African Crop Science Conference Proceedings Vol. 8. pp. 1149-1153
Printed in El-Minia, Egypt
ISSN 1023-070X/2007$ 4.00

Sunflower pollinators in Kenya: Does diversity influence seed yield?

M. KASINA[1], J. NDERITU[2], G. NYAMASYO[3] & M. L. ORONJE[2]
[1]Centre for Development Research (ZEF), University of Bonn. Postfasch: Walter-Flex-Str.3, 53113 Bonn Germany. Tel. +49-228-73-1715; Fax: +49-228-73-1889; jkasina@uni-bonn.de
[2]Department of Plant Science and Crop Protection, University of Nairobi, P. O Box 30197, Nairobi, Kenya;
[3]Department of Zoology, University of Nairobi, P .O Box 30197, Nairobi, Kenya;

Abstract : A field experiment was carried out in 2004 and 2005 to study diversity of sunflower (*Helianthus annuus* L.) pollinators and their influence on seed yield in Makueni district, a semi-arid area in Eastern Kenya. The crop is prefered by the local community as one of the main sources of income. Farmers do not manage pollination in any way for enhanced crop yield and hence they rely on feral pollination. Insect flower visitors were recorded and pollen was dusted in their body to aid in determining pollination efficiency index for each visitor. The influence of these flower visitors on the yield was assessed by comparing seed yield from plots that insects had access to and those to which they were denied access. In total, individuals of 6 Lepidopteran species, 5 Hymenopteran species, 2 Dipteran species and one coleopteran species were observed visiting sunflower floral heads. *Apis mellifera* L. was the most frequent visitor and had the highest pollination efficiency index. Plots which insect visitors had access produced on average 59% more seeds than plots which insect visitors were excluded. Presence of different species of visitors improved the crop yield, implying diversity is beneficial in pollination of sunflower.

Key words: *Apis mellifera*, insects, non-*Apis* bees, pollination efficiency index

Introduction

Kenya relies heavily on imports of edible oil to offset the low production levels of oil crops that cannot meet the demands of the oil factories. Sunflower is one of the main oil crops cultivated by small-scale farmers. Its production has been diminishing due to effects of pests/diseases, poor soil fertility or water stress (MOA, 2006). However, these factors have overshadowed the role of pollinators, unlike in the highly mechanized agriculture, e.g., USA, where honeybee (*Apis mellifera* L pollination is nationally recognized (Morse and Calderone, 2001). Honeybee pollination increases sunflower seed yield by 30% and oil content by more than 6% (Jyoti and Brewer, 1999). Honeybees constitute large number of the flower visitors (Hoffmann, 1994). Non-*Apis* bees are also known to visit sunflower and have been reported to improve crop yield by enhancing efficiency of *Apis mellifera* (DeGrandi-Hoffman and Watkins, 2000; Greenleaf and Kremen, 2006). Many other insect species also visit flowers of sunflower (Arya *et al*., (1994). The foraging time of a visitor on a flower usually indicates its pollinating capability.

Information about sunflower pollination and its pollinators in Eastern Kenya is scanty although many farmers depend on this crop as a main source of income. This study was therefore done to elucidate the pollinators of sunflower in the region, and assess their effectiveness to pollinate the crop, with an aim of enlightening the farmers and other stakeholders of the importance of pollination management.

Material and Methods

This field experiment was conducted during the long rain season (14 November 2004) and repeated in the short rain season (15 April 2005) at Makueni district, Eastern Kenya. Sunflower seeds (*cv*. Hybrid 8998) were sown in plots of 4 m x 4 m within a randomized complete block design with four replicates at 30 cm spacing within a row and 60 cm between rows. A 5 m alley between blocks and 2 m path between plots was maintained. All locally recommended cultural practices were adhered to.

Treatments included bagging and not bagging sunflower heads to deny and allow insect visits to the flowers. Four levels of bagging were done, each on an independent and entire plot: leaving flower heads un-bagged the whole flowering period; bagging flower heads throughout the blooming period; bagging only during the day; and, bagging only at night. Day bagging lasted from 0600 hour (h) to 1800 h while night bagging lasted from 1800 h to 0600 h.

Different flowers visitors were observed and recorded during the day from 0600 h to 1800 h. Their foraging time per bout was recorded. They were also collected to brush pollen from their body for counting and analysis. They were then ranked for their importance as pollinators using pollination efficiency index method (Vithanage, 1990).

