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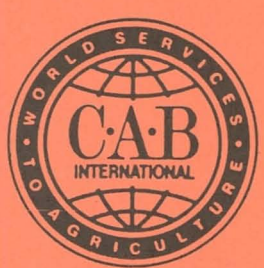

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PREFACE

This work was prepared as part of research project R4365 funded by the Overseas Development Administration of the British Government, on the natural enemies of Helicoverpa armigera in East Africa. It is hoped that this review will be of value to researchers in African countries, and also in other parts of the world where Helicoverpa spp. and Heliothis spp. are a major problem.

Part of the study was conducted at the C.A.B International Institute of Entomology (CIE) and the British Museum of Natural History (BMNH), both in London. The authors would like to thank K.M. Harris (Director), Z. Bouček, A. Polaszek and A.K. Walker (all CIE), and R.W. Crosskey, I.D. Gauld and T. Huddleston (all BMNH), who have greatly helped in the search of museum material and have made valuable contributions to this work with their taxonomic comments on the parasitoid species presented in Part II of this review.

Thanks are also due to P.J. Guest (Jealotts Hill Research Station, Bracknell, UK), N.J. Mills (CIBC, UK), B.T. Nyambo (Agricultural Research Institute, Ilonga, Tanzania) and P. Rivett (Plant Protection Division, Fernhurst, UK) for providing useful information, and to D.J. Girling (CIBC) and K. Howard (CIE) for their assistance in the literature search. We are grateful to D.J. Greathead (Director, CIBC) for his comments on the manuscript.

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ABSTRACT

The natural enemies of Helicoverpa armigera Hübner in Africa are reviewed, using published, unpublished and museum sources. A large variety of natural enemies are represented in almost 300 host records, including 83 parasitoids identified to species and 93 identified only to genus. The taxonomy, distribution, biology, alternative hosts or prey, host-plant associations and secondary natural enemies are detailed for all recorded natural enemies, and the different aspects are summarized and evaluated for the total natural enemy complex. Striking differences are found in the reported parasitoid complexes between East Africa and southern Africa. Methods for sampling natural enemies of H. armigera are discussed, and suggestions are made for accurately estimating parasitism rates for the different types of parasitoids attacking H. armigera.

PART I

1. INTRODUCTION

The bollworm Helicoverpa armigera Hübner (Lepidoptera: Noctuidae), better known under its previous name Heliothis armigera, is a major constraint to food and cash-crop production in Africa, attacking various crops including cotton, legumes, maize, sorghum, sunflower, tobacco and tomato. Damage is frequently localized on the reproductive parts of crops, i.e. those parts which are harvested. Nearly all the detailed studies on the biology and control of this pest have been made in cotton.

Generally, Helicoverpa armigera larvae live hidden within the fruiting parts of the plant during most of their development. Thus, large amounts of insecticide are needed if larvae are to ingest a lethal dose during their short period of contact with the foliage between hatching and entering the host-plant. Moreover, H. armigera has a strong ability to develop resistance to insecticides (Joyce 1982), and cases of resistance of H. armigera to organochlorines and pyrethroids in the field have been reported in several parts of the world (Wilson 1974; Goodyer et al. 1975; Gledhill 1982; Collins 1986). It seems that the impact of parasitoids on H. armigera populations in cotton has declined during the last decades with the escalating use of insecticides (Reed 1965; Balla 1982). Currently, more durable and ecologically sound management systems are being studied.

Biological control is a major component of integrated pest management which seeks to maximize the contribution of naturally occurring parasitoids, predators and pathogens to depression of pest populations. Certain characteristics of H. armigera, e.g. the migratory ability of the adults and the aggressiveness of the larvae, may make it a difficult target for biological control, however there is a large number of parasitoid species attacking H. armigera in Africa. Only limited data exist on the role they play in controlling the pest.

In the past, information on the major parasitoids of H. armigera in Africa has been summarized on several occasions (e.g. Henrard 1937; Pearson 1958; Risbec 1960; Greathead 1966; Greathead & Girling 1988). However, this review is an attempt to give a complete picture of all natural enemy records of H. armigera from Africa, with comments on their taxonomy, distribution, biology, alternative hosts or prey, host-plant associations and secondary natural enemies, thereby using published, unpublished and museum sources.

