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"Biological Control of Diamondback Moth in Cole Crops in South Africa"

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EXECUTIVE SUMMARY

A major feature of the initial proposal was to enroll a South African participant in this project, as a doctoral student at the Hebrew University of Jerusalem (HU). Towards this goal, Mr. Sicelo Robert Nofemela, due to complete his MS studies in South Africa in the next few months, spent three months in Israel during this report period. Mr. Nofemela plans to enroll in the PhD program at the Hebrew University, beginning his studies in February 2004. During his stay, Mr. Nofemela assisted in data collection, familiarized himself with the Israeli cole crop system, and developed an outline for his Ph.D. research.

The work carried out during this report period in both South Africa and Israel involves the characterization of diamondback moth (DBM) and its parasitoid populations in cole crops. Once promising parasitic wasps are identified in Israel, they will be used in a biological control program in South Africa against DBM, an important pest of cole crops.

Results to date show that: i) as predicted, the pest attains relatively low population densities in Israel; ii) our efforts to date have yielded four DBM parasitoid species in Israel, iii) over 87% of the parasitism in Israel is attributed to *Diadegma semiclausum*, and iv) in South Africa too, DBM is attacked by four species of primary parasitoids, but they are different from those found in Israel. Results to date (work under Objective 1) provide good baseline data on the guild structure of DBM parasitoids prior to the release of new biocontrol agents in South Africa.

Section I

IA. Research Objectives:

The overall aim of this project is to use natural enemies from Israel to suppress diamondback moth populations in cole crops in South Africa.

Our working hypothesis states that parasitoids and predators effectively control the densities of the diamondback moth in Israel (and the Mediterranean area), the center of distribution and probably the area of origin of both the pest and its cruciferous host plants. By introducing effective natural enemies from Israel to South Africa, we shall be able to suppress diamondback infestations in cole crop systems.

The specific objectives are:

1. Compare the guild structure and population dynamics of diamondback moth parasitoids on cultivated and wild crucifer host plants in South Africa and Israel.
2. Compare the performance of important diamondback moth parasitoids on various cultivated crucifers in Israel and South Africa.
3. Introduce the most promising parasitoids from Israel into South Africa to control the diamondback moth in cole crops.
4. Evaluate the performance of field-released parasitoids.

The long-term goal of this project is to integrate the introduced natural enemies from Israel into an IPM program in cole crops in South Africa. The integrated program promises to reduce pesticide use while maintaining low levels of pest-induced losses. This, no doubt, will improve the well being of growers and consumers and establish sustainable cole crop production in South Africa.

IB. Research Accomplishments:

Field studies in Israel:

Material and Methods

An intensive survey for diamondback moth parasitoids consisted of weekly visits to 5-7 commercial cabbage and cauliflower fields. Fields surveyed received a minimal number of insecticide applications. Visits were made to the following sites, according to crop availability on a particular sampling date: Malikishua, Sde Elyahu, Netaim, Kfar Mordehai, Be'er Tuvia, Shiler, Hazav, Ein Hakore. On a given sampling date, about half of the fields were situated in the south coastal plain region and the other half in the Izra'el and Beit Shean valleys in the north of Israel.

On each visit, 30 randomly selected plants were examined in each field and the numbers of diamondback moth larvae, pupae and parasitoid cocoons were recorded. All the larvae, pupae and parasitoid cocoons found on the sampled plants were collected and held in the laboratory at 25 ± 1°C until adult moths or parasitoids emerged. In the laboratory, DBM larvae were provided with sections of fresh cabbage leaves until pupation. The number of emerging moths and parasitoids was recorded.

Three delta-shaped traps (0.26x0.095x0.13m, 'Biotrap') were posted in each of the sampled fields, 1m above ground. The traps were baited with one pheromone lure (AgriSense-BCS Limited, UK) impregnated with synthetic DBM sex pheromone and placed on a sticky floor. The traps were inspected on each visit to the field and the number of moths caught on the sticky floor of each trap was recorded. The lures were replaced every 5 weeks.

