3. DIVERSITY, ABUNDANCE AND ACTIVITY OF INSECT POLLINATORS IN COMMERCIAL SUNFLOWER FIELDS

3.1. INTRODUCTION

A wide range of insects visit the head (capitulum) of commercial sunflower to seek nectar and / or pollen as food. Others use the capitulum as mating site or shelter. During their various activities on the capitulum insects play a more or less important role in transferring pollen to the stigmas.

In their study on insect pollinators, Radford et al. (1979a) recorded only insects likely to play a role in crop pollination. Apart from being inactive, soft-bodied insects and small beetles were omitted as it was believed that little pollen adheres to their smooth bodies. In the present study all insects visiting the sunflower capitulum were recorded in order to gain an overview of the diversity and abundance of the different taxa. This was essential in order to conduct behavioral studies and to determine the relative contribution of the different taxa to the pollination of commercial sunflower, since a very high abundance of a poor pollinator may be more important than a good pollinator in low numbers.

3.2. MATERIAL AND METHODS

The survey of insects visiting sunflower heads was undertaken on the Springbok Flats on commercial fields of ca. 200 hectare. During the flowering period of the cultivar SO323, all insects visiting the head were recorded for three consecutive seasons. One or two specimens of unknown species were collected for identification, and this removal sampling can certainly be negated in the results. Honeybee colonies were introduced to the sunflower fields by migratory beekeepers at a density of 1 colony per hectare.

Counts of the abundance and diversity of insects per 100 heads receptive for pollination, were made. Rows of sunflowers were selected at random. While walking down a row, insects were recorded on the adjacent row. This procedure was followed so as not to disturb the insects. These counts were carried out at hourly intervals throughout the day and on consecutive days during bloom. General environmental and behavioural data were recorded for all insects visiting the head, by recording observations onto a table using single character abbreviations (table 1).

To compare the insect pollinator fauna with other regions, limited surveys were undertaken in the Western Transvaal (Hartbeesfontein, Klerksdorp district) and on the University of Pretoria Experimental Farm (Pretoria). In the Western

Transvaal with its more arid climate, honey production on sunflower is not as profitable. Commercial beekeepers do not migrate their hives to this area. On the other hand, farming practices are characterized by more restricted use of insecticides and large tracts of uncultivated lands. Consequently more potential natural nesting sites are available for both solitary bees and honeybees.

At the University of Pretoria Experimental Farm, an apiary with 40-50 hives is kept within 400 meters of thirty experimental plots (100 m^2 or 0.01 ha) of commercial sunflower. These plots were surrounded by similar ones of various crop plants and weeds. During the sunflower bloom a dearth of nectar is experienced in Pretoria resulting in an over-abundance of honeybees on the sunflowers, foraging for both nectar and pollen.

The same method for observations of diurnal insect activity was repeated for nocturnal insects. An electric torch was used as source of light. It was found that this weak light neither attracted nor disturbed the insects on the heads. This was also the experience of Radford _et al_. (1979a) working in Australia.

Definitions related to Data sheet for strip counts.

Surrounding forage: This includes commercial crops and weeds which flower at the same time as the target crop to be pollinated, and attracts pollinators. These crops and weeds are regarded as competitors (See Chapter 7, page 95).

Flowering stage of field: Because the disk florets on the sunflower capitulum open in whorls on consecutive days, it is important to indicate the stage of development of capitula in the field. The object of the study was to determine the agents and degree of pollination. Records of flowering stages were therefore determined by the percentage florets on heads that were receptive for pollination (two stigmatic lobes unfolded). The flowering stage was indicated on a 1 - 100% scale, 100% indicating that all florets had opened. A peak in receptive florets is reached at 50% flowering stage. The flowering stage was determined by a visual estimate of the total sunflower field.

Range of honeybees: This denotes the minimum and maximum number of honeybees on heads, within the sample of 100 receptive heads.

Nectar robbers: Denotes honeybees which visit wilting, already pollinated florets with no contact to florets with available pollen. These foragers have learned to visit these florets only and don't contribute to pollination.

TABLE 1. FIELD RECORD DATA SHEET WITH ABBREVIATIONS FOR STRIP COUNTS OF POLLINATORS ON 100 SUNFLOWER HEADS RECEPTIVE FOR POLLINATION.