2. THE PEST

2.1 TAXONOMY

There has been much confusion about the taxonomy of Heliothidinae (Nye 1982). Traditionally, the taxon armigera Hübner has been placed in the familiar genus Heliothis. However, Hardwick (1965) erected the new genus Helicoverpa to separate armigera and similar species from Heliothis. There have been strong urgings from agricultural scientists to revert to Heliothis armigera because of the enormous literature, and familiarity with this name. However, there is a growing consensus among taxonomists that Helicoverpa and Heliothis are separate genera (e.g. Holloway, Bradley & Carter 1987; Poole 1988) so that we reluctantly use the combination Helicoverpa armigera here.

Four species occur in Africa: Helicoverpa assulta Guenée, H. fletcheri Hardwick, H. peltigera Schiffermüller and H. armigera. The latter is by far the most economically important species and is the subject of this review. Host records from H. armigera are likely to include misidentifications of the related species above.

2.2 LIFE-HISTORY

2.2.1 Adult

The pre-oviposition period is 1-4 d (=days), the oviposition period 2-5 d, and the post-oviposition period 1-2 d, at 30-33°C (Singh & Singh 1975). Reed (1965) reported a fecundity of 1,200 eggs during the rainy season and 200 eggs during the dry season. With the availability of food, the longevity is 11 d, and the sex ratio 1:1 at 21-27°C (Reed 1965). Adults are strongly attracted to crops with honeydew or nectar and feeding is important for survival. Nocturnal flights and oviposition mostly occur just after dusk (Topper 1987b).

2.2.2 Oviposition

Females oviposit at night. Beeden (1974) found that eggs on cotton were laid uniformly over the field throughout the season. Eggs (0.5 mm in diameter) are laid singly on the leaves or on reproductive parts of the plant. In the vegetative stage of cotton oviposition is low and eggs are mostly laid on the upper surface of the leaves on the top part of the plant. Oviposition usually increases in the reproductive stage of the crop. Favoured oviposition sites are fertile portions, such as tassels of maize or the flower buds of cotton.

2.2.3 Development

Larvae feed externally or internally on different parts of the host plants, preferentially the reproductive portions such as the fruits of tomato, peppers and legumes, inflorescences of sorghum and sunflower, squares of cotton and cobs of maize. After six instars the larvae have completed feeding and bury themselves in the soil to pupate.

At 21-27°C, the duration of instars one to six is 2.8, 2.2, 2.5, 2.4, 3.1 and 5.4 d respectively, the prepupal period is 2.7 d (total larval period: 21 d), and the pupal period 16-18 d (Reed 1965). Towards the dry season, a proportion of the pupal population enter diapause, which lasts 30-170 d (Reed 1965; Roome 1979).

2.3 HOST PLANTS

Helicoverpa armigera can feed and breed on a wide variety of host plants, including horticultural and field crops (Pearson 1958). Pigeon pea, beans and maize are more favoured for oviposition than cotton (Pearson 1958; Jayaraj 1982). The former crops were also preferred by feeding larvae. In several cases however, larval weights were higher on cotton than on maize, legumes or sunflower, and it was concluded that cotton was the most suitable crop for development and reproduction of H. armigera (Jayaraj 1982).

2.4 PHENOLOGY

Because the adults of H. armigera are migratory and have a high reproductive rate, pest populations can invade fields very rapidly. However, the susceptible period of crops to attack by H. armigera is usually very short and restricted to the reproductive growth stage, although some crops and weeds are attacked from the seedling stage onwards. The pest oviposits on sorghum during the short period of flowering, so that only one generation can develop per crop (Nyambo 1986). The attractive stage of maize is during silking, for about three weeks. Tomato is most suitable for oviposition during flowering and fruiting. Cotton is attacked from the vegetative stage onwards, but mostly during the flowering stage (Reed 1965). During the season, H. armigera populations can move from crop to crop, following the susceptible stages of each crop (Topper 1987a; Balla 1982).

