5. THE IMPORTANCE OF CERTAIN INSECTS AS POLLINATORS OF COMMERCIAL SUNFLOWER

5.1. INTRODUCTION

Studies by various researchers confirm that the absence of insect pollinators, particularly honeybees, has an adverse influence on the seed set and yield of commercial sunflower (Diez, 1978; Freud and Furgala, 1982; Krause and Wilson, 1981; Langridge and Goodman, 1974). In South Africa, preliminary studies by Birch et al. (1985) also indicate a loss in yield with inadequate numbers of pollinators.

After reviewing the literature, Hurd et al. (1980) emphasized that honeybees should be considered as the most important pollinators of commercial sunflower. They stated that the role of solitary bees should, however, not be ignored, and deserved more attention. The role of insects other than honeybees, has been acknowledged by various researchers, but no studies have been carried out to determine their actual importance. Mostly accounts of their diversity and activity are given (Arnason, 1966; Furgala, 1954; Langridge and Goodman, 1974; Palmer-Jones and Forster, 1975; Parker, 1981). Radford et al. (1979a) have conducted studies to determine the influence of American bollworm moths (Heliothis armigera) on seed set in Australia, where they are the major nocturnal flower visitors. They concluded that their role as pollinators is insignificant.

The two most important methods of studying the influence of honeybees on seed set are the single head bag method (Krause and Wilson, 1981 and Robinson, 1980) and the caged plot method (Birch et al., 1985; Langridge and Goodman, 1974; Palmer-Jones and Forster, 1975). Both these methods have advantages as well as disadvantages. With the single head bag method only the influence of the exclusion of pollinators can be assessed. The greatest disadvantage of this method is mechanical pollination occurring as a result of the bag touching the florets in windy conditions. Parker (1981) used this method to study the amount of pollination accomplished by a single bee visit. The influence of a specific insect pollinator species can be studied with the caged plot method, while its main disadvantage is the uncertain influence of shading of the plants. It was decided to use the caged plot method in this study because it offered the widest range of applications.

Radford et al. (1979a) made a thorough investigation into the effect of windborne pollen on yields of plants inside cages and those outside. In their research they found 105 sunflower pollen grains per m^{-3} air outside the cage and 115 inside. This windborne pollen inside the cages did not have any influence on the percentage seed set. Putt (1940) and Birch (personal communication, 1988) reached the same conclusion.

After consulting the information recorded during the survey on activity and abundance of insect pollinators (Chapter 3, page 11), it was decided to investigate the pollination efficiency of honeybees, spotted maize beetles, house flies and American bollworm larvae on seed set. Honeybees are believed to be the most important pollinators, while the actual role of the other three species has not been investigated. These specific treatments were compared with those without insect pollinators, as well as with open-pollinated control treatments in the field.

5.2. MATERIAL AND METHODS

Caged plot experiments were carried out in fields of the commercial cultivar SO323 near Settlers on the Springbok Flats during 1986 and 1987. The 200 ha fields were planted on unfertilised black Arcadia soils on 1986-01-10 and 1986-12-10 and started flowering on 1986-03-13 and 1987-02-11 respectively. A final stand of ca. 30 000 plants per hectare was achieved. Production colonies of honeybees were introduced by migratory beekeepers at a density of one colony per hectare.

Insect proof cages were erected at random in the field, each cage covering a similar number of plants of more or less the same size and stage of development (physiological evenness). The cages were made from slotted angle iron, measuring 4,4m long x 3,0m wide x 2,2m high and covered with white nylon parachute netting, providing less than 20% shade. The mesh size of the parachute netting only provided entrance for insects less than 1mm wide. Each cage covered three rows of sunflowers, with 10 to 15 plants in each row. The plots were trimmed at both ends of the rows to avoid contact of sunflower heads with the netting. Three replicates were used for each of the six treatments.

