Free (1964) that sunflower pollen and nectar are attractive to various insect pollinators throughout the day. The visitation length per flower for *Apis mellifera* is not affected by time of the day. This agrees with other studies by Landrige and Goodman (1974) that the length of visits on sunflower ranges from 3 to 187 seconds. The long length of visitation indicates that sunflower pollen and nectar are attractive to pollinators throughout the day. The populations of *A. mellifera*, non-apis bees and other insect visitors reduced as the flowering period progressed. An average of one (1) *A. mellifera* per head per day throughout the flowering period gave higher sunflower yields. This agrees with Landrige and Goodman (1974) that one (1) honeybee per plant during anthesis can optimize yield but is lower than 8-10 visitation per head per day for the flowering season for maximum pollination proposed by Avertsyun (1965). This may be due to the fact that honeybee populations are on the decline due to fragmentation of habitat, modern agriculture especially monoculture of non-nectar bearing cereals that displace native forage and lead to loss of breeding, nesting and hibernation sites, pesticide poisoning that is common at the study area.

It is evident that insect pollination increased sunflower seed yield by over two times. These results also agrees with other findings by Moreti *et al.*, (1996), who found over 75 % increase in seed yield, and Hoffmann (1994), who found an increase of 56 % in seed yield from pollinators .The 66.5 % increase in oil content is consistent with other findings by Schelotto and Pereyras (1971) that plots exposed to pollinators had an oil increase of 66.7 % than in plots isolated from pollinators during flowering. High number of deformed kernels was noted in plots not exposed to pollinators indicating inadequate pollination. Higher number of seeds, seed weight and lower number of deformed seeds in plots exposed to pollinators than those plots where pollinators were excluded indicates that heavy honeybee visitation not only increased seed set and weight but also limited the number of caterpillars. Khalifman, (1959) found that honeybee visitation reduced egg deposition by the moths and butterflies thereby reducing damage by these pests' larval stages. It was evident that cross – pollination by floral visitors' increased sunflower seed yield(number of seeds and weight) than was realized in self - pollination. This indicates that insect pollination still increases yield in hybrid cultivars that are more self-fertile.

## References

- MoA, (2003). Crop Development Division .Annual Report. Ministry of Agriculture, Kenya.
- Arya, D. R.; Sihag, R. C.; Yadav. P. R. (1994). Diversity, abundance and foraging activity of insect pollinators of sunflower (*Helianthus annuus* L.) at Hisar (India). *Indian Bee Journal* 56(3/4): 172-178.
- Avertisyan, G. A.( 1965) .Bee Poliination of Agricultural Crops. Hi Pchelovodstvo :209-248
- Calmsur, Ö.; Özbek, H.,(1999). Pollinator bees (*Hymenoptera, Apoidea*) on sunflower (*Helianthus annuus* L.) and their effects on seed setting in the Erzurum region [Turkey]. *Turkish Journal of Biology* 23: 73-89.

- Facgri, K., and Iversen, J.(1975). Textbook of pollen analysis, Blackwell Oxford, Third Edition, 195 pp.
- Free J.B. (1964). The behaviour of honeybees on sunflower (*Helianthus annuus* L.). *Journal of Applied Ecology*, 1(10) 19-27.
- Freund, D. E. and B. Furgala. (1982). Effect of pollination by insects on the seed set and yield of ten oilseed sunflower cultivar. *American Bee Journal*. 21: 648-652.
- Furgala B. (1954 a). Honeybees increase seed yields of cultivated sunflowers. *Gleanings Bee Culture* . 82 : 532-534.
- Furgala, B., D. M. Noetzel, and R. G. Robinson.(1979). Observations on the pollination of hybrid sunflowers. Proc. IVth Int. Symp. On Pollination, Md Agric. Exp. Sta. Spec. Misc. Publ. 1: 45-48.
- Hoffmann, M. (1994). Observações sobre a polinização entomófila de *Helianthus annuus* L. em Viamão, Rio Grande do Sul. *An. Soc. Entomol. Bras.*, Londrina, v.23,n.3 : 391-397.
- Jyoti, J. and G. J. Brewer. (1999 a). Effect of honeybee (Hymenoptera: Apidae) pollination on sunflower hybrids. Proc. 21st Sunflower Research Workshop. Nat. Sunflower Assoc. Jan. 14-15, 1999: 103-107.
- Khaemba ,B.M.and Mutuku,J.Mutinga .(1982).Insect pests of sunflower (*Helianthus annuus* L.) in Kenya In : *Insect Science, Applications* Vol.3,(4) : 281-286,Pergamon Press.
- Khalifman, I. A. (1959). Heterosis in plants as the after-effects of pollination by bees (hysteresis). *Bee world* 40: 303-313.