2.5 SAMPLING METHODS

2.5.1 Adults

The most commonly used technique for sampling adults has been the light trap, which catches moths of different ages and physiological conditions. Recently, synthetic pheromone traps have been developed, trapping only sexually mature males. In Tanzania, pheromone trap catches gave relative population estimates that were better correlated with subsequent infestation levels than were light trap catches (Nyambo 1986). However, in order to estimate population size of H. armigera in a restricted area, it is necessary to sample the populations of eggs, larvae or pupae, rather than the highly migratory adults.

2.5.2 Eggs

To sample egg populations of H. armigera in the field, visual counting is the only available method, which can be conducted on a per plant basis for absolute densities (based on known plant spacings), or on the basis of plant portions that are favoured as oviposition sites, for relative counts. The latter method is generally preferred because most crops have a great amount of foliage during their susceptible stage. The eggs are randomly distributed within a field (Beeden 1974; Haggis 1982). In South Africa, van Hamburg (1981) found egg counts on cotton to be poor estimates of larval densities, and attributed this to variation in egg viability and variation in egg parasitism; he did not consider predation. Reed's (1965) observations on cotton in Tanzania indicated that a poor survival of eggs later in the season may have been due to predation.

2.5.3 Larvae

Larval populations of H. armigera can be estimated by visual counts,

sweepnet, D-vac, plantshake or whole plant bag sampling (Kogan & Pitre 1980). In North America, the most commonly used technique on soybean is the plantshake method, using a drop cloth at the base of the plant. This method is reasonably accurate for all larval instars, including the first instars which are often overlooked in visual counts (Stinner, Bradley & van Duyn 1980), but is likely to be less efficient for plants on which the larvae feed internally. The efficiency of different sampling methods will depend on the crop species and crop phenology, and needs to be evaluated for different crop situations.

2.5.4 Pupae

Pupal sampling has been evaluated by Stinner, Bradley & van Duyn (1980). Most suitable methods are soil sifting and soil scraping (removing the top layer of the soil to count pupal tunnels).

3. SAMPLING NATURAL ENEMIES

3.1 PARASITOIDS

The occurrence of parasitoids is generally recorded as a percentage parasitism of the host population. Usually, host stages are collected and reared in the laboratory on plant material or artificial diet, until emergence of parasitoids. Where larval stages of the parasitoid are known, dissection of field collected material may be more efficient and accurate, because the host may die during laboratory rearing before parasitoids emerge. Dissection also permits measurement of superparasitism (multiple parasitism by the same species) and multiparasitism (multiple parasitism by different species).

Assessment of the impact of parasitoids on pest populations can be difficult, because estimates can be greatly hampered by sources of bias and other problems resulting from the characteristics of parasitoid-pest interactions (Marstom 1980; van Driesche 1983). Major problems in determining percent parasitism of H. armigera in the field are discussed below.

(i) Host-age specificity of parasitoids

The species in the extensive parasitoid complex of H. armigera often attack a particular stage of the host and emerge from a different stage of the host. For example, some ichneumonids attack the first host instar and emerge from the second host instar. Tachinids, on the other hand, tend to attack only late host instars. Therefore, per cent parasitism should be assessed separately for each major parasitoid species, based on different host instars. Figure 1 shows the host-stage specificity of major parasitoids of H. armigera, extracted from the literature (see Part II).

(ii) Exposure period of susceptible host stages

Apart from the fact that parasitism should be calculated separately for each parasitoid species, host stages must be selected to give the most accurate estimate of parasitism. Sampling of host stages commonly interrupts the exposure period of stages susceptible to certain parasitoids, and thus results in underestimation of parasitism by that particular parasitoid species. Ideally, the host should be sampled after the susceptible period, but prior to the host stage from which the parasitoid(s) emerge. For example, if the parasitoid attacks the first and emerges from the third host instar, the host should be sampled during the second instar. As is clear from Figure 1, only few parasitoids of H. armigera have such an optimal stage for sampling. In some parasitoid species there is an overlap between the host stages attacked and those from which they emerge. Table 1 shows the host instars to be selected for most accurate measurement of the level of parasitism for some major larval parasitoids of H. armigera. Alternatively, one could also include the host stages susceptible to attack, or host stages from which parasitoids emerge, and then correct for underestimates (Marstom 1980). However, methods should be applied consistently. The selection of host instars requires the measurement of head-capsule widths in relation to instars (Hansen, Owens & Huddleston 1981). Head-capsule widths of H. armigera can vary between crops (P.J. Guest pers. comm.); measurements from cotton are presented in Table 2.