Results

Overall density of DBM was relatively low in all sampled field sites (Figures 1 & 2). A maximum of less than one male was captured in pheromone traps per night. Likewise, a maximum average infestation of 1.7 larvae was found per plant. There is no apparent correlation between adult trapping rate and larval infestation. For example, the highest trapping rate was recorded at Be'er Tuvia in March, but larval density at the site was low in March and April. Similarly, the highest infestation was recorded in April at Netaim but the male trapping rate there was low at that time.

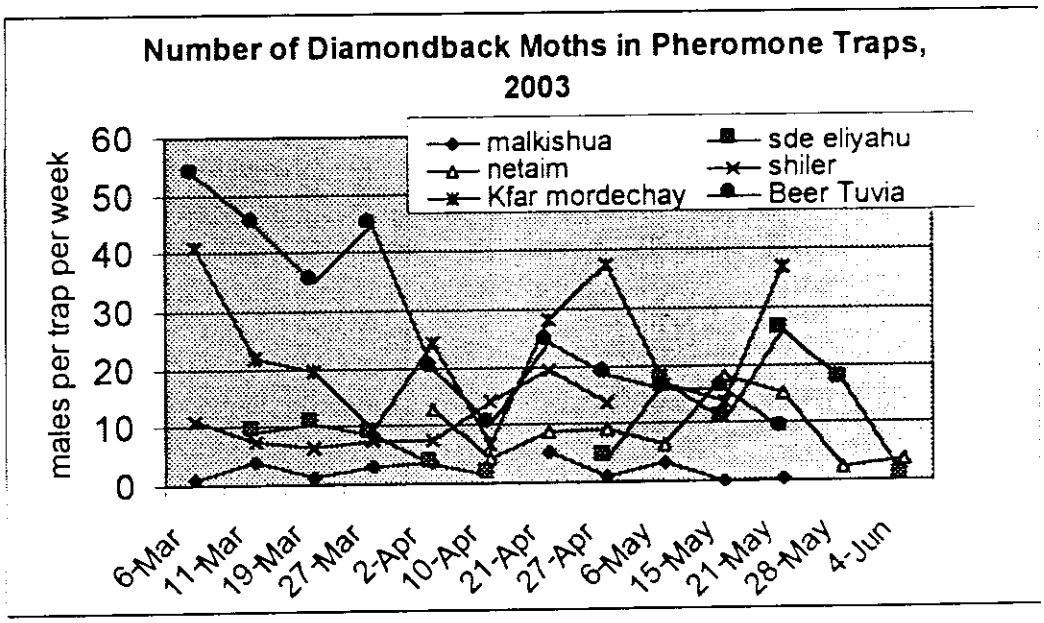

Figure 1: Number of male diamondback moths captured in pheromone traps in six cabbage and cauliflower fields in 2003.

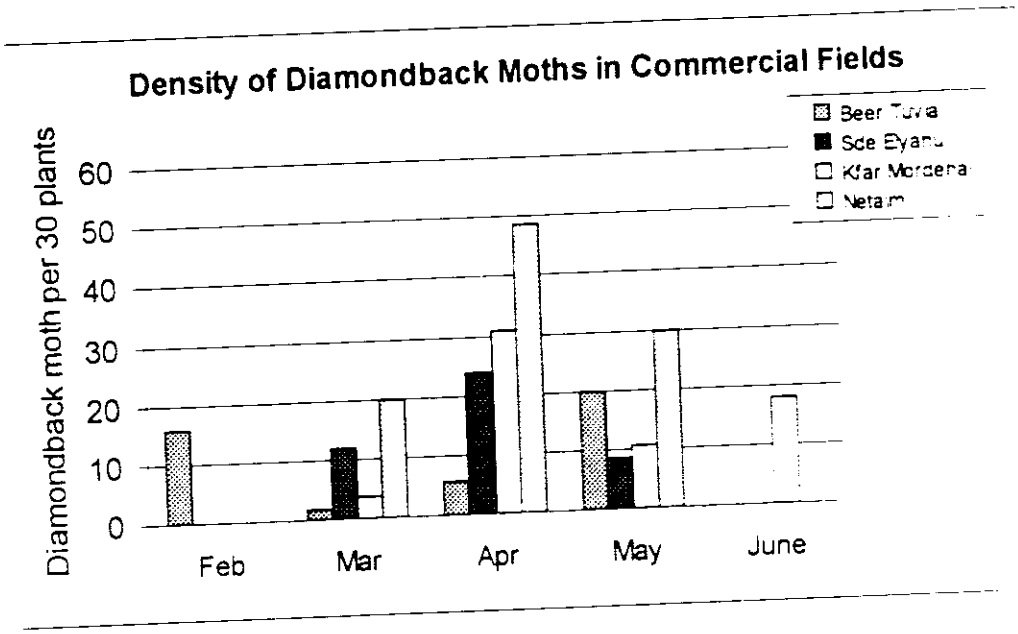

Figure 2: Density of DBM larvae and pupae on plants in four commercial cabbage and cauliflower fields in 2003.