Cages were provisioned as follows: 1. Cages provided with a small colony of honeybees, consisting of three frames of brood (fig. 21). Water was supplied in the cage. 2. Cages provided with 150 spotted maize beetles, which had previously been collected from maize tassels. The beetles were left to settle on the heads by themselves. 3. Cages in each of which 50 house flies was released. 4. Cages where 3 one day old American bollworm larvae were placed on each sunflower head, just after the ray florets had opened. 5. Cages with no insect pollinators. All insects having been removed by hand before bloom. 6. The sixth treatment was an uncaged, open-pollinated 4,4 x 3,0 area in the same sunflower field, which served as a control.

The cages were erected before the ray florets had started opening. The netting was left on the cages until the

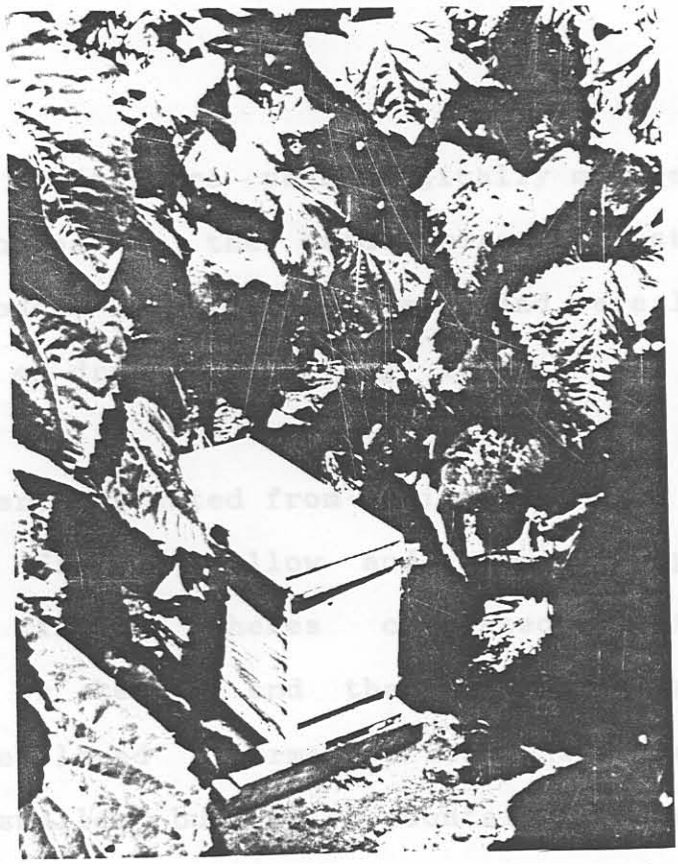

Fig. 21. Small colony of honeybees inside an insect proof cage.