- Kumar, R.; Chaudhary, O. P.; Lenin, J. K., (1994). Studies on the foraging behaviour of honeybees and their role as pollinators of sunflower (*Helianthus annuus* L.). *Indian Bee Journal* 56 (3/4): 207-210.
- Kurenno, N. M., (1957). An experiment in increasing effectiveness of bee pollination of sunflowers. *Pchelovodstvo* (1957) 34(9): 42-48.
- Langridge, D. F. and Goodman, R. D.,(1974). A study on pollination of sunflowers (*Helianthus annuus*). *Australian Journal of Experimental Agriculture and Animal Husbandry*, Vol. 14 (67): 201 – 204.
- Maheshwari, J.K., (2003). Endangered pollinators. In *Environmental news Newsletter of ISEB India*, Vol.9 (1).
- Michener , C.D. (2000).The bees of the world. The John Hopkins University Press. London, 877pp.
- Moreti, A. C. De C. C.; Silva, E. C. E. D; Alves, M. L. T. M. F.; Silva, R. M. B.; Otsuk, I. P.(1993). Initial observations regarding the pollination of sunflower (*Helianthus annuus* L.) by *Apis mellifera* L. Pindamonhangaba, São Paulo. *Boletim de Indústria Animal* 50(1) : 31-34.
- Radford B,Nielson R,Rhodes, J.(1979). Agents of pollination in sunflower crops in the central Darlingdowns,Queensland. *Australian Journal of Experimental Agriculture and Animal Husbandry* 19 : 565-69.
- Schelotto, B. and Pereyras,N.L.(1971). An Evaluation of the Economic Significance of pollinating Sunflower with Bees. *Ciencia y Abejas* 1 (2) : 7-25.
- Soares, J. (1977). Como aumentar a produção agrícola utilizando-se abelhas para polinização. *Agroquímica CIBAGEIGY*, Vol.19: 4-9, 1982. VRANCEANU, A. V. *El girasol*. Madrid : Mundi-Prensa.

Vithanage, H.I.N.V.(1990). The role of the European honeybee (*Apis mellifera* L.) in avocado pollination. *Journal of Horticultural Science* 65: 81-89.

Von Frisch, K. (1967). The dance language and orientation of bees. Harvard University Press, Cambridge, MA. 566 p.

Waddington, K.D. (1983). Foraging behavior of pollinators, pp. 213-239. In L. Real [ed.], Pollination biology. Academic Press, Orlando. 338 p.

## CHAPTER FIVE

### EFFECT OF INSECTICIDE USE ON SUNFLOWER (*Helianthus annuus* L.) SEED YIELD.

#### Abstract.

A field experiment was conducted during the long rains, 2004 and the short rains, 2005 in Makueni District, Kenya. Two insecticides dimethoate (Dimethoate 40 % EC) and L- cyhalothrin (Karate 1.75 % EC) were evaluated for their effect on the sunflower pollinators and seed yield. The insecticides were sprayed after flowering in the morning and evening to establish the effect of time of spray on the pollinators and seed yield.

Numbers of foraging honeybees were high in the untreated plots compared to treated plots in the short rains with no significant difference in the long rains season. Higher number of seeds, seed weight and lower numbers of deformed seeds per head were recorded in the untreated plots. However insecticides applications after flowering in the evening had higher yields compared to the morning applications. Higher numbers of deformed seeds were recorded in the insecticides application in the morning. An average of 52 % reduction in the number of seeds per head, 38 % reduction in the weight of seeds and 63 % increase in the number of deformed seeds when insecticides were applied compared to the untreated. This yield reduction may be as a result of pesticide toxicity on honeybees and that yield gain from pollinator activity may often offset the loss from seed feeders.