Four primary parasitoids, namely *Diadegma semiclausum*, *Cotesia* sp., *Diadromus* sp. and *Apanteles* sp., and one *Diadegma* hyperparasitoid, a *Gelis* species, were recovered in our survey. *D. semiclausum* was the predominant species, accounting for more than 87% of the parasitism (Figure 3).

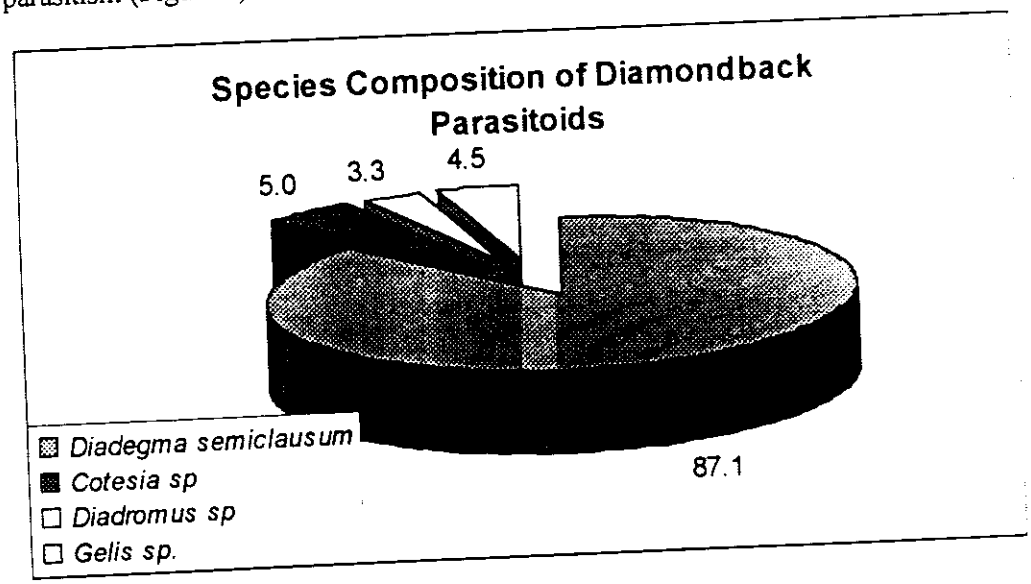

Figure 3: Species composition of primary and hyper-parasitoids of diamondback moths recovered in the February-June 2003 survey.

These species inflected an average parasitism rate of about 60% on the diamondback moth population (Figure 4). A single case of 100% parasitism was recorded in late April at Be'er Tuvia. The relatively stable rate of parasitism recorded throughout March, April and May suggests a high level of parasitoid movement and rapid colonization of continuously planted new fields. A similar trend is apparent when the parasitism dynamics of the predominant species, *Diadegma semiclausum*, is depicted (Figure 5).