(iii) Change in host stage development

Egg parasitoids can prolong the presence of the host stage they attack in the field. For example, H. armigera eggs parasitized by Telenomus spp. (Scelionidae) emerge after a period several times the length of the incubation period of unparasitized eggs. Consequently, field samples of

Parasitoid species	Host stage: EGG	L1	L2	L3	L4	L5	L6	PUPA
Apanteles diparopsidis		+	+	+	x	x	x	
Apanteles maculitarsis		+	+	+	o	o	x	x
Apanteles ultor-group		-	-	-	-	-	-	
Apanteles vitripennis-group		+	+	+	x	x	x	
Brachymeria sp.								-
Carcelia illota					-	-	-	-
Cardiochiles nigricollis			+	+	+	+	x	x
Cardiochiles sp.			-	-	-	-	-	
Charops sp.		+	+	+	-	-	x	x
Chelonus curvimaculatus	+	+	+	o	o	o	o	x
Enicospilus sp.					-	-	-	-
Euplectrus sp.		-	-	-	-	-	-	
Goniophthalmus halli					+	+	+	+
Linnaemya longirostris						+	+	+
Metopius sp.				-	-	-	-	-
Nemoraea capensis						-	-	-
Palexorista laxa					+	+	+	x
Paradrino halli					+	+	-	-
Pristomerus sp.			-	-	-	-	-	
Pseudogonia rufifrons					+	+	+	+
Telenomus spp.	-	-						
Trichogrammatoidea spp.	-	-						

Figure 1. Host stages of H. armigera during which its parasitoids are active. **+**, indicates host stage attacked; **o**, indicates optimal stage for sampling; **x**, indicates host stage from which parasitoids emerge; **-**, indicates that (i) the parasitoid is present in the host stage, but no information is available on attack or emergence of parasitoid, or (ii) that the parasitoid emerges from the host stage it attacks.

Table 1. Host instars of H. armigera to be selected for most accurate measurement of the level of parasitism by different parasitoid species.

Parasitoid	**Host instar**
Apanteles diparopsidis	Early second
Apanteles maculitarsis	Second
Cardiochiles sp.	Second
Charops sp.	Second
Chelonus curvimaculatus	First, second
Goniophthalmus halli	Sixth
Linnaemya longirostris	Sixth
Palexorista laxa	Fifth, early sixth
Paradrino halli	Fifth, early sixth

Table 2. Mean head-capsule width (mm) of H. armigera instars on cotton in Tanzania (n=35) (Source: Reed 1965).

Instar	1	2	3	4	5	6
Head-capsule width	0.25	0.4	0.6	1.0	1.6	2.4

host eggs can overestimate parasitism levels, because for any cohort of eggs laid, unparasitized eggs might have hatched and disappeared from the plant, while their parasitized counterparts remain. Likewise, some larval and pupal parasitoids can retard the development of their host such that unparasitized hosts of the same age may have passed on to the next larval or pupal stage, which might not be sampled. This can also cause overestimation of parasitism, but retardment and the errors it brings are usually not as extreme as with egg parasitoids (Table 3).

A partial solution for this problem (and those posed by (i) and (ii) above) is to place cohorts of a particular life stage into the field for subsequent monitoring. Clearly, this is easier for sessile stages such as eggs and pupae, although larger larvae may be tethered to plants (Weseloh 1974, 1982). This method will also measure other mortalities acting on the exposed stage, such as disappearance of hosts due to predation. Natural placement of hosts in the field is important, and if possible, it might be better to clean plants and mark newly laid cohorts of eggs (Metcalfe & Brenière 1969), or confine pupating larvae under cages in the soil (P.J. Guest, pers. comm.) to ensure natural distribution of the stage exposed.

(iv) Mortality of parasitized hosts

When field mortality is higher for parasitized than for unparasitized hosts, and when hosts are not dissected, the contribution of parasitism to mortality of the host will be underestimated.