**Key words:** pollinators, pollination, pesticide toxicity, yield reduction.



## 5.1 Introduction

Sunflower (*Helianthus annuus* L.) is an important oil crop in the agricultural and industrial sector in Kenya. Kenya is one of Africa's leading producers with an average of 7793 hectares under sunflower production giving 8129 tonnes of sunflower annually (MoA, 2003). The bulk of the crop is grown in Western, Central and Rift Valley Provinces. Sunflower seed is mainly used for oil extraction. The oil accounts for 80 % of the value of sunflower crop and is rich in linoleic acid and vitamin E. The refined oil is used in the manufacture of paints, varnishes and plastics, canning industry, cooking and in the manufacture of margarine and other compound fats. The press cake left after processing of the oil is highly nutritious and is used as livestock feed (Putnam *et al.*, 1990).

A wide range of insects, pollinators as well as pests visit sunflower during its growth. Honeybees, (*Apis mellifera* L.), are the most important pollinators of sunflower (Freund and Furgala, 1982). Moreti *et al.*, (1993) reported an increase in sunflower productivity by about 98.4 %, due to the pollination made by honeybees. Honeybees pollination can increase seed yield in sunflower by 30 % and oil content of seed by 6 % in hybrid varieties with self-fertility (Jyoti and Brewer, 1999a). Each floret should receive 8 to 10 bee visit for optimum pollination and sunflower seed yield (Avetisyan, 1965).

Major sunflower pests in Kenya include, *Agrotis segetum* Schiff, *Agrotis ypsilon* Hfn, *Plusia orichalcea* F., *Nezara viridula* L. and *Heicoverpa armigera* (Khacmba and Mutinga, 1982). Most of these insect pests are active during pollen shed when pollinator activity is crucial for seed set. Use of insecticides is one of the strategies that are commonly used to manage seed feeding insects.

Applications of these insecticides is usually recommended during pollen and nectar shed when the pollinating agents are at their peak and therefore conflicts with pollinator activity and may have adverse effects on pollinators' population, sunflower production, as well as other crops.

Insecticides are toxic to pollinators and have been linked to the decline of honeybees. Bee recovery from the insecticide poisoning is slow due to their low fecundity hence presents possibility of extinction (Allen- Wardell *et al.*, 1998). Helson *et al.*, (1994) found *Apis mellifera* L. to be susceptible to permethrin, mexacarbate, carbaryl, aminocarb, fenitrothion and trichlorfon. Kevan (1975) found several dead honeybees and low number of foraging bees in a blueberry field sprayed with Fenitriothion, consequently the yield of the blue berries were reduced. Honeybees were repelled for at least two days from Dimethoate treated apple field (Danka *et al.*, 1985). Deltamethrin has been found to affect the homing behaviour of foraging honeybees (Vandame *et al.*, 1995) also sprayed colonies of honeybees gained less weight, collected less pollen and had low bee populations in the hive (Pankiw & Jay, 1992). Other findings by Broadley and Ironside (1980) suggested that the presence of lepidopteran larvae might not have significant effect on the seed yield. However, there is no documentation of bee resistance to insecticide. Little research has been done to evaluate the effect of insecticides on pollinators and the subsequent yield of crops. This study aimed at establishing the effect of insecticides on the sunflower pollinators and the consequent effect on yield to promote pollinator conservation as a component of sunflower production.