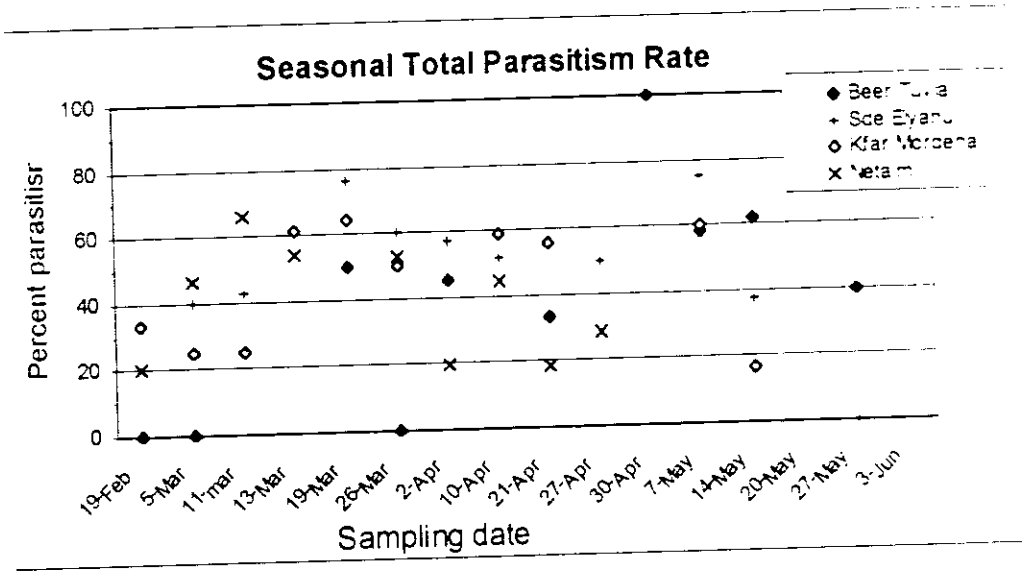

Figure 4: Percent parasitism of diamondback moth in four cabbage and cauliflower fields in 2003.

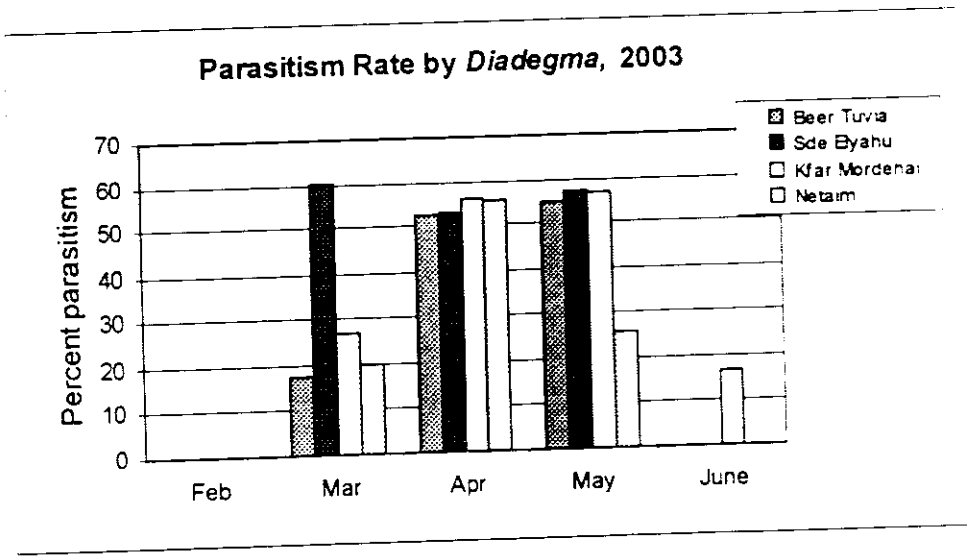

Figure 5: Seasonal dynamics of parasitism rate of diamondback moths by *Diadegma semiclausum* in four cabbage and cauliflower fields in 2003.

Field studies in South Africa:

Flight patterns of male *P. xylostella* moths

Methods

The flight patterns of male *P. xylostella* moths was monitored with synthetic sex pheromone traps in cabbage plots at Hartebeespoort Experimental Research Station near Brits (25°25'33"S, 27°76'67"E, altitude 1102m) in the North West Province of South Africa. Three delta-shaped traps (registered trade name 'Biotrap'), (26 X 9.5 X 13cm), were deployed in each cabbage plot. The traps were mounted on steel posts erected around the cabbage plot approximately 1m above the ground. Waxy paperboards were cut to fit the sliding bottom panels of the traps, thus covering the trap floors. The floors were then sprayed with a sticky polybutene adhesive. The lure, a small cylindrical-shaped rubber impregnated with a formulation of *P. xylostella* sex pheromone (supplied by Agrisense-BCS Limited, UK), was placed at the center of the sticky floor in each trap. The sticky floors were replaced at weekly intervals after counting the number of moths caught in each trap. The synthetic sex pheromones were replaced every five weeks.