Date: ____

Locality: ____

Time: ____

Temperature: ______________________________________

General weather: __________________________________

Surrounding forage: _______________________________

Flowering stage: __________________________________

Natural colonies/Hives: ____________________________

Distance from hives: ______________________________

Honeybees: _______________________________________

Range of honeybees: _______________________________

Honeybee nectar robbers: ___________________________

Anthophoridae: ____________________________________

Megachilidae: _____________________________________

Halictidae: _______________________________________

Wasps and ants: ___________________________________

Diptera: ____

Lepidoptera adults: _______________________________

Lepidoptera larvae: _______________________________

Spotted maize beetle: _____________________________

Other beetles: ____________________________________

Hemiptera: ____

Other insects: ____________________________________

TABLE 1. (CONTINUED). FIELD RECORD DATA SHEET WITH ABBREVIATIONS FOR STRIP COUNTS OF POLLINATORS ON 100 SUNFLOWER HEADS RECEPTIVE FOR POLLINATION.

General weather	
r - raining	a - directly after rain
s - sunshine	o - cloudy
Surrounding forage	
b - urban area	e - competitor nectar source
l - agricultural activity	f - competitor pollen source
z - natural pasture	
Records of all flower visitors	
n - nectar collector	d - dusted with pollen
p - pollen collector	v - accidental visitor
t - pollen and nectar	w - nectar robber
Other abbreviations	
c - natural colonies	
h - hives	
Unknown species indicated as follows: 5	

Statistics

The standard error of the mean (S.E.) (Van Ark, 1981) was calculated as:

$$S.E. = \frac{S.D.}{\sqrt{n}}$$

S.D. = standard deviation

n = number of observations

3.3 RESULTS

3.3.1. Diversity and abundance of diurnal insects

The results of the survey of insects on commercial sunflower heads near Settlers, Pretoria and Hartbeesfontein for three consecutive years are presented in table 2. The mean numbers of the various insect taxa per hundred heads for the three sites are summarized in table 3, while the parameters which may have influenced the differences between sites are tabulated in table 4.

From the results it is clear that the sunflower capitulum provided food for a wide range of insects (table 2. See also Appendix A, p 136). A mean number of 45 individual insects was counted on 100 sunflower heads at Settlers, while the mean at Pretoria and Hartbeesfontein, was 147 and 64 respectively (table 3). This low presence of insects at Settlers can be attributed to the intensive crop production and chemical crop protection activities in that region (table 4). Honeybees were the most abundant anthophilous insects in all three regions. At Settlers (70,71%) and Pretoria (86,69%) these high representations were the result of introduced, managed hives and that at Hartbeesfontein (46,5%) represented the natural honeybee population.

TABLE 2-1. DIVERSITY AND ABUNDANCE OF DIURNAL ANTHOPHILOUS INSECTS IN COMMERCIAL SUNFLOWER FIELDS AT SETTLERS, 1985 -1987.

Taxon		Total insects 153x100 heads	$\bar{x}$ / 100 heads (SE)	Range / 100 heads	% of total
Hymenoptera					
Apis mellifera		4836	31,61 (±1,36)	0-71	70,71%
Honeybee nectar robber		116	0,76 (±0,07)	0-4	1,70%
Anthophoridae	(3 spp.)	21	0,14 (±0,04)	0-3	0,30%
Megachilidae		0	-	-	-
Halictidae	(5 spp.)	19	0,12 (±0,04)	0-4	0,28%
Wasps and ants	(5 spp.)	20	0,13 (±0,07)	0-10	0,29%
Diptera	(10 sp)	41	0,26 (±0,05)	0-3	0,60%
Lepidoptera					
Adults	(7 spp.)	10	0,06 (±0,02)	0-2	0,14%
Larvae					
Heliothis armigera		703	4,59 (±0,51)	0-34	10,28%
Trichoplusia orichalcea		35	0,23 (±0,10)	0-12	0,52%
Coleoptera					
Astylus atromaculatus		479	3,12 (±1,07)	0-88	7,00%
Other Coleoptera	(7 spp.)	23	0,15 (±0,05)	0-5	0,34%
Hemiptera	(7 spp.)	530	3,47 (±0,30)	0-23	7.75%
Neuroptera	(1 sp.)	4	0,03 (±0,02)	0-2	0,06%
Mantodea		0	-	-	-
Orthoptera	(2 spp.)	2	0,01 (±0,01)	0-1	0,03%
Total	(50 species)	6839	$\bar{x}$: 45		100%

TABLE 2-2. DIVERSITY AND ABUNDANCE OF DIURNAL ANTHOPHILOUS INSECTS IN EXPERIMENTAL SUNFLOWER PLOTS AT PRETORIA, 1985-1987.