## 5.2 Materials and Methods

A field experiment was conducted twice during the long rains, 2004 and short rains, 2005 in Makueni District, Eastern Kenya. The sunflower hybrid 8998 first planting was initiated on 14<sup>th</sup> November 2004 and the second on 15<sup>th</sup> April 2005. Five treatments in a randomized complete block design (RCBD) with plot sizes of 4 × 4 m replicated thrice and two insecticides; dimethoate

(Dimethoate 40 % EC) and L-cyhalothrin (Karate 1.75 % EC) and a control were evaluated for their effect on sunflower pollinators and seed yield. Urea was applied at the rate of 150 kgs per hectare at planting. Weeding was done at 2 weeks and 4 weeks after germination while furrow irrigation was done to supplement rainfall. Insecticides sprays were done at the R- 5 phenological stage (when the flowerheads are completely opened) in the evening and morning at a concentration of 700 g of a.i./ha (12 ml/ 10 l of water) and 300 g of a.i./ha (16 ml /10 l of water) for Dimethoate and Karate respectively.

Honeybees' data were collected daily from each plot from the time of spraying for five (5) days at 2- hour interval from 8.00 am to 6.00 pm. Number of foraging honeybees per treatment were recorded. Sampling frame of 3 m x 2 m each having 10 plants per plot were selected and tagged based on the same flag leaf size and used to compare yields (number of seeds, seed weight per head, head diameter) from the different treatments. Heads were harvested after physiological maturity (R-9) and the diameters measured. The achenes per head were counted then dried at 129°C for 3 hours to a moisture content of 12 % and weighed individually. Data from the control (untreated) was used to establish the benefit of pollinators over the seed feeding insect pests. Percentage increase in seed number and weight due to no insecticide use was calculated as the difference in number of seed and weight of seed per head between untreated and the insecticides applications  $\times 100$ .

### 5.3 Results

Mean numbers of foraging honeybees per treatment were not significantly different ( $P > 0.05$ ) among treatments. However, head diameter, number of seeds per head, weight of seeds per head, and the number of deformed seeds were significantly different ( $P < 0.05$ ) at the different insecticides application times (Table 8).

**Table 8 Means of sunflower seed yield during the long rains season, 2004 of different insecticides sprayed at different spray regimes.**

Treatments	Mean no. of honeybees per treatment (5 days)	Head Diameter (cm)	Mean number of seeds per head	Mean number of deformed seeds per head	Mean seed weight (g) per head
Karate sprayed morning	5.0	13.4 d	1241 c	309 b	446.9 d
Dimethoate sprayed morning	5.2	15.9 c	1242 c	594 a	391.5 e
Control	8.2	22 a	4278 a	219 c	916.9 a
Karate sprayed evening	6.9	16.8 b	1502 b	222 c	694 b
Dimethoate sprayed evening	5.6	15.6 c	1620 b	332 b	521.8 c
Control	10.7	22.5 a	4278 a	219 c	916.9 a
<b>GM</b>	<b>7.2</b>	<b>18.3</b>	<b>2512</b>	<b>269</b>	<b>727.4</b>
<b>LSD</b>	<b>1.4</b>	<b>1.1</b>	<b>190</b>	<b>26</b>	<b>12.8</b>
<b>P value</b>	<b>0.086</b>	<b>&lt;0.001</b>	<b>&lt;0.001</b>	<b>&lt;0.001</b>	<b>&lt;0.001</b>
<b>Cv (%)</b>	<b>64.7</b>	<b>0.4</b>	<b>1.0</b>	<b>1.2</b>	<b>1.7</b>

Means followed by the same letter (s) are not significantly different using LSD test at 5 % level of significance.

The highest head diameter, number of seed per head, seed weight per head and the lowest number of deformed seeds per head were realized in the control plots where no insecticides were applied. Insecticides applications in the morning had lower head diameter, number of seeds per head, seed weight per head and higher number of deformed seeds per head when compared to evening insecticides applications. There was 67 % reduction in seed set, 44 % in seed weight per head, and 69 % increase in number of deformed seed per head when insecticides were used compared to control (untreated). Lower reductions in seed set, and seed weight per were recorded when the insecticides were applied in the evening compared to morning applications.