Results

Trap catches indicated that *P. xylostella* was active throughout the year (Fig. 1). Catches were low during the summer (December-February), autumn (March-May) and winter (June-August), often fluctuating between 0 and 5 moths per trap. The highest moth activity was observed in spring (September-November), particularly in October, when catches were as high as 35 moths per trap. The flight activity of moths corresponded with larval infestations of the crops.

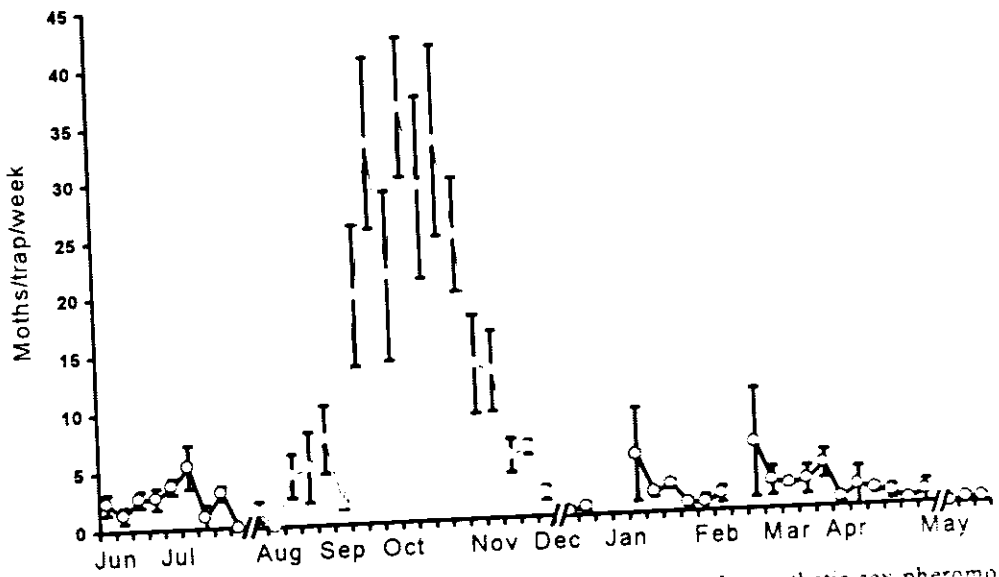

Fig. 1. Flight activity of *Plutella xylostella* male moths as shown by synthetic sex-pheromone trap catches during June 2002-May 2003 at Brits, South Africa. Bars represent standard errors when larger than symbol size. Diagonal lines on the x-axis represent transplanting of new cabbage seedlings.

Seasonal abundance of *Plutella xylostella* larvae, pupae and parasitoid populations

Methods

Cabbage seedlings were transplanted in three consecutive plantings during the study period (June 2002-May 2003) in plots of about 1000^2 m (0.5m between plants, 1m row spacing). Standard cultivation practices that include fertilising, weeding and irrigation were followed. Natural infestation of pests was allowed to take place without any application of insecticides. Scouting for DBM larvae and pupae commenced two weeks after transplanting the new cabbage seedlings in the field. At weekly intervals, 30 plants selected randomly were inspected and the number of DBM larvae, pupae and parasitoid cocoons found in each plant was recorded. In order to determine parasitism, samples of larvae (third and fourth instars), pupae and parasitoid cocoons were collected. The samples were taken to the laboratory where they were maintained at 25±1°C, 65±5% RH and 16:8 (L:D) photoperiod. The larvae were provided with sections of fresh cabbage leaves and held singly in Petri dishes. The leaves were replaced every second day until the larvae pupated or parasitoid cocoons formed. Samples of parasitoid cocoons and DBM pupae were confined individually in ventilated glass vials (2.5X10cm). Emerging parasitoids were identified and their incidence calculated. The number of moths that emerged from samples of larvae and pupae were also recorded. Larvae and pupae that died of unknown causes were excluded from the calculations.