Taxon		Total insects 67x100 heads	$\bar{x}$ / 100 heads (SE)	Range / 100 heads	% of total
Hymenoptera					
<u>Apis mellifera</u>		8425	127,65 (±4,43)	23-228	86,69%
Honeybee nectar robber		372	5,63 (±1,12)	0-30	3,82%
Anthophoridae	(3 spp.)	4	0,06 (±0,03)	0-1	0,04%
Megachilidae	(2 spp.)	8	0,12 (±0,05)	0-2	0,08%
Halictidae	(4 spp.)	88	1,31 (±0,26)	0-11	0,91%
Wasps and ants	(7 spp.)	32	0,50 (±0,10)	0-4	0,32%
Diptera	(9 spp.)	148	2,24 (±0,24)	0-7	1,52%
Lepidoptera					
Adults	(3 spp.)	22	0,33 (±0,07)	0-2	0,24%
Larvae					
<u>Heliothis armigera</u>		20	0,30 (±0,09)	0-4	0,21%
<u>Trichoplusia orichalcea</u>		0	-	-	-
Coleoptera					
<u>Astylus atromaculatus</u>		548	8,30 (±2,85)	0-120	5,64%
Other Coleoptera	(4 spp.)	12	0,18 (±0,07)	0-4	0,12%
Hemiptera	(5 spp.)	38	0,58 (±0,11)	0-4	0,39%
Neuroptera		0	-	-	-
Mantodea	(1 sp.)	1	0,02 (±0,02)	0-1	0,01%
Orthoptera	(1 sp.)	1	0,02 (±0,02)	0-1	0,01%
Total	(42 species)	9719	$\bar{x}$: 147		100%

TABLE 2-3. DIVERSITY AND ABUNDANCE OF DIURNAL ANTHOPHILOUS INSECTS IN COMMERCIAL SUNFLOWER FIELDS AT HARTBEESFONTEIN, 1985-1987.

Taxon		Total insects 39x100 heads	$\bar{x}$ / 100 heads (SE)	Range / 100 heads	% of total
Hymenoptera					
Apis mellifera		1263	26,60 (±2,42)	10-70	46,50%
Honeybee nectar robber		19	0,49 (±0,12)	0-2	0,70%
Anthophoridae	(3 spp.)	8	0,21 (±0,08)	0-2	0,30%
Megachilidae		0	-	-	-
Halictidae	(2 spp.)	19	0,49 (±0,11)	0-2	0,70%
Wasps and ants	(3 spp.)	10	0,26 (±0,15)	0-5	0,37%
Diptera	(7 spp.)	27	0,69 (±0,12)	0-3	1,00%
Lepidoptera					
Adults	(2 spp.)	2	0,05 (±0,04)	0-1	0,07%
Larvae					
Heliothis armigera		622	15,95 (±1,51)	0-38	22,90%
Trichoplusia orichalcea		0	-	-	-
Coleoptera					
Astylus atromaculatus		406	10,41 (±2,91)	0-75	14,95%
Other Coleoptera	(2 spp.)	3	0,08 (±0,04)	0-1	0,11%
Hemiptera	(6 spp.)	337	8,64 (±1,39)	0-33	12,40%
Neuroptera		0	-	-	-
Mantodea		0	-	-	-
Orthoptera		0	-	-	-
Total	(28 species)	2716	$\bar{x}$: 64		100%

TABLE 3. SUMMARY OF THE MEAN NUMBERS OF ALL INSECT TAXA PER HUNDRED SUNFLOWER HEADS AT SETTLERS, PRETORIA AND HARTBEESFONTEIN, 1985-1987.