In the short rains, 2005, the mean number of honeybees per treatment for the first five (5) days after insecticides application was significantly different ( $P < .05$ ). Head diameter, mean number of seeds per head, number of deformed seeds and the weight of seed per head were significantly different ( $P < .05$ ). Higher number of foraging honeybees was high in the untreated plots compared to the treated plots though not highly significant ( $P = 0.048$ ). Control plots had the highest number of seeds per head, mean seed weight per head and the lowest number of deformed seeds per head. There was 36 % reduction in the number of seeds per head, 31 % reduction in seed weight per head compared to no insecticide application (Table 9). On average 52 % reduction in the number of seeds per head, 38 % reduction in seed weight per head and 63 % increase in the number of deformed seeds per head. In both long and short rains seasons, the number of seeds per head for Dimethoate and Karate were not significantly different at the different application times except for the weight and number of deformed per head. However, there was higher co-efficient of variation for the number of foraging honeybees per treatment as their numbers vary with time of the day.

**Table 9 Means of sunflower seed yield during the short rains season, 2005 of different insecticides sprayed at different spray regimes.**

<b>Treatments</b>	<b>Mean no. of honeybees per treatment (5 days) after spraying</b>	<b>Head Diameter (cm )</b>	<b>Mean number of seeds per head</b>	<b>Mean number of deformed seeds per head</b>	<b>Mean seed weight (g) per head</b>
Karate sprayed morning	5.0 d	17.4 c	1118 b	195 a	825.1b
Dimethoate sprayed morning	5.2 d	16.6 c	803 b c	194 a	487.8 d
Control	9.2 a	26.5 a	1496 a	98 b	852 b
Karate sprayed evening	6.9 c	19.3 b	1011 b	120 b	658.3 c
Dimethoate sprayed evening	5.5 d	17.4 c	1000 b	114 b	513 d
Control	10.6 a	25.9 a	1541 a	102 b	926 a
<b>GM</b>	<b>7.4</b>	<b>21.4</b>	<b>1247</b>	<b>131</b>	<b>696.5</b>
<b>LSD</b>	<b>1.4</b>	<b>1.2</b>	<b>220</b>	<b>26</b>	<b>68.7</b>
<b>P value</b>	<b>0.048</b>	<b>&lt;0.001</b>	<b>&lt;0.001</b>	<b>&lt;0.001</b>	<b>&lt;0.001</b>
<b>Cv (%)</b>	<b>64.7</b>	<b>0.9</b>	<b>12.1</b>	<b>10.8</b>	<b>3.6</b>

Means followed by the same letter(s) are not significantly different using LSD test at 5 % level of significance.

#### 5.4 Discussion

On average, no insecticides applications had the highest number of seeds per head, seed weight per head, head diameter and lower number of deformed seeds. This suggests that pollinator population; diversity and activity were higher in control - no application treatment than did those treated with insecticides. Low yield in the pesticide treatments can be attributed to the low honeybees population due to repulsion and death of the foraging honeybees and the brood as well as contamination of the nectar and pollen being carried to the hive. Dimethoate and Karate are in the toxicity class II and are toxic to honeybees with the former having a lethal dose (LD 50) of 0.12  $\mu$  g per bee. This agrees with Danka *et.al.*, (1985) findings that Dimethoate repelled honeybees in apple treated orchard for at least two days. The reduced number of foraging honeybees agrees with Pankiw and Jay, (1992) that honeybee colonies treated with Malathion had lower numbers of foraging honeybees compared to non-treated. Reduced number of foraging honeybee interfered with the pollination and subsequent seed yield of sunflower in the insecticide treated plots. Indeed, the low number of foraging bees reduced pollen and nectar collection and consequently pollination. This agrees with Avertisyan, (1965) findings that 8 to 10 honeybees are required per head per day for sufficient pollination. It is therefore evident that insecticide use resulted into higher number of deformed seeds, low number of seeds and seed weight than the option control – no insecticides use and that Karate and Dimethoate are toxic to honeybees. Insecticides applications after flowering in the evening are safer to honeybees and possibly more effective in the control of lepidoterans pests than after flowering applications in the morning. This is because at R-5 (when the florets have not fully opened) the eggs previously deposited by lepidoterans pests starts to hatch and on applications of insecticides they are killed. In some cases, evening insecticides applications