Results

Infestations were low during summer (December-February), autumn (March-May) and winter (June-August) with infestations fluctuating between 0 and 2 larvae per plant (Fig. 2). Infestations increased substantially in spring (September-November), particularly in September and October, reaching a peak of 25 larvae per plant. However, the infestations declined sharply towards the end of October and November, reaching very low levels in summer and remaining low throughout this season (Fig. 2). Even at low pest densities, a relatively high number of plants were infested (Fig. 2), an indication of a regular distribution of the pest on the crop. All the developmental stages of *P. xylostella* were present throughout the year, an indication that *P. xylostella* occurred in overlapping generations.

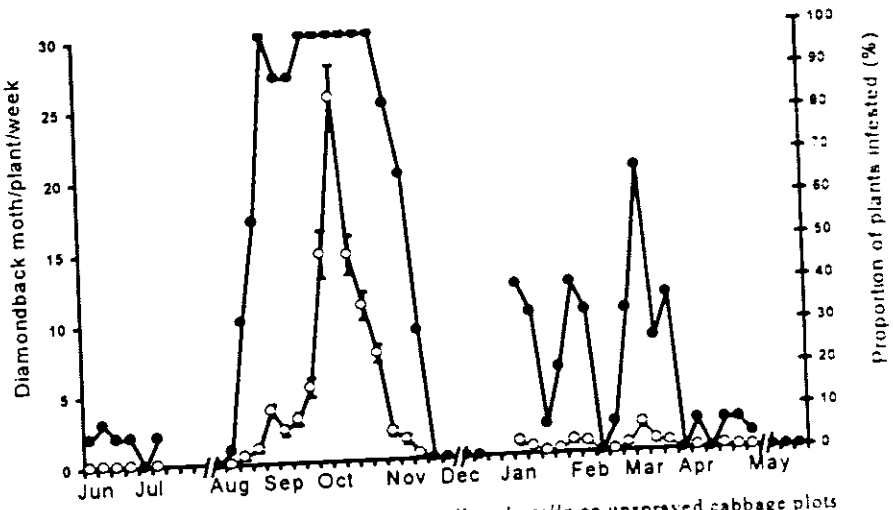

Fig. 2. Abundance of larvae and pupae of *Plutella xylostella* on unsprayed cabbage plots during June 2002-May 2003 at Brits, South Africa. Solid circles represent proportion of plants infested; open circles represent number of *P. xylostella* larvae and pupae per plant. Bars represent standard errors (S.E.) when larger than symbol size. Diagonal lines on the x-axis represent transplanting of new cabbage seedlings.

Composition, seasonality and relative abundance of *P. xylostella* parasitoids

During this period of the study, seven species of hymenopterous parasitoids were reared from *P. xylostella* (Table 1). Some of the primary parasitoids were active throughout the year (Fig 3), and were largely responsible for the very high parasitism levels that reached 100% on several occasions (Fig. 4). Hyperparasitoids were also active during most of the year (Fig 4). Hyperparasitism was generally low, except for the spring (Fig. 4).

Table 1. Parasitoids associated with *Plutella xylostella* recorded during June 2[illegible]-May 2[illegible] at Brits, South Africa, and their host relations.

	Species	Family	Host relations
Primary parasitoids			
	Cotesia plutellae	Braconidae	Larval parasitoid
	Oomyzus sokolowskii	Eulophidae	Larval-pupal parasitoid
	Diadromus collaris	Ichneumonidae	Pupal parasitoid
	Apanteles halfordi	Braconidae	Larval parasitoid
Hyperparasitoids			
	Eurytoma sp.	Eurytomidae	Attacks *C. plutellae* cocoons
	Mesochorus sp.	Ichneumonidae	Attacks *C. plutellae* inside DBM larva. The offspring emerges from *C. plutellae* cocoon
	Pteromalus sp.	Pteromalidae	Attacks *C. plutellae* cocoons

An annotated list of the recorded parasitoids

Cotesia plutellae (Kurdjumov) (Braconidae), a larval parasitoid, was active throughout the year and dominated the parasitoid complex (Fig. 3). *Oomyzus sokolowskii* (Kurdjumov) (Eulophidae), a larval-pupal parasitoid was also active throughout the year and was the second most abundant parasitoid (Fig. 3). *Oomyzus sokolowskii* was the only gregarious parasitoid of *P. xylostella* recorded during this study. Although it emerged from samples of *P. xylostella* pupae, in the calculations of percentage parasitism it was regarded as a larval parasitoid. On a few occasions, *O. sokolowskii* also emerged from *C. plutellae* cocoons, but its activity as a primary parasitoid far exceeded its hyperparasitic activity.