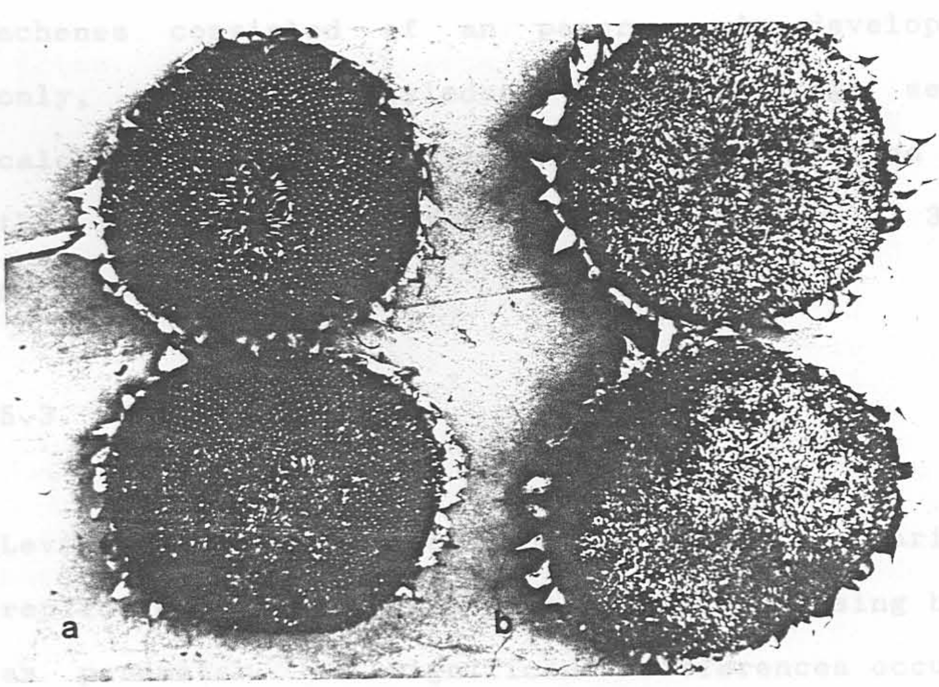

Fig. 22. Sunflower heads harvested from plants inside insect proof cages. a. treatment with honeybees as pollinators, b. treatment with no pollinators.

sunflower heads were physiologically mature (6 weeks after bloom). Thereafter the heads were harvested by hand to prevent rodent or any other damage and were left for another four weeks on drying-racks (fig. 22).

Achenes were harvested from individual heads by hand and the number of filled, hollow and under-developed achenes were counted. Filled achenes consisted of the oil-bearing cotyledon or kernel and the surrounding pericarp. Hollow achenes developed a normal pericarp, which occasionally was somewhat smaller but which contained no cotyledon. These achenes also had a much lower mass and were blown out with the chaff during mechanical harvesting. Under-developed achenes consisted of an papery under-developed pericarp only, with no cotyledon. The percentage seed set was calculated, and the filled achenes were weighed to calculate the crop yield as for the achieved stand of 30 000 plants per hectare.

5.3. RESULTS

Levin's test was used to determine the variance between replicates of each treatment beforehand, using head diameter as parameter. No significant differences occurred between replicates of treatments. For further statistical analysis of data, the replicates of each treatment could thus be combined.

TABLE 9. STATISTICAL RESULTS OF VARIOUS CAGE EXPERIMENTS WITH DIFFERENT INSECT POLLINATORS AT SETTLERS, 1986-1987.

Pollinator		Head diameter (mm)	Number of achenes per head		
			filled	hollow	papery
Control (Open field)	Mean	165,6	1286,4	82,6	402,2
	S.D.	20,2	310,0	76,5	204,8
	S.E.	1,9	29,4	7,2	19,4
	Max.	210,0	1944,0	603,0	1044,0
	Min.	120,0	568,0	21,0	79,0
	n	111	111	111	111
Honeybees	Mean	158,8	1270,7	74,2	425,8
	S.D.	23,4	327,1	72,4	151,3
	S.E.	02,7	37,7	8,3	17,4
	Max.	215,0	2106,0	419,0	982,0
	Min.	110,0	521,0	11,0	160,0
	n	75	75	75	75
	L. Sign.		0.9094 NS	0.1220 NS	0.0985 NS
Spotted maize beetles	Mean	166,9	1313,0	72,9	343,7
	S.D.	24,3	331,5	68,0	182,3
	S.E.	02,7	37,3	7,6	20,5
	Max.	230,0	2445,0	372,0	957,0
	Min.	110,0	596,0	9,0	68,0
	n	79	79	79	79
	L. Sign.		0.7869 NS	0.0577 NS	0.0498 NS
House flies	Mean	167,8cm	718,8	499,5	676,0
	S.D.	24,1	401,5	469,2	448,7
	S.E.	02,7	46,3	54,1	51,8
	Max.	240,0	1448,0	1771,0	1884,0
	Min.	120,0	14,0	32,0	51,0
	n	75	75	75	75
	L. Sign.		0.0000 **	0.0000 **	0.0000 **
American bollworm larvae	Mean	148,3	870,5	74,9	1021,6
	S.D.	23,8	317,8	48,3	355,2
	S.E.	02,6	34,6	5,2	38,7
	Max.	195,0	1550,0	319,0	2150,0
	Min.	100,0	155,0	17,0	356,0
	n	84	84	84	84
	L. Sign.		0.0000 **	0.7682 NS	0.0000 **
No insect pollinators	Mean	152,0	723,2	199,9	698,0
	S.D.	19,5	294,9	308,4	404,2
	S.E.	02,2	34,0	35,6	46,6
	Max.	195,0	1221,0	1573,0	1986,0
	Min.	100,0	129,0	13,0	152,0
	n	75	75	75	75
	L. Sign.		0.0000 **	0.0160 NS	0.0000 **

Level of significance (L. Sign.): NS - Not significant at 1% level.
** - Significant at 1% level.

n - number of flower heads.