had better yield than the morning application. This may be attributed to the honeybees are not active late in the evenings hence numbers exposed to insecticide toxicity is low compared to the morning applications which coincides with foraging time. After flowering in the morning, honeybees are very active and at the same time the lepidopteran larva are actively feeding on the pollen. Applications of insecticides to kill the pests would repel or kill the foraging honeybees and other pollinators there by affecting the seed yield. Insecticides use after flowering in the evening gave better yields because by the time the honeybees visit the next day for pollen and nectar, the pests had been controlled and possibly the insecticides active ingredient would have broken down to levels that would not repel or kill the honeybees and other pollinators. When insecticides are not used, there seems to be better yields an indication that yield reduction due to seed feeding pest may be less than the potential gain from pollinators and no spray at all may have greater yield gain than use of insecticides. Damage caused to achenes with untreated plots supports results by Broadley and Ironside (1980) that suggests that sunflower plants are compensate for the damage by a number of larvae without a significant effect on yield.

## References

- Allen-Wardell, G., P. Bernhardt, R. Bitner, A. Burquez, S. Buchmann, J. Cane, P.A. Cox, V. Dalton, P. Feinsinger, M. Ingram, D. Inouye, C.E Jones, K. Kennedy, P. Kevan, H. Koopowitz, R. Medellin, S. Medellin-Morales, and G. P. Nabhan, (1998). The potential consequences of pollinator declines on the conservation of biodiversity and stability of food crop yields. *Conservation Biology*: 12 (1): 8-17.
- MoA, (2003). Crop Development Division Annual Report. Ministry of Agriculture, Kenya.



- Avertisyan, G. A. (1965) .Bee Pollination of Agricultural Crops. *Hi Pchelovodstvo* : 209-248.
- Broadley, R.H. and Ironside, D.A. (1980). Insect pests of sunflower. Part 1. Queensland *Agricultural Science Journal* 106: 25- 28.
- Danka, R.G., Collison, C.H.and Hull, L.A.,(1985). Honeybee (Hymenoptera: Apidae) foraging during bloom in dimethoate – treated apple orchards. *Journal of Economic Entomology* 78: 1042-1047.
- Freund, D. E. and B. Furgala (1982). Effect of pollination by insects on the seed set and yield of ten oilseed sunflower cultivars. *American Bee Journal*. 21: 648-652.
- Helson B.V., Barber K.N., and Kingsbury P.D., (1994). Laboratory toxicology of six forestry insecticides to forest species of bees (Hymenoptera: Apoidea) *Archives of Environmental Contamination and Toxicology* 27. (1): 107 – 114.
- Jyoti, J. and G. J. Brewer (1999 a). Effect of honeybee (Hymenoptera: Apidae) pollination on sunflower hybrids. Proc. 21<sup>st</sup> Sunflower Research Workshop. National Sunflower Association. Jan. 14-15, 1999: 103-107.
- Khaemba, B.M.and Mutinga, J.M.,(1982).Insect pests of sunflower (*Helianthus annuus* L.) in Kenya *In: Insect Science, Applications* : 3, (4): 281-286.
- Kevan G.P., (1975). Forest application of Fenitrothion and its effects on non-apis bees' pollinators (Hymenoptera: Apoidea) of lowbush blueberries (*Vaccinium spp*) in Southern New Brunswick, Canada. *Journal of Biological. Conservation*. 7: 301 –309.

- Moreti, A. C. De C. C., Silva, E. C. E., Alves, M. L. T. M. F., Silva, R. M. B., Otsuk, I.P., (1993). Observação inicial sobre a polinização do girassol (*Helianthus annuus* L.) efetuado por *Apis mellifera* L., Pindamonhangaba - SP. *Boletim de Indústrias Animal*. Nova Odessa, v.50, n.1, p.31-34 muskmelon. *Proceedings of the American Society of Horticultural Science*. 76: 455-459.
- Pankiw, T. and Jay, S.C.(1992). Aerially applied ultra- low- volume Malathion effects on colonies of honeybees (Hymenoptera: Apoidea) *Journal of Economic Entomology* 85: 692-699.
- Putnam D. H, E.S Ophinger, D.R Hicks, B.Durgan, D.M Noetzel, R.A Meronuck, J.D Doll and E.E Schute,( 1990).Sunflower *In* Alternative Field Crops Manual, A3532. Univ. of Wisconsin Ext. 8 pp.
- Vandame, R., Meled, M., Colin, M-E.and Belzunces, L.P.,( 1995). Alteration of the homing flight in the honeybees *Apis mellifera* L., exposed to sublethal doses of deltamethrin. *Environmental Toxicity and Chemistry* 14: 855-860.