Moreover, when parasitized hosts are sampled from the field, they are removed from possible subsequent attack by other parasitoids, hyperparasitoids, predators and diseases. Hence, such sampling may overestimate the contribution to mortality of the particular parasitoid recovered. This problem may also arise with cohort studies (see (iii) above) depending on the time of recollection, and will be more severe when

Table 3. Retardment of host development and change in host appearance due to parasitism by different parasitoid species.

Parasitoid	Stage attacked	Retardment of host stage development	
Apanteles spp.	Larva	+	(1)
Bracon brevicornis	Larva	+	(1)
Chelonus curvimaculatus	Larva	+	(1)
Euplectrus laphygmae	Larva	+	(1)
Goniophthalmus halli	Larva	-	(2)
Palexorista laxa	Larva	-	(2)
Paradrino halli	Larva	-	(2)
Telenomus ullyetti	Egg	+	(3)
Trichogrammatoidea lutea	Egg	+	(3)

(1) Larva becomes inactive and stops feeding
(2) Larva continues feeding until emergence of parasitoid(s)
(3) Host is killed during embryonic development, and the egg turns black

parasitism makes hosts susceptible to other mortalities (e.g. Carroll & Risch 1983). Thus particular attention should be paid to this possible source of sampling error when parasitized hosts are rendered more sluggish than healthy hosts (see Table 3).

3.2 PREDATORS

Plant-inhabiting predator complexes and their impact on Helicoverpa spp. is poorly understood in African agroecosystems. Sampling methods for estimating population sizes and spatial distributions of predators of Helicoverpa and Heliothis spp. have been evaluated in North America, and these methods may be applied for some African cropping systems. Samples may be obtained from standard parts of the plants or from entire plants, depending on the predator species, the crop species and crop phenology.

In general, the simplest and most reliable sampling methods are direct observation, plant shaking and sweepnet sampling. On soybean and cotton, plant shaking is considered the best method for sampling small slowly moving hemipterans, except for Orius spp. (Anthocoridae), whereas sweepnet sampling is more suitable for larger insect predators such as chrysopids and coccinellids (Bechinski & Pedigo 1982; Irwin & Shepard 1980; Goodenough 1986). Wilson & Gutierrez (1980) report that, compared to the immature stages, adult predators on cotton were consistently found higher on the plant, especially on the developing squares. Adults were accurately sampled using a sweepnet. Direct observation is time consuming, but is probably the best method for measuring the activity of predators such as ants. D-vac sampling (Dietrick 1961) is usually least reliable (Gonzalez et al. 1977; Irwin & Shepard 1980). Byerly et al. (1978) report that sweepnet and D-vac sampling were not accurate enough for following population trends of predators of H. armigera and other pests on cotton, when compared to bag sampling of entire plants.

The efficiency of the different sampling methods will however largely depend on the crop species and crop phenology. Furthermore, it should be

noted that some predators, e.g. syrphid and chrysopid larvae, may be more active on plants at night and may therefore be undersampled by day.

In order to relate predator densities to the impact on pest populations, additional experimental methods on predation are needed (Luck, Shepard & Kenmore 1988). The use of exclusion/inclusion field cages is perhaps the most suitable quantitative method for demonstrating the action of predators of Helicoverpa spp. (van den Bosch et al. 1969; Barry, Hatchett & Jackson 1974; Thead, Pitre & Kellogg 1987).

Other little known natural enemies in African agroecosystems are ground dwelling predators. Most important are probably carabids and ants. They attack pupating larvae and pupae of Helicoverpa spp. in the soil, or may forage on plants. A reason why ground predators are generally overlooked is that many are nocturnal. Ground predator populations are probably best sampled using pitfall traps (Muma 1975; Southwood 1978).

3.3 PATHOGENS

As with parasitism levels, the assessment of the level of diseased hosts is biased by various factors.

Pathogens are generally not specific to a certain larval instar. They may attack, and kill, both young and older larvae. However, in Botswana, Daoust (1974) found that mortality of H. armigera by nuclear polyhedrosis virus (NPV) was highest in young larvae, so young instars should preferably be selected for measuring mortality due to NPV.

Larvae collected in the field should be placed directly into sterile diet containers for individual rearing, so as to prevent cross contamination by diseases from field equipment or other larvae. Similarly, because natural food may be contaminated, sterile artificial diet is to be preferred.