Apanteles halfordi (Ullyett) (Braconidae), [=*A. eriophyes* (Nixon)], a larval parasitoid, was also recorded throughout the year but its activity was sporadic (Fig. 3). *Apanteles halfordi* is specific to *P. xylostella* and is endemic to South Africa. *Diadromus collaris* (Gravenhorst) (Ichneumonidae) was the only pupal parasitoid recorded during this study; it was active from March to November (Fig. 3). Although pupal samples were few, it accounted for between 20 and 100% pupal parasitism.

Hyperparasitoids were active mainly in spring (September-November) when they accounted for up to 50% hyperparasitism of *P. xylostella* larvae and *C. plutellae* cocoons (Fig. 4). The most abundant was *Pteromalus* sp. (Pteromalidae), followed by *Eurytoma* sp. (Eurytomidae) and *Mesochorus* sp. (Ichneumonidae). *Pteromalus* sp. and *Eurytoma* sp. attacked *C. plutellae* cocoons and emerged from them. *Pteromalus* sp. also attacks cocoons of *A. halfordi* and *D. mollipla*, and occasionally also *D. collaris* inside *P. xylostella* pupae. *Mesochorus* sp. oviposits on developing *C. plutellae* larvae inside *P. xylostella* larva, and its offspring completes development once the primary parasitoid has formed a cocoon. It then pupates inside the cocoon of its host and emerges from it.

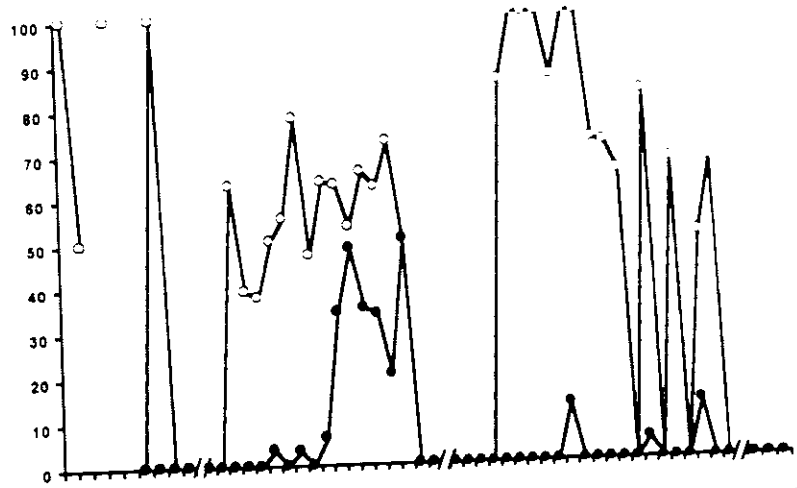

Fig. 3. Parasitism (open circles) and hyperparasitism (solid circles) of *Plutella xylostella* larvae on unsprayed cabbage during June 2002-May 2003 at Brits, South Africa. Numbers in brackets indicate sample size. Diagonal lines on the x-axis represent transplanting of new cabbage seedlings.