Taxon	Settlers	Pretoria	Hartbeesfontein
Hymenoptera			
Apis mellifera	31,61	127,65	26,60
Honeybee nectar robber	0,76	5,63	0,49
Anthophoridae	0,14	0,06	0,21
Megachilidae	-	0,12	-
Halictidae	0,12	1,31	0,49
Wasps and ants	0,13	0,50	0,26
Diptera	0,26	2,24	0,69
Lepidoptera			
Adults	0,06	0,33	0,05
Larvae			
Heliothis armigera	4,59	0,30	15,95
Trichoplusia orichalcea	0,23	-	-
Coleoptera			
Astylus atromaculatus	3,12	8,30	10,41
Other Coleoptera	0,15	0,18	0,08
Hemiptera	3,47	0,58	8,64
Neuroptera	0,03	-	-
Mantodea	-	0,02	-
Orthoptera	0,01	0,02	-
Total	45	147	64

TABLE 4. POSSIBLE PARAMETERS AFFECTING THE DIVERSITY AND ABUNDANCE OF INSECT POLLINATORS IN COMMERCIAL SUNFLOWER FIELDS

Parameter	Locality		
	Settlers	Pretoria	Hartbeesfontein
Main bloom period	Mar - Apr	Jan	Jan - Feb
Average rainfall	moderate	moderate	low
Feral colonies	very few	very few	abundant?
Managed beehives	present	present	absent
Food competition	moderate	moderate	moderate
Pesticides	high	absent	absent
Bird predation	absent	absent?	present?
Arthropod predation	low	low	moderate
Average field size	>200 ha	1-2 ha	50-100 ha

The overall diversity of insect species differed in the three regions not only because of climatic differences, but also because of agricultural practices, such as pesticides applications and extensive cultivation. The number of solitary bees in an area can be regarded as a good parameter for the intensiveness of agricultural practices in that region, as these bees are very susceptible to disturbances in the environment and pesticides. At Pretoria, where the ecologically diverse peri-urban surroundings provide a more lasting environment, a mean of 1,49 solitary bees per hundred heads was recorded. At Hartbeesfontein a mean of 0,7 / 100 heads was found and at Settlers 0,26 / 100 heads (table 3). The most abundant taxa, excluding the Hymenoptera, were Diptera, bollworm larvae (Heliothis armigera Hübner) and spotted maize beetle (Astylus atromaculatus Blanchard) (table 3). In the three regions studied, these taxa also showed differences in numbers.

The presence of honeybee nectar robbers was negligible in Settlers (mean 0,76 / 100 heads and 1,7% of total insects) and Hartbeesfontein (mean 0,49 / 100 heads and 0,7% of total insects). On the other hand, honeybee nectar robbers were the third most abundant group at Pretoria (mean 5,63 / 100 heads, and 3,82% of total insects). This could be the result of honeybees being abundantly present in an area with little forage.

3.3.2. Activity and behaviour of diurnal insects

Activity and behaviour of all insects excluding honeybees is presented in this section, as honeybees are discussed in detail in Chapter 4, page 34.

The long-tongued solitary bees (Anthophoridae and Megachilidae) visited sunflowers for both nectar and pollen. On windless days with temperatures above 15°C these bees were active on the sunflower heads throughout the day. In their search for nectar and pollen, they moved very rapidly over florets of the same head, making contact with a number of stigmas. The movement of these bees between capitula was also very rapid. Generally they did not forage systematically from head to adjacent head but rather skipped five to ten heads or even rows.

The short-tongued Halictidae visited the sunflower only for pollen, as their probosces could not reach the nectar in the tubular sunflower florets. These small bees have to walk over stigmas to reach the next floret. Halictids tend to forage from head to head within the same row.

The most abundant Diptera family on sunflower were the hover flies (Syrphidae). Most of the observed Diptera often sat very still on the capitulum for long periods, and it was difficult to determine whether they were seeking food, perching or simply resting. In the early morning they mainly seemed interested in collecting dew on the florets. Their movements between heads were indiscriminate and no pattern was observed.