After reaching physiological maturity, sunflower heads were harvested and their diameter were measured. Seeds were hand-threshed from the heads and dried at 129 ^{o}C in an oven for three hours to 12% moisture content. The number of seeds and their weight was recorded.

Seeds were also analyzed for oil content using soxhlet extraction procedure (Pearson, 1973).

GENSTAT statistical package ver.7 was used for data analysis. The mean values were separated by least significance difference (LSD). Analysis of variance was done and significance tested at 95% level.

Results

Diversity, abundance and pollination efficiency of flower visitors

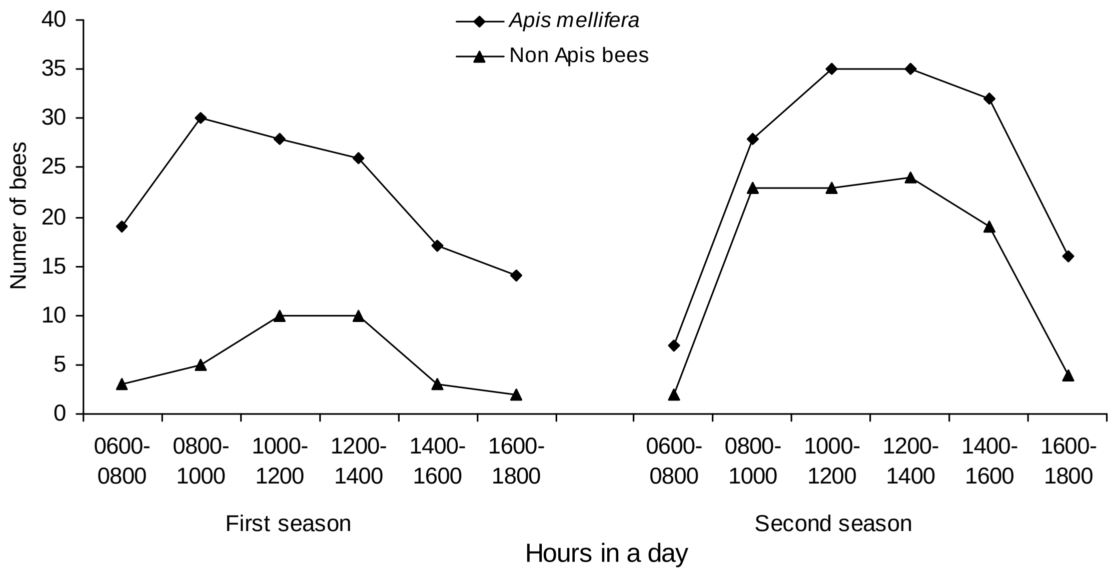
Individuals belonging to fourteen (14) insect species (4 Orders, 7 Families) were observed visiting flowers of sunflower at the study site (Table i). Most of the species belonged to the Orders Hymenoptera and Lepidoptera. Other than *A. mellifera*, there were four hymenopteran species, non-*Apis* bees, observed visiting the flowers (except for identification purposes, all non-*Apis* bees were treated as a single population). Among non-bee species, Order Lepidoptera had individuals from five genera, while Coleoptera and Diptera had representative individuals belonging to one and two genera respectively.

Table i. Observed flower visitors on sunflower crop during long rain (2004) and short rain (2005) seasons at Makueni, Eastern Kenya

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

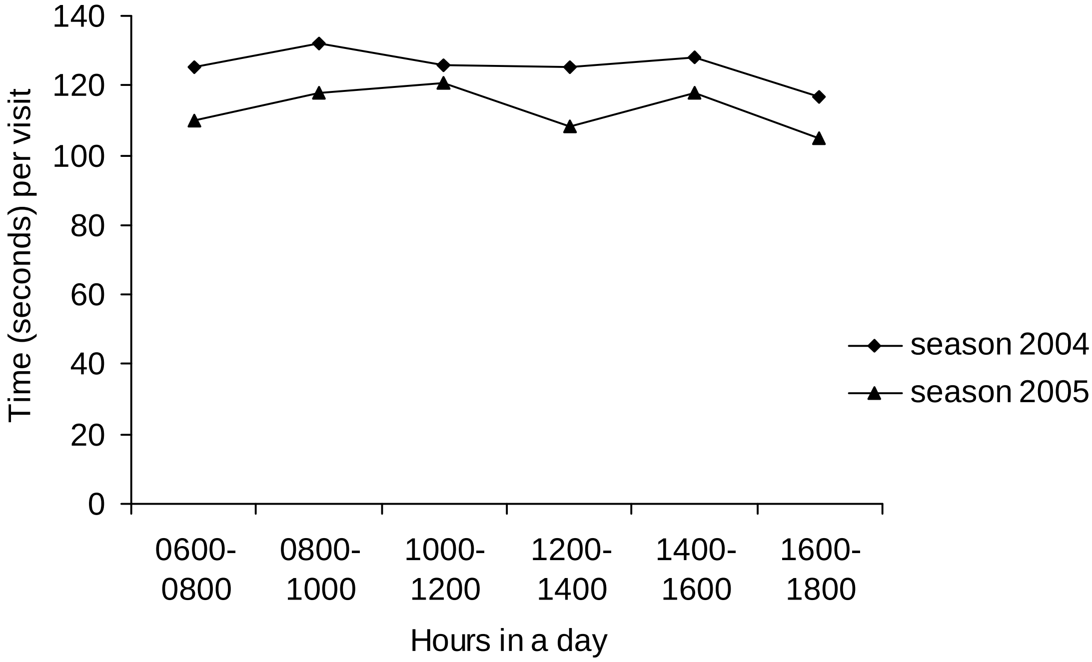
The diurnal activity density of *A. mellifera* and non-*Apis* bees on sunflowers was significantly different from 0600 h to 1800 h (P<0.05) (Figure i) but there was no significant difference on the trend due to seasonal influence. Generally, the activity density of both *Apis* and non *Apis* bees on sunflower peaked between 1000 h to 1400 h, and *A. mellifera* was the most frequent visitor. The mean number of *A. mellifera* individuals was similar in both seasons but individuals of non-*Apis* bees were significantly more in the second season than in the first season. By average, individuals of honeybees were 71.6% of all individuals of bees observed in the 2 seasons, while 76.0% of non-*Apis* bees were observed in the short rain season.

Figure i: Mean number of bees observed visiting flowers of sunflower in a day during the long and short rain season at Makueni, Eastern Kenya (2004-2005).



Apis mellifera spend an average of 108-125 seconds (s) on a flower head per each single visit (Figure ii). This was not influenced by the day-time period as well as the seasons. The non-*Apis* bee visitors were not so regular and only their numbers were recorded but not time spend per visiting bout, but they were recorded to calculate pollination efficiency index.

Figure ii: Mean time (seconds) spent by *Apis mellifera* on each visit to sunflower head at each specific day time in the long rain and short rain seasons at Makueni, Eastern Kenya.



Apis mellifera had the highest number of pollen grains collected from their bodies, followed by the non-*Apis* bees (Table ii). Some pollen was also retrieved from *Rhynchomydaea* spp. About 97.7% of the pollen retrieved from *A. mellifera* was from sunflower compared to 18% retrieved from non-*Apis* bees. Only foreign pollen was brushed from *Merylis flavipes*. Individuals of other species that were caught had no pollen on their body. Using the number of pollen dusted and flower/insect ratio per hour, *A. mellifera* was found to have the highest pollination efficiency, followed by the non-*Apis* bees.

Table 2: Mean number of pollen grains dusted from flower visitors of sunflower crop at Makueni, Eastern Kenya in 2004 and 2005.

Species	Sunflower pollen	Foreign pollen	Percent sunflower pollen on species body	Flower: insect ratio per hour	Pollination efficiency Index
Apis mellifera	1667	38	97.7	4.6	7606
Non *Apis* bees	9	40	18	7.3	66
Rhynchomydaea sp.	4	1	80	9.7	39
Merylis flavipes	0	1	0	14.6	0

Effect of flower visitors on sunflower yield

In the first season, plots with sunflower heads bagged only during the day had significantly fewer number of seeds than plots bagged only at night (P>0.05) (Table iii). This was similar in the second season although seed yield was low (Table iv). Likewise, seeds obtained from plots not bagged at all and those bagged throughout were significantly different in both seasons. Surprisingly, the number of seeds obtained from plots bagged only at night was higher than all the treatments, probably due to the effects of shaking heads during bagging and un-bagging sessions, in addition to their exposure to visitors during the day.

The diameter of the flower heads correlated positively with the number of developed seeds, as expected a priori. Un-bagged heads were wider than the bagged. The seed weight also conformed to the number of seeds recorded but on average, the weight per single seed was similar. Plots un-bagged throughout the bloom period recorded the highest seed oil content (Table iv).

Generally, seasonal variation of sunflower yield was noted. There was 53% enhancement of seed number in the long-rain season (2004) compared with 65% in the short-rain season. This corresponded to the increased number of non *Apis* bee individuals in the short-rain season. However, the change in seed weight was not significantly different.

Table 3:: Mean number of sunflower yield parameters during the long rains season, 2004 at Makueni, Eastern Kenya

Treatments	Head diameter (cm)	Developed seeds / head	Un developed seeds / head	Seed weight* / head (g)
Bagging at daytime	16.1c	1866.0b	242b	484.1c
Bagging at night	20.4b	2702.0a	356a	731.1b
Bagging throughout	14.2d	1253.0c	269b	397.1d
Un-bagged throughout	22.6a	2650.0a	224b	853.0a
P	<0.001	<0.001	0.003	<0.001
LSD	0.9	295.2	73.6	8.22

* weight of developed seeds only

Table 4:. Mean number of sunflower yield during the short rains season, 2005 at Makueni, Eastern Kenya

Treatments	Head diameter (cm)	Developed seeds / head	Un-developed seeds / head	Seed weight/ head (g)	Percent seed oil content
Bagging at daytime	20.6c	1034.0b	123.2c	662.0b	32.9c
Bagging at night	24.9b	1418.0a	159.7b	785.0a	39.2b
Bagging throughout	17.2d	483.0c	286.2a	413.0c	26.9d
Un-bagged throughout	27.5a	1364.0a	145.9c	855.0a	44.8a
P	<0.001	<0.001	<0.001	<0.001	<0.001
LSD	1.2	193.1	27.2	92.9	4.3

Discussion

Among the diverse flower visitors of sunflower at the research area, *A. mellifera* was the most abundant and important floral visitor in effecting pollination. This was confirmed from the pollen count on their body and the estimated pollination efficiency index. Their high visitation rate shows that they are reliable pollinators of sunflower in the area. Other studies elsewhere in the world have also reported the importance of *A. mellifera* in sunflower productivity e.g., Moreti *et al.*, (1993) and Hoffman (1994) who found that 80% of sunflower pollinators were *A. mellifera.* Although the non *Apis* bees had low sunflower pollen count and pollination efficiency index, their increase in number in the second season may have resulted to the increased seed yield. This implies that even though they may not play a role as main pollinators, their interaction with *A. mellifera* while foraging could improve the efficiency of *A. mellifera* (DeGrandi-Hoffman and Watkins, 2000; Greenleaf and Kremen, 2006). Most dipteran and lepidopteran visitors observed in this study were merely considered nectar thieves and had no notable effect on the sunflower seed set. Presence of sunflower pollen on the *Rhynchomydaea* spp. body implies that it could be a potential pollinator, especially when number of bees is too low (Khaemba and Mutinga, 1982). However, occurrence of foreign pollen on *Merylis flavipes* body may indicate to a possible pollination reduction or failure as such pollen may block sunflower pollen from getting into contact with the stigma. Although other bees had foreign pollen, sunflower pollen was higher and hence may not posses much threat as *M. flavipes* which didn't have any sunflower pollen.

The peak of *A. mellifera* and non *Apis* bees between 1000 h and 1400 h is different from observations reported by Kumar *et al*. (1994) who found that peak of between 0900 h and 1100 h in India, implying that peak activity density of foragers may be site/ region specific. Bees were attracted to the sunflower throughout the day probably due to the regular day-time period experienced in the research area, and favorable weather for bees. Free (1964) suggested that sunflower pollen and nectar are attractive to various insect pollinators throughout the day. Foraging time per bout by *A. mellifera* was within the Landrige and Goodman' (1974) range of 3 to 187 s and was close to the average time (150 s/head) reported by Fell (1986) who observed bees spending as much as 2089 s/head per each visit.