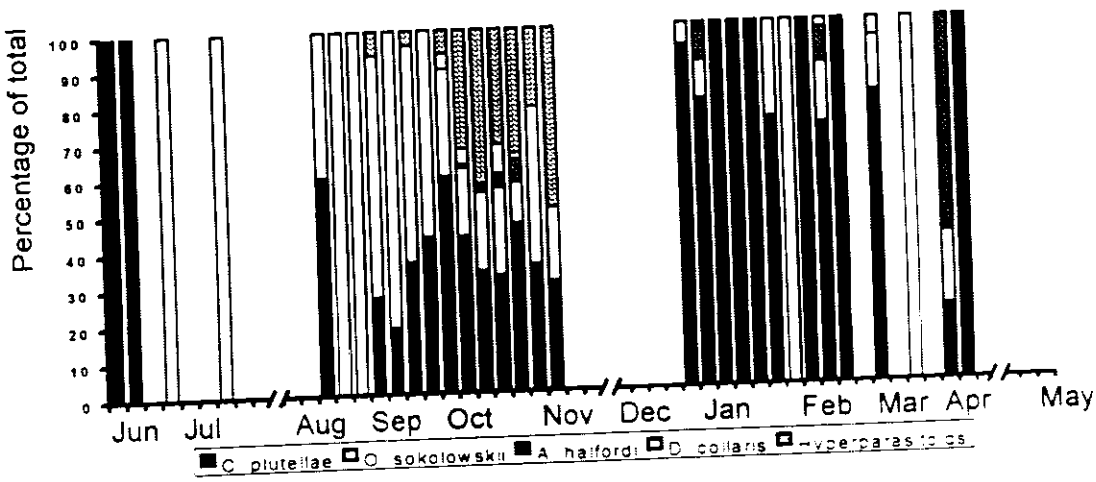

Fig. 4. Composition, relative abundance and seasonality of parasitoids associated with *Plutella xylostella* on unsprayed cabbage during June 2002-May 2003 at Brits, South Africa. Diagonal lines on the x-axis represent transplanting of new cabbage seedlings

I.C. Scientific Impact of Collaboration:

A major feature of the initial proposal was to enroll a South African participant to this project, as a doctoral student at the Hebrew University of Jerusalem (HU). After the last minute withdrawal of Mr. Satch Mosiane from the project in early 2002, we identified a new suitable South African candidate, Mr. Sicelo Robert Nofemela. Mr. Nofemela is in the final stages of his Master's studies at Rhodes University in South Africa. Mr. Nofemela arrived in Israel in February 2003 and was involved in the intensive survey for Diamondback moth parasitoids until his departure in May. In addition, Mr. Nofemela was exposed to and took part in all aspects of academic life in the Department of Entomology (HU) in Rehovot. The plan is for Mr. Nofemela to apply for the PhD program at the Hebrew University and that major parts of his dissertation will consist of aspects of this CDR project.

In April 2003, Dr. Rami Kfir arrived to Rehovot to coordinate research protocols and discuss Mr. Nofemela's dissertation work plan. It was decided that Mr. Nofemela would submit his application material to the Hebrew University once his Master's thesis is approved in late summer. He will then spend 6 months in Rehovot, starting at the beginning of spring semester in February 2004. During this time he will assist in research on parasitoid biology, take courses, develop his dissertation proposal, and have it approved by his dissertation committee. He will then return to South Africa to perform most of his dissertation work, and will return to Israel to present a progress report and finish writing his dissertation and scientific publications.

I.D. Description of Project Impact:

During this second year of the project, data on pest population dynamics and parasitism rate were collected in South Africa and in Israel. While these are important background data for the project, they are not of an applied nature.

I.E. Strengthening of Developing Country Institutions:

Investments in equipment and in facilities, including field facilities, are an ongoing process. They proceed reasonably well.

I.F. Future Work:

The work in Israel is about one year behind schedule. This setback is due to the last minute withdrawal of the South African trainee during the first year of the study. We hope to be able to make up for at least some of this lost time during the next three years of the project.

Section II

II.A. Managerial Issues: None

II.B. Budget: There were no major changes in budget items during this reporting period

II.C. Special Concerns: It appears that the uncertain security situation in Israel affects our ability to recruit South African trainees. Mr. Nofemela expressed such concerns during his stay in Rehovot.

II.D. Collaboration, Travel, Training and Publications:

Collaboration - Collaboration level is satisfactory. The principle investigator and the co-principle investigator keep in contact through email, fax and telephone communications. These contacts allow the coordination of fieldwork and experimental procedures. Some communication also takes place with Mr. Nofemela concerning his progress

Travel – Dr. Rami Kfir traveled to Rehovot in April 2003. This trip, originally scheduled for 2002, was postponed because of the setbacks we experienced in recruiting a South African trainee. During his visit, the PI and co-PI spent many hours discussing results to date, comparing DBM parasitoid complexes in South Africa and Israel, and making plans for the next phase of the project, including Mr. Nofemela's dissertation research.

Training - Mr. Nofemela had benefited much from the academic environment at Rehovot and was involved in the projects' research on a regular basis. He had the opportunity to interact with other faulty members, graduate students and staff in the department and got to know the cole cropping system in Israel.

Publications - None

II.E. Request for US Embassy (Tel Aviv) AID or BOSTID Actions: None