While feeding, adult Lepidoptera perched with only their legs in direct contact with the florets. They were not consistent in visiting flowers and most often flew 10 - 50 meters before settling again. Lepidopterous larvae can be

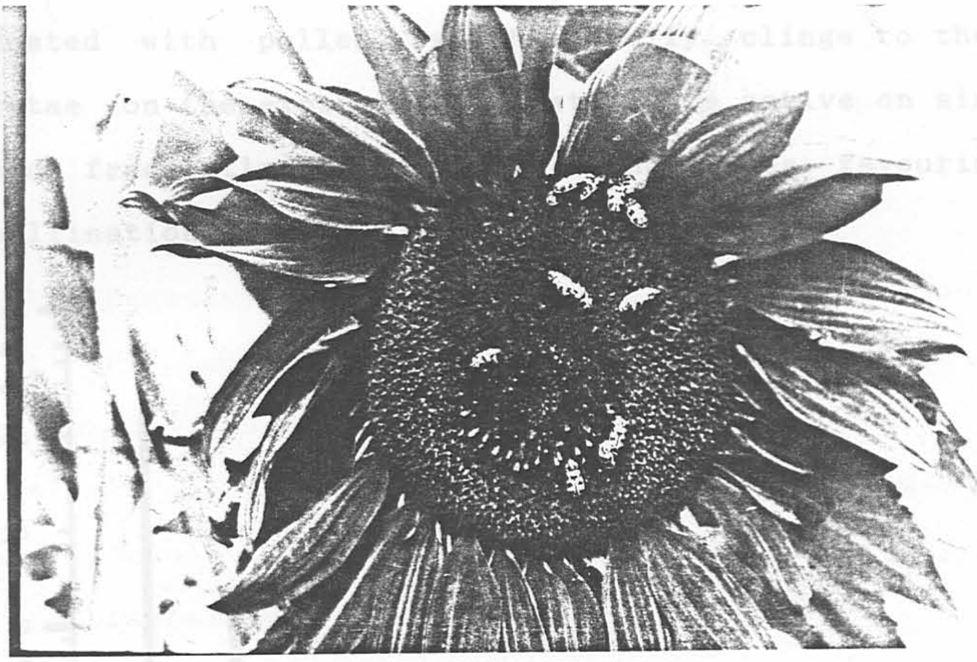

Fig. 4. Spotted maize beetle on a sunflower head at Pretoria, 1986.

regarded as practically passive pollinators, as their movement on the head is extremely slow. No movement between heads was observed.

At the three study sites the numbers of spotted maize beetles was directly influenced by the time of the year. Beetles were present in low numbers and as scattered individuals from January to February. From February to April they formed breeding aggregations with as many as 30 - 40 beetles on a single head (fig. 4). The distribution of spotted maize beetles in a field is given in fig. 5. As adults are pollen feeders they are almost always very well dusted with pollen, which readily clings to the numerous setae on the exosceleton. Beetles are active on single heads and frequently fly between heads thus favouring cross-pollination.

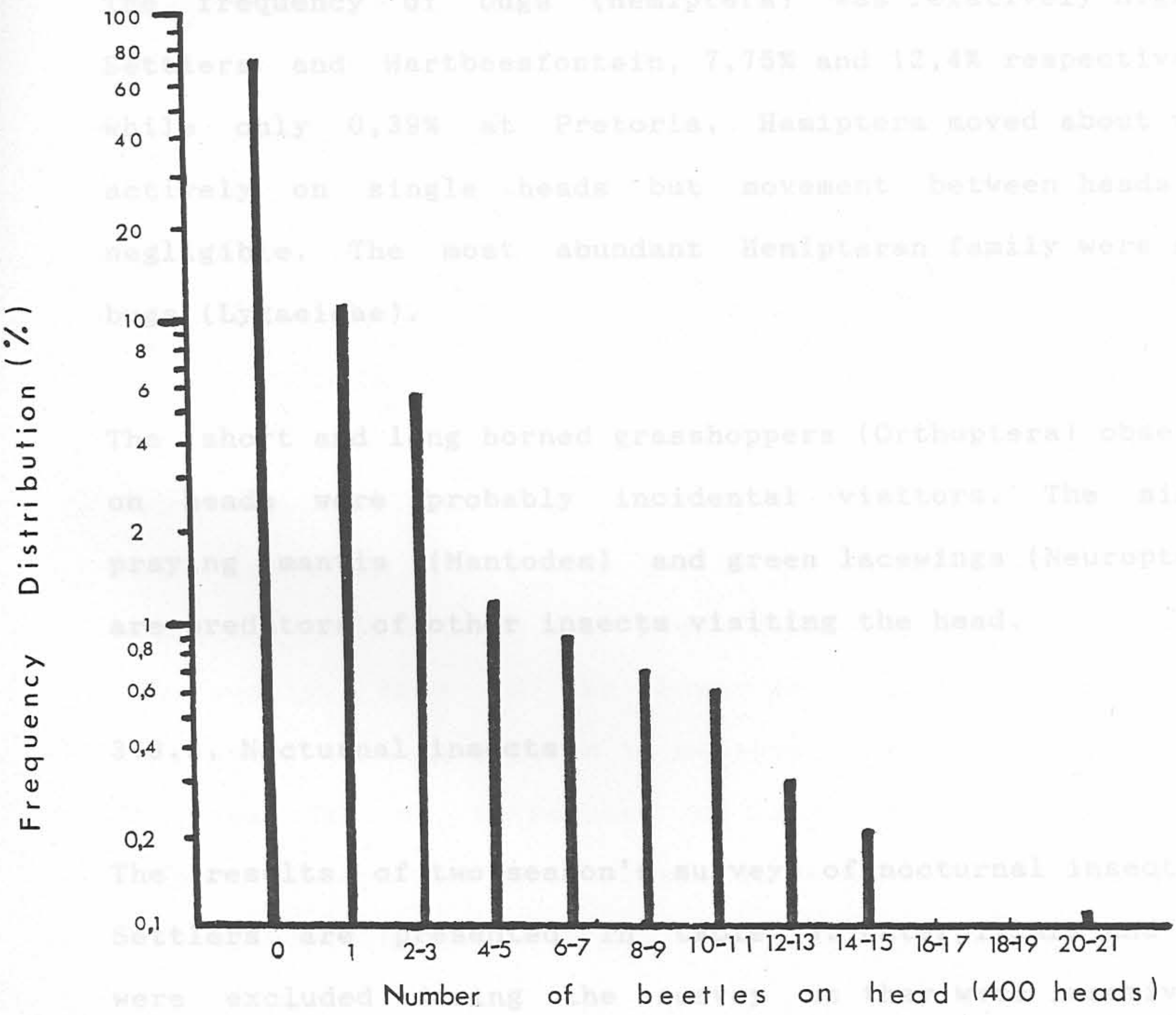

Fig. 5. The distribution of spotted maize beetles in a sunflower field early in the season at Hartbeesfontein, 1987.

The fruit chafers (Cetoniinae) and oil beetles (Meloidae) encountered on heads, behaved very similarly to spotted maize beetles. The flea beetles (Alticinae, Chrysomelidae) and seed weevils (Bruchidae) found on capitula were very small and made little or no contact with stigmas.

The frequency of bugs (Hemiptera) was relatively high at Settlers and Hartbeesfontein, 7,75% and 12,4% respectively, while only 0,39% at Pretoria. Hemiptera moved about very actively on single heads but movement between heads was negligible. The most abundant Hemipteran family were seed bugs (Lygaeidae).

The short and long horned grasshoppers (Orthoptera) observed on heads were probably incidental visitors. The single praying mantis (Mantodea) and green lacewings (Neuroptera) are predators of other insects visiting the head.

3.3.3. Nocturnal insects

The results of two season's surveys of nocturnal insects at Settlers are presented in table 5. Caterpillars and bugs were excluded during the survey as they were inactive at night.

Fourteen species of insects were recorded, of which eleven species were moths (Lepidoptera). <u>Heliothis</u> <u>armigera</u> was the most abundant species (76,63%), with a mean of 6,3 moths / 100 receptive heads. The abundance of the other species was very low, less than 5%, with means 0,02 - 0,41 / 100 flowering heads. Honeybees were the second most abundant taxon (5,16%). These honeybees were however neither active between heads nor on the head itself, because they had been caught foraging in the field after the sun had set.

H. armigera moths were most active between dusk and 20h00. The number of moths then declined with no activity after 24h00 (fig. 6).

3.4. DISCUSSION

According to Faegri and Van der Pijl (1979) the honeybee, Apis mellifera, is a more flexible pollinator than solitary bees. It is active all year round and visits flowers continually. This is why honey production and pollination efficiency with honeybees in managed hives is so successful. Colonies can be introduced at any time to a region where crops flower and will respond, weather permitting, by maximum activity.

Honeybee nectar robbers form an easily recognized group although their numbers are small. However, they contribute little to pollination. These honeybees are just as flower constant as other foragers and will only visit flowers that

TABLE 5. NOCTURNAL INSECTS COUNTED ON 100 RECEPTIVE HEADS OF COMMERCIAL SUNFLOWER AT SETTLERS, 1986-1987.

Taxon	Insects on 46x100 heads	$\bar{x}$ / 100 heads (SE)	Range / 100 heads	% of total
LEPIDOPTERA				
Noctuidae				
Heliothis armigera	282	6,13 (±0,80)	0-17	76,63%
Agrotis segetum	15	0,33 (±0,08)	0-2	4,08%
Agrotis spinifer	10	0,22 (±0,07)	0-2	2,72%
Mythimna loreyi	5	0,10 (±0,05)	0-2	1,36%
3 unidentified species	19	0,41 (±0,13)	0-3	5,16%
Sphingidae (2 spp.)	5	0,10 (±0,05)	0-1	1,36%
Arctiidae				
Utetheisa pulchella	1	0,02 (±0,02)	0-1	0,27%
Pyralidae				
Zinkenia fascialis	10	0,22 (±0,07)	0-2	2,72%
HYMENOPTERA				
Apis mellifera	19	0,41 (±0,11)	0-3	5,16%
ORTHOPTERA				
Tettigoniidae (1 sp.)	1	0,02 (±0,02)	0-1	0,27%
PHASMATODEA				
Phasmatidae (1 sp.)	1	0,02 (±0,02)	0-1	0,27%
Total: 14 species	368	$\bar{x}$: 8		100%

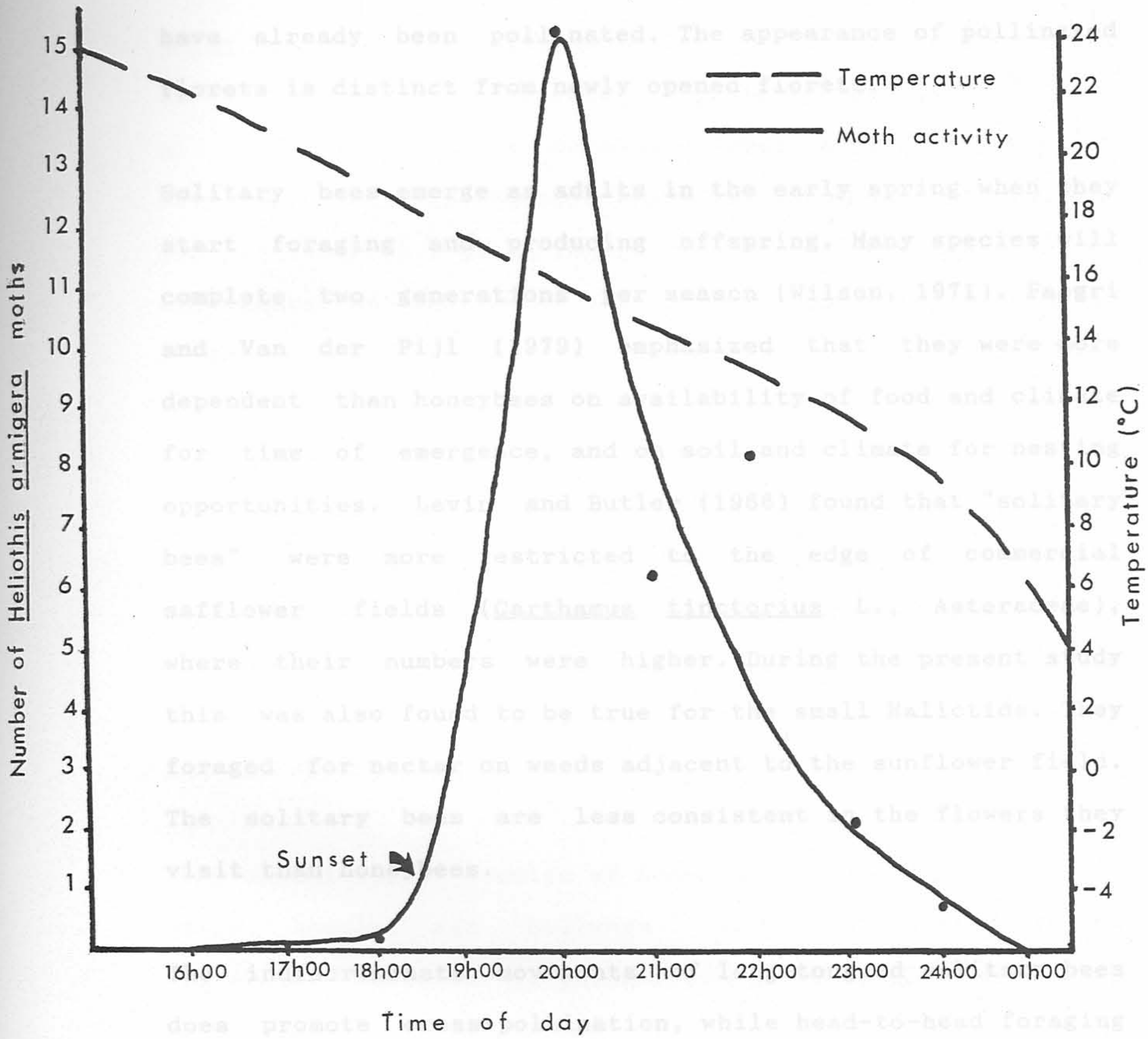

Fig. 6. Activity of Heliothis armigera moths in sunflower fields at Settlers, 1986-1987.

have already been pollinated. The appearance of pollinated florets is distinct from newly opened florets.

Solitary bees emerge as adults in the early spring when they start foraging and producing offspring. Many species will complete two generations per season (Wilson, 1971). Faegri and Van der Pijl (1979) emphasized that they were more dependent than honeybees on availability of food and climate for time of emergence, and on soil and climate for nesting opportunities. Levin and Butler (1966) found that "solitary bees" were more restricted to the edge of commercial safflower fields (Carthamus tinctorius L., Asteraceae), where their numbers were higher. During the present study this was also found to be true for the small Halictids. They foraged for nectar on weeds adjacent to the sunflower field. The solitary bees are less consistent in the flowers they visit than honeybees.

The indiscriminate movements of long-tongued solitary bees does promote cross-pollination, while head-to-head foraging within the same row, as observed in the Halictidae may pose limitations in hybrid seed production of sunflower.

The larvae of both species of Lepidoptera observed are phytophagous and regarded by Annecke and Moran (1984) as agricultural pests. Their abundance on sunflower do not reach levels making chemical control necessary. Though