## CHAPTER SIX

### GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

#### 6.1 General Discussion

The performances of hybrid variety 8998 shows that yield of sunflower hybrid are adversely affected by absence of pollinators. This study on sunflower pollinators indicates that honeybees are the primary pollinating agents. Other wild bees, the sub family megachilinae and xylocopinae are also important sunflower pollinators. The yield of sunflower hybrids is enhanced by the presence of pollinators'. It is evident that low pollinator populations would result in reduced sunflower number of seeds, seed weight, number of deformed seeds and % oil content per head. It is evident that honeybees prefer sunflower pollen and nectar to other alternative sources.

Insecticides use in the management of pests during crop bloom results into loss of yield in sunflower due to pollinators' repulsion. It is evident that potential gain from pollinators may exceed the loss due to seed feeding pests as sunflower has the ability to recover from pests attack. Applications of bee toxic insecticides should be avoided after flowering and in the morning as this coincides with pollinators foraging time. Insecticide applications done after flowering should be done in the evening. Evening applications ensures that the target pests are controlled and the residue degraded sufficiently by morning so that daytime foragers are safe. Other than repulsion, death of pollinators and yield loss, pollen and nectar contamination is avoided.

## 6.2 Conclusions

Pollinators are important in sunflower production.

The study also showed that honeybees are the most important sunflower pollinators in Makueni District, Kenya. And therefore modern beekeeping would enhance the honeybee and stingless bee population for crop and wild plants pollination in the ecosystem. Using the modern bee keeping technology e.g. the use of Kenya Top bar hive and the Langstroth bee hive, commercialization of honeybees for pollination of other crops for example coffee, beans and other fruits and vegetables may help to increase seed yield as well as source of income and employment.

Use of insecticides to control pests when sunflower is in bloom results in reduced yields. This is a blue print of what happens in the ecosystem, with other crops and wild plants that rely on the insect pollinators to set fruits and seeds. Other methods, for example, use of *Baccillus thuriensis* (Bt) a biological control method for the lepidopteran pests and the use of natural enemies for the control of seed feeding pests in sunflower should be used instead of insecticides applications.

## 6.3 Recommendations

Future research should focus on the individual pollinator contribution to sunflower pollination.

Research should focus on amount of pollen deposited on flower head per visit, nectar and pollen variation with flowering time and time of day relative to pollinator visitation.

Additional research is needed to determine the exact number of honeybee needed for maximum production of sunflower seed.

Potentiality of meniponiculture should also be considered to improve the populations of wild sting less bees and improve their pollination efficiency of crops and other wild plants. Reaserch should be carried on the possibility for the commercialization of honeybees for large scale crop

pollination for industrial crops like coffee, cotton and other horticultural crops using the modern bee keeping technology .

Review the toxicity of various commonly used insecticides to pollinators especially honeybees. Research on Integrated Pest Management (IPM), biological and botanical control methods should be encouraged to yield pests control products that are safer to pollinators. Review of economic injury levels of major sunflower pests should also be done in order to reduce insecticide use and at the same time conserve yield.

Research on the bee floral calendar for beekeeping areas in order to indicate to the beekeeper and apicultural extension workers the approximate date and duration of the blossoming periods of the important honey and pollen plants in an area and bee-forage availability for proper management of bee colonies.

There is need to compare the diversity of pollinators and other insects in the hedgerows relative to that in the farmland and compare crop yield in farms relative to the distance from forest lands in order to ascertain the benefits of conservations of forests, in agriculture.