Bonferroni's t-test was first used to determine whether data obtained from the different treatments could be compared with one another. Head diameter was used as the variable (table 9). Based on the means of treatments, honeybee, spotted maize beetle and house fly treatments did not differ significantly from the uncaged control treatments. Treatments with bollworm larvae and without pollinating insects showed a significant difference from the control plots at a 1% level. In the control plots the mean head diameter was 165,6mm, while for cages without insects and cages with bollworm larvae, the mean diameter was 152,0 and 148,3mm respectively.

The Mann-Whitney U-test was used to show the level of significance between the results of the five treatments against the uncaged controls. In terms of mean number of filled, hollow and under-developed seeds, the treatments with honeybees and spotted maize beetles did not differ significantly from the control at a 1% level (table 9). House flies and bollworm larvae treatments differed significantly at a 1% level from the control, except for the number of hollow seeds in the bollworm larvae treatment. In the treatment without pollinating insects the number of filled and under-developed seeds differed significantly from the control, while the number of hollow seeds did not differ significantly (table 9).

TABLE 10. SEED SET, MASS AND YIELD IN CAGE EXPERIMENTS WITH DIFFERENT INSECT POLLINATORS AT SETTLERS, 1986-1987.

Pollinator	Plants per cage	Achenes per head			% Seed set		Yield (kg/ha)**
		filled	total	mass (g)*			
Control (Open plots)	33	1286	1772	59,98 (46,64)	Mean	72,6	1799
					S.D.	11,1	
					S.E.	1,05	
					Max.	92,5	
					Min.	36,2	
					n	111	
Honeybees	34	1270	1763	61,98 (48,80)	Mean	72,0	1859
					S.D.	7,22	
					S.E.	0,84	
					Max.	90,1	
					Min.	50,2	
					n	74	
Spotted maize beetles	36	1313	1728	72,01 (54,85)	Mean	75,9	2160
					S.D.	9,52	
					S.E.	1,07	
					Max.	94,2	
					Min.	53,8	
					n	79	
House flies	33	718	1890	43,66 (60,81)	Mean	37,9	1309
					S.D.	18,68	
					S.E.	2,15	
					Max.	76,9	
					Min.	1,2	
					n	75	
American bollworm larvae	33	870	1967	38,60 (44,36)	Mean	44,2	1158
					S.D.	12,25	
					S.E.	1,33	
					Max.	66,8	
					Min.	8,4	
					n	84	
No insect pollinators	34	723	1621	40,70 (56,28)	Mean	44,6	1221
					S.D.	19,07	
					S.E.	2,21	
					Max.	80,4	
					Min.	6,6	
					n	74	

* Mass of 1000 filled seeds in parentheses.
** Yield as achieved with 30000 plants per hectare.

The percentage seed set (table 10) in treatments with spotted maize beetle was slightly higher than those of the control, while those for honeybees were very much the same. Percentage seed set in house fly, bollworm larvae and no pollinating insect treatments differed significantly at a 1% level from the control. The large standard deviation (S.D.) and error of the mean (S.E.) reflected large variation in percentage seed set between individual heads of this commercial cultivar (table 10).

The number of plants per cage, filled seeds, and seed mass was used to calculate the yield of each treatment (table 10). The level of significance of the treatments and the control is illustrated in table 9, and is again clearly indicated by the differences in yield of treatments (table 10). The yield is dependent on plant density, number of filled seeds and mass of filled seeds. To evaluate the differences in mass of filled seeds of treatments, it is best to recalculate to mass of a 1000 filled seeds (given in parenthesis in table 10). It can be seen clearly that commercial sunflower compensate well for the loss in number of filled seeds where seed set was poor, by producing larger seeds. However, this compensation is not altogether adequate to make up for the poor seed set as shown by the achieved yields.