McKinley (1971) reported that larvae in the field appeared less susceptible to NPV than those in the laboratory, and attributed this to physical stress. Likewise, larvae collected from the field and reared in the laboratory may suffer higher mortality due to diseases than in the field, i.e. diseases may be effectively dormant in larvae in the field, only becoming active when larvae are subjected to stress, thereby leading to overestimates of field mortality.

Pathogens develop rapidly in hosts, hence, it should be noted that sampling hosts from the field may underestimate generational mortality due to diseases, because healthy hosts, if left in the field, may have subsequently contracted and died of disease before the next life stage.

3.4 POPULATION STUDIES

The effect of parasitoids, predators and pathogens is best studied in the context of their action and interaction, over a pest generation in the field. Methods of life-table analysis, combined with sampling techniques described above, may be used to quantify the contribution of different natural enemies to generational mortality (e.g. Hogg & Nordheim 1983) and, through extension into key-factor analysis, to population change. Design of life-table and key-factor analysis is discussed by Southwood (1978) and Varley, Gradwell & Hassell (1973).

However detailed the studies, samples of natural enemies or estimates of their impact should always be made in combination with quantitative samples of H. armigera population size for the relevant stages. Otherwise, much valuable information on the relationship between natural enemy impact and host population change may be lost.

4. SUMMARY OF THE NATURAL ENEMIES OF H. ARMIGERA

Literature on natural enemies of Helicoverpa spp. from Africa (predominantly Helicoverpa armigera) is very limited as compared with that for North America (Kogan et al. 1978; Johnson, King & Bradley 1986). Most African studies come from southern Africa and East Africa (Table 4). Detailed studies from East Africa are limited to those from Uganda by Coaker (1959), and from Tanzania by Reed (1965) and Nyambo (1986). These studies mostly concern larval parasitoids. In East Africa, hymenopteran larval parasitoids are the most commonly recorded parasitoids, whereas in southern Africa dipterans were more frequently recorded. Egg parasitoid records are common only from southern Africa.

Table 4. Number of records of H. armigera parasitoids from African countries.

Country	Diptera larval and pupal parasitoids *	Hymenoptera egg parasitoids	Hymenoptera parasitoids - other than egg parasitoids **	Total
East Africa	**30**	**5**	**55**	**90**
Kenya	6	0	3	9
Tanzania	18	2	29	49
Uganda	6	3	22	31
Southern Africa	**59**	**26**	**34**	**119**
Botswana	7	2	6	15
South Africa	31	17	23	71
Zimbabwe	21	7	5	33
Other	**29**	**4**	**37**	**70**
Madagascar	0	1	3	4
Nigeria	1	0	3	4
Senegal	11	1	13	25
Sudan	9	0	12	21
Miscellaneous	11	2	13	26
Total	**121**	**35**	**133**	**289**

* Predominantly Tachinidae
** Predominantly Braconidae and Ichneumonidae

4.1 TAXONOMY

In addition to the 83 identified species of natural enemies recorded from H. armigera in Africa, there are 93 records of partially identified natural enemies (Table 5). Some of these are important biological control agents (e.g. Nyambo 1986), and most are found in the Ichneumonidae and in the smaller parasitoid families. Particularly difficult parasitoid genera are Charops and Pristomerus (Ichneumonidae), and Apanteles and Cardiochiles

(Braconidae). The huge genus Pristomerus might have several hundreds of undescribed species in Africa (I.D. Gauld pers. comm.).

Identification of the tachinid genera Exorista, Carcelia, Pales and Palexorista is difficult because species are morphologically very similar (Crosskey 1980, 1984). Furthermore, some of the currently described species in these genera may represent a complex of sibling or semi-sibling species (R.W. Crosskey pers. comm.).

Revision of African parasitoids of H. armigera in the genera Cardiochiles and Palexorista is underway at the BMNH and CIE.

Table 5. Number of species of parasitoids of H. armigera recorded from Africa. **I**, identified species; **II**, records not identified to species level.

	I	II
Tachinidae	34	11
Ichneumonidae	10	24
Braconidae	21	24
Miscellaneous	18	34
Total	**83**	**93**

4.2 ALTERNATIVE HