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Effects of Insecticide Applications on Sunflower (*Helianthus annuus* L.) Pollination in Eastern Kenya

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Abstract: Two insecticides (Dimethoate and Lambda cyhalothrin), commonly used in eastern Kenya to control sunflower pests, were assessed to determine their use-effect on the crop pollination and its subsequent yield. Sunflower, cv Hybrid 8998, was planted in plots of 4x4 m in a Randomized Complete Block Design experiment. The insecticides were applied at two levels: at pre-flowering period and flowering period. Another two levels of insecticide treatment involved timing of spray applications: in the morning and in the evening. Unsprayed were maintained as control. The experiment was done in two consecutive growing seasons in 2004 and 2005. The results show that there was a significant difference in the productivity of sunflower across the different treatments. Insecticide-treated plots had lower number of developed seeds per sunflower head than the unsprayed plots. Likewise, the number of seeds per head from plots that were sprayed at pre-flowering stage had significantly higher number of seeds than from plots sprayed while at flowering stage. The sunflower-head size and the seed weight per head had similar trend as the number of seeds. The role of pollination was confirmed in the number of observed bees on each plot. Insecticide-treated plots had significantly lower number of foraging honeybees (*Apis mellifera* L.) compared with unsprayed plots. Among the insecticides, Dimethoate-sprayed plots had the least number of bee foragers. The findings suggest that insecticide application on a blooming sunflower reduces the efficiency of bees to pollinate, which results to lower yields. It is suggested that farmers should manage sunflower pests at earlier growth stages and avoid pesticide use at flowering period but instead they should use other control options that are friendly to bees.

Key words: *Apis mellifera* · dimethoate · lambda cyhalothrin · pest management · seed yield

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is an important crop for the agrarian sector and supports development of the edible oil industry in Kenya. In some areas of the country, organized groups have acquired simple technologies for oil extraction in order to add value to the commodity and hence improve their income. The locals also roast seeds for use in special occasions and ceremonies, hence serving a cultural role. Although the demand for the crop in the country is high, its production has been stagnating over the years [1], despite its potential for expansion. For example, the local production of edible oils in 2005 was a paltry US$ 2.3 million compared with imports of US$ 0.2 billion. Most of the local production was sunflower (61%), while rest was shared mainly by coconut and soybeans. The low productivity of sunflower has been blamed on the poor marketing options available to farmers, pests, as well as soil fertility [1]. These factors have masked the importance of pollination on the productivity of sunflower, which is least regarded as a limiting factor [2]. Honeybees (*Apis mellifera* L.) are the main pollinators of sunflower but current evidence suggest that non-*Apis* bees enhance the effectiveness of *A. mellifera* to pollinate the crop [3, 4]. Farmers in Eastern Kenya do not manage pollination in any way. They use insecticides as the main strategy against insect pests of sunflower throughout its

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developmental stages. Some of the pests that cause farmers to apply insecticides at flowering period belong to coleopteran, diptera, heteroptera and lepidopteran orders [5-7]. Farmers do not consider effects of such insecticides on pollinators. The many insecticide products available in the market and campaigns by the sellers, sometimes cause farmers to buy cheap ones, which in most cases are toxic to bees e.g., Dimethoate 40EC (Dimethoate®; organophosphate) and Lambda cyhalothrin 1.75 EC (Karate®; pyrethroid). Although these products carry a label showing the chemical is toxic to bees, there is no evidence in Kenya on their effects on crop pollination. In US, Dimethoate sprays were reported to reduce foraging activity-density of *A. mellifera* on apple orchards [8]. This present study was designed to examine the effects of Lambda cyhalothrin (henceforth L-cyhalothrin) and dimethoate on the honeybees foraging on sunflower and the subsequent yield. It was intended to provide strong reasons why farmers should consider bees while managing crop pests. The study was not intended to measure effectiveness of the insecticides against the pests but only on their influence on crop pollination.

MATERIALS AND METHODS

The most commonly grown sunflower variety (Hybrid 8998) was planted in a Randomized Complete Block Design and replicated three times in plot sizes of 4x4 m. A factorial combination of treatments was adopted, using three levels of insecticide applications (Dimethoate, L-cyhalothrin and control plots where no insecticide was sprayed), two levels of sunflower growth period (pre-flowering and flowering (i.e., when 50% of the sunflower had opened their heads)) and two levels of application time in a day (morning and evening) Table 1. These levels were deemed capable of capturing the variability in the spray schedules followed by farmers and that may have impact on the crop pollination. Land preparation was done manually leaving a 1 m-wide alley between plots and 5 m between blocks. Sunflower seeds were hand-sown and a spacing of 30x60 cm maintained within and between rows respectively. Planting was done on 14 November 2004 and repeated on 15 April 2005. Weeding was done regularly while drip irrigation was only done to supplement rainfall as need arose. The locally recommended rate of insecticide application was used: 400 g a.i. L^{-1} (30 ml/ 20 l water) and 17.5 g a.i. L^{-1} (50 ml/ 20 l water for Dimethoate and L-cyhalothrin respectively. The insecticides were applied using a single lever operated knapsack sprayer for each insecticide. The first sprays were applied just before sunflower heads opened. Insecticide treatments were applied once in a season. Observations of the foraging bees started one day after the final spray applications, by walking in adjacent rows to avoid disturbing the bees. This was done between 08:00 h and 18:00 h daily during the whole flowering phase. Towards the time when the seeds were ripening, the common bird-pests of seed crops were kept out of the plots as much as possible by bird-scarers. After reaching physiological maturity, sunflower heads were harvested, dried and their diameters measured. This was followed by manual threshing of seeds. The seeds were then dried to 12% moisture content before they were weighed. Yield parameters (number of seeds and their weight per head) were determined. The data were analyzed using GENSTAT statistical software version 8.1. Analysis of variance (ANOVA) was done to determine significance of the treatments at 95% level. The standard error (SE) was used as a post-ANOVA test.

Table 1: Treatments used in the determination of the effect of insecticide sprays on sunflower pollination in Eastern Kenya in 2004 and 2005

Spray application	Sunflower growth period	Application time in a day	Treatment abbreviation
Lambda cyhalothrin	Pre-flowering	Morning	LPM
		Evening	LPE
	Flowering	Morning	LFM
		Evening	LFE
Dimethoate	Pre-flowering	Morning	DPM
		Evening	DPE
	Flowering	Morning	DFM
		Evening	DFE
No spray	Pre-flowering	Morning	NPM
		Evening	NPE
	Flowering	Morning	NFM
		Evening	NFE

NB: Unsprayed plots were used as control for each set of insecticide treatment

RESULTS

The number of foraging *A. mellifera* individuals was significantly different (P<0.05) among the treatments in 2004 Table 2. Sunflower in the unsprayed plots attracted more bees compared with sunflower in the insecticide-treated plots. Among the insecticides, Karate-treated plots had higher number of foraging *A. mellifera* than the Dimethoate-treated plots. Sunflower sprayed at

Table 2: Mean number of *A. mellifera* observed visiting blooming sunflower and yield parameters recorded after its harvest in Makueni, Eastern Kenya in 2004

Treatment	*A. mellifera*	Head size (cm)	Developed seeds/head (No.)	Undeveloped seeds/head (No.)	Seed weight/ head (g)
LPM	6.68	15.6	1962	198	793.8
LPE	6.89	16.2	2214	154	816.5
LFM	5.02	13.4	1241	309	446.9
LFE	6.89	16.8	1502	222	694.0
DPM	6.63	17.5	2283	292	678.6
DPE	6.57	19.8	1888	292	712.2
DFM	5.18	15.9	1242	594	391.5
DFE	5.63	15.6	1620	332	521.8
NPM	9.54	22.2	3812	201	929.4
NPE	8.71	22.4	3821	201	929.4
NFM	8.22	22.0	4278	219	916.9
NFE	10.73	22.5	4278	219	916.9
SE	0.69	0.55	95	13	6.4
$P_{(95\%)}$	0.086	0.001	0.001	0.001	0.001

Table 3: The mean number of *A. mellifera* observed visiting blooming sunflower and yield parameters measured after its harvesting in Makueni, Eastern Kenya in 2005

Treatment	*A. mellifera*	Head size (cm)	Developed seeds/head (No.)	Undeveloped seeds/head (No.)	Seed weight/ head (g)
LPM	6.77	19.8	1381	128	666.8
LPE	7.19	22.2	1668	137	825.1
LFM	5.02	17.4	1118	195	658.3
LFE	6.93	19.3	1011	120	746.7
DPM	6.83	19.3	1171	160	583.0
DPE	6.82	20.8	1418	133	693.1
DFM	5.18	16.6	803	194	487.8
DFE	5.52	17.4	1000	114	513.6
NPM	9.73	25.0	1221	102	853.0
NPE	8.99	26.5	1496	92	852.0
NFM	9.17	26.5	1496	98	852.0
NFE	10.60	25.9	1541	102	926.0
SE	0.70	0.60	110	13	34.9
$P_{(95\%)}$	0.048	0.001	0.001	0.001	0.001