Heliothis armigera moths can pollinate sunflower, their role as pollinators is regarded as insignificant by Radford et al. (1979a). This is because of small populations and low levels of activity. Factors which influence moth populations and activity in a given region are field size, plant density and phase of the moon (Radford et al., 1979a). Another factor which could have an indirect influence, is pesticide application to surrounding crops.

Small beetles and other small insects have a negligible influence on seed set (Radford et al., 1979a). Morphologically the Hemiptera are not suitable as pollinators. Most species have a hard, smooth exosceleton with little or no setae to which pollen can cling (Faegri and Van der Pijl, 1979).

The actual relative roles of honeybees, house flies, spotted maize beetle and bollworm larvae in pollination of commercial sunflower is further discussed in Chapter 5, page 66.

The total absence of carpenter bees (Xylocopa spp., Anthophoridae) in this study is significant. It was believed that if carpenter bees were significantly as pollinators in sunflower fields, they could possibly be encouraged in and around fields. Herrmann (personal communication, 1985), made only one observation of two Xylocopa sicheli Vachal, in a small sunflower field (less than one hectare) at the Horticultural Research Institute, Roodeplaat. Hurd (1978) reached the conclusion that Xylocopa spp. do not feed on sunflower, though both sunflower and carpenter bees are indigenous in North America. Carpenter bees do use sunflower stalks as nesting sites, however. Goel and Kumar (1981) recorded two species of carpenter bees working on sunflower in India, although in very small numbers.

Working in South Africa in lucerne fields, Watmough (1987) found that carpenter bees were not all that easy to establish as pollinators. Within two years after the initial attempt to concentrate nesting sites around lucerne fields, emigration of these bees took place on such a scale that establishing had to start again. Futhermore their season of activity did not correspond with the main sunflower bloom period which is from February to April (Watmough, personal communication 1987).

The honeybees observed at night on sunflower heads could not play a role in pollination because of their inactivity. According to Radford et al. (1979a) those honeybees were all dying. It is known that African honeybees do forage at night (Fletcher, 1978), but it is not known whether they could successfully spend the night outside the hive. Night temperatures of under 6°C were recorded at Settlers during the sunflower bloom.