The yield increase in the open-pollinated control plots against treatments without insect pollinators was 47%. Honeybees produced a 52% yield increase when compared with the treatment without insect pollinators. The yield increase of spotted maize beetles and house flies was 76% and 7% respectively, while a 5% decrease was obtained with American bollworm larvae.

5.4. DISCUSSION

A decrease in seed set in sunflower treatments without pollinating insects was recorded by various researchers (Birch et al., 1985; Freud and Furgala, 1982; Furgala et al., 1978; Langridge and Goodman, 1974). The present study supports the findings of these researchers.

The results clearly indicate that house flies play no role in pollination. American bollworm larvae eat the floral parts and can even effect seed set adversely on a small scale. Damage done by these larvae is less significant in commercial plantings, because larvae are distributed between many plants.

Observations on the behaviour of house flies (Chapter 3, page 24) showed that they did not move as actively on heads or between heads as honeybees do. This may result in slow movement of pollen between florets and between heads. The poor seed set of 37,9% could not be attributed to insufficient numbers of flies, as more than 25 flies per cage were still alive when the bloom period had ended. The fifty house flies were also far more than the highest average of 2,24 flies per hundred heads recorded at Pretoria (table 2-2, page 19).

Though the best seed set and yield were obtained from treatments with spotted maize beetle, the usefulness of these beetles is restricted by biological factors (Chapter 3, page 25). The number of 150 beetles per cage was much higher than the highest natural mean of 10 beetles per 100 heads, observed in the western Transvaal during the survey. This high number of beetles was used, however, to facilitate the maximum range of up to 120 beetles per single head found in the field (see Table 2-2, page 19). Spotted maize beetle may contribute to pollination during certain times of the season or in localized areas, but in large commercial fields the influence of these beetles would be less significant due to clamped and sporadic occurrence. It must therefore be concluded that honeybees are the major pollinator of commercial sunflower in South Africa, though other insects may play a contributing role.

As in this investigation, Freud and Furgala (1982) also found a compensation in seed mass when fewer seeds were set, but this compensation was not enough to make up for the higher seed set in treatments with adequate pollination.

The number of underdeveloped seeds was relatively high, even for treatments with good pollination (table 9). According to Khanna (1972) the number of under-developed seeds is mainly affected by competition for water and nutrient supplies, as a physiological scarcity develops when good set is achieved. Herring (1981) reported on the phenomenon of the sterile head center and stated that this factor is normally overlooked when seed set is determined. Abortion of the central florets is a general phenomenon, and results in poor or no seed set of the central florets (Khadiikar and Mahajan, 1974), though it could also be induced or increased by drought or a boron deficiency.

As the physiology associated with hollow-seededness is still undecided it is difficult to explain the high percentage (24,6%) of hollow achenes in the treatment with house flies. The level of hollow-seededness in the control plots and treatments with other insect pollinators was below 5%. In the treatment with no pollinating insects it was 12,3%. A possible explanation is that where cross-pollination is inefficient, a high level of self-pollination could occur, resulting in either poor fertilization or abortion of the seed after fertilization.

Jain <u>et al</u>. (1978) listed the following factors as contributing to hollow-seededness: insufficient number of insect pollinators, slow movement of pollen, extremes of temperature, humidity and rainfall, heavy dose of nitrogenous fertilizers and large head size. In South Africa, hollow-seededness is usually noticeable when good yields are expected (Birch <u>et al</u>., 1985). In marginal or poor seasons hollow-seededness is hardly noticed as poor crops are excepted by farmers. These findings were confirmed during the present study. Hollow-seededness became most evident when conditions for growth were exceptionally good or when thin stands led to very large head size (mean head diameter larger than 250mm.) or when continuous bad weather results in inadequate pollination because of reduced insect activity.

With adequate numbers of pollinators present and good movement of pollen, the stigma is pollinated within the first 24 hours after it becomes receptive for pollen. In the absence of pollination the stigma can stay receptive for a period of 10 days or longer. During this period the style continues its growth and after ten days it can reach a size of twice its normal length. This elongated style can be an explanation for hollow-seededness, as the overgrown style may not supply the growing pollen tube with enough nutrients to reach the egg cell for fertilization.