pre-flowering period had significantly more *A. mellifera* visits than those sprayed at flowering period. Similarly, significant ($P<0.05$) number of *A. mellifera* individuals visited sunflower that was sprayed in the evening compared with that was sprayed in the morning. The number of developed seeds, their weight and the sunflower-head size measurements were reflective of the number of observed *A. mellifera* foragers in each treatment. These parameters were significantly different across the treatments ($P<0.05$), with unsprayed plots having the highest, while Dimethoate-treated plots had the lowest, except in plots treated during flowering period, which had more developed seed number than L-cyhalothrin-treated plots applied at the same period. Sunflower from plots sprayed at pre-flowering stage recorded higher values than those sprayed while at flowering stage. Sunflower in the plots sprayed in the evening had also higher values than those sprayed in the morning. In contrast, more undeveloped seeds were obtained from sunflower in the plots sprayed with Dimethoate, where insecticides were applied at flowering period and also where insecticides were sprayed in the morning.

The number of foraging *A. mellifera* individuals in flowers of sunflower and the crop productivity in 2005 were similar to the 2004 findings (Table 3). However, unlike in 2004, the numbers of developed seeds obtained from sunflower in Dimethoate-treated plots at flowering period were significantly lower than those obtained from L-cyhalothrin-treated plots at the same period. The number of *A. mellifera* individuals and the size of sunflower head were higher in 2005 than in 2004 but not significant. Likewise, the seed number and weight was not significantly different ($P>0.05$) in the two years although it was higher in 2004, probably due to less rain received in 2005.

DISCUSSION

The findings from this study suggest that the number of foraging *A. mellifera* individuals on flowering sunflower was influenced by the insecticide sprays. *Apis mellifera* is generally known worldwide as the main pollinator of sunflower. In addition, there is evidence that non-*Apis* bees that forage on sunflower enhance efficiency of *A. mellifera* to vector sunflower pollen [3, 4]. The *A. mellifera* foraging visits were positively correlated with the resulting seed yield. It is therefore not surprising that the number and weight of sunflower seeds obtained from sprayed plots was lower than of seeds obtained from unsprayed plots, which had higher number of foraging *A. mellifera*. Although non-*Apis* bee visitors are not reported, any management of sunflower that favors *A. mellifera* would also support non-*Apis* bees' population growth. Application of insecticides at pre-flowering period had less effect on foraging *A. mellifera* compared with sprays at flowering period. This is probably because at pre-flowering period, bees are yet to visit the crop. Once the crop reaches flowering period, the effects of the insecticides that had been applied earlier are at minimal due to the normal degradation process. Insecticide applications during flowering, however, have higher impact on bees, especially through direct contact. Bees may also get poisoned by imbibing water (dew) on the sprayed plants [9]. The toxic effects of the insecticides are also higher compared to sprays at pre-flowering period. Evening applications, even at flowering period, reduced the impact of the insecticide on bees because of the large exposure period before bees visit the crop unlike the morning applications. Although L-cyhalothrin is toxic to bees, it has short persistence. This is the reason why pre-flowering and evening sprays had lower effects on bees compared with the effects recorded when it was applied at flowering period and in the morning. Dimethoate has longer persistence and it is considered highly toxic to bees [10], which were confirmed by the low number of *A. mellifera* foragers in plots where it was sprayed. Studies done in other parts of the world also reported a negative effect of Dimethoate on *A. mellifera* visits. For example, Dank *et al.* [8] reported fewer *A. mellifera* visiting Dimethoate-treated apple trees compared with the untreated trees. However, they found no significant difference in the number of *A. mellifera* visitors on trees sprayed at pre-flowering phase compared with the unsprayed trees. Although farmers in Eastern Kenya use these insecticides as the main mechanism for pest control, the results from this study show that pre-flowering and flowering sprays are not economically viable. The unsprayed plots had significantly more developed seeds that were heavier compared with seeds that were obtained from the insecticide-treated plots. This evidence explains that bee pollination can offset expected damage of pests at flowering period. Therefore farmers should consider controlling pests in early stages of sunflower development and avoid pesticide usage that can interfere with crop pollination. If it is a must, farmers should only insecticides that are not toxic to bees that degrade in short period and have less pre-entry period. Evening applications are most preferred. This would also encourage build up of natural enemies of the pests, e.g., anthocorids [7, 11, 12] that are able to reduce pest build up. Other management practices such as mechanical control, use of resistant varieties, etc. can be practiced by farmers during flowering periods of sunflower.

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