Apis mellifera visitors averaged one individual per flower head per day, which has been reported as sufficient in pollinating sunflower (Landrige and Goodman, 1974). It is however not possible to know whether bee population is on decline in the research area due to absence of previous studies. However, habitat fragmentation, modern agriculture especially monoculture of non-nectar bearing crops that displace native forage and lead to loss of breeding, nesting and hibernation sites or high use of pesticides was common at the study area and may contribute to low or future decline of bees, especially the non *Apis* bees that are not managed in any way.

This study showed that bee pollination increased sunflower seed number by 59%. Studies elsewhere in the world have reported increased seed yield by 56- 75% (e.g., Moreti *et al*., 1993; Hoffmann, 1994). The finding that seeds obtained from sunflower exposed to pollinators had higher oil content agrees with other studies elsewhere in the world such as Schelotto and Pereyras (1971). In this study, bees were not augmented and hence the change in sunflower yield due to change in pollination was an indicator of the importance of bee pollinators in the studied area. It may be probable that fields in the research area may not be receiving sufficient pollination, especially considering the number of undeveloped seeds obtained from plots with un-bagged sunflower. Therefore pollination management is required in the research area to improve yield performance of sunflower. This can be done by observing farming practices that do not have adverse effects on bees such as pesticide use when bees are not foraging, and landscape management to provide suitable environment for bees. Some other cost effective strategies would be to introduce trap nests where bees can emerge.

Acknowledgement

This study was part of a project funded by RPSUD. Authors are grateful to Dr. Esther Kioko and Dr. Mary Gikungu (both of National Museums of Kenya) for their technical assistance, and Mr. Jean-Pearre Sandwidi (ZEF) for translation of the abstract.

References

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**, 172-178.

Degrandi-Hoffmann, G. & Watkins, J.C. 2000. The foraging activity of honeybees *Apis mellifera* and non *Apis* bees on hybrid sunflower (*Helianthus annuus*) and its influence on cross-pollination and seed set. Journal Apicultural Research **39,** 37-45.

Fell, R.D. 1986. Foraging behaviors of *Apis mellifera* L. and *Bombus* spp. on oilseed sunflower (*Helianthus annuus* L.). Journal of Kansas Entomological Society **59**, 72-81.

Free, J.B. 1964. The behavior of honeybees on sunflower (*Helianthus annuus* L.). Journal of Applied Ecology **1**, 19-27.

Greenleaf, S.S. & Kremen, C. 2006. Wild bees enhance honeybees' pollination of hybrid sunflower. Proceeding of the National Academy of Science, USA, **103**, 13890-13895.

Hoffmann, M. 1994. Observações sobre a polinização entomófila de *Helianthus annuus* L. em Viamão, Rio Grande do Sul. An. Soc. Entomol. Bras., Londrina **23 (3)**, 391-397. [in Portuguese].

Jyoti, J. & Brewer, G.J. 1999. Effect of honeybee (Hymenoptera: Apidae) pollination on sunflower hybrids. Proc. 21st Sunflower Research Workshop. Nat. Sunflower Assoc. Jan. **14-15**, 103-107.

Khaemba, B.M. & Mutinga, M.J. 1982. Insect pests of sunflower (*Helianthus annuus* L.) in Kenya. Insect Science and its Applications **3**, 281-286.

Kumar, R., Chaudhary, O.P. & Lenin, J.K. 1994. Studies on the foraging behavior of honeybees and their role as pollinators of sunflower (*Helianthus annuus* L.). Indian Bee Journal **56**, 207-210.

Langridge, D.F. & Goodman, R.D. 1974. A study on pollination of sunflowers (*Helianthus annuus*). Australian Journal of Experimental Agriculture and Animal Husbandry **14,** 201 – 204.

Ministry of Agriculture, Kenya (MOA). 2006. Annual report of year 2005, Nairobi, Kenya.

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, Sào Paulo. Boletim de Indústra Animal **50**, 31-34.

Morse, R.A. & Calderone, N.W. 2001. The value of honey bees as pollinators of US crops in 2000. Bee Culture **128 (3),** 1-15

Pearson, D. 1973. A laboratory techniques in food analysis. Butterworth, London, UK. 315 pp.

Schelotto, B. & Pereyras, N.L. 1971. An evaluation of the economic significance of pollinating sunflower with bees. Ciencia y Abejas **1(2),** 7-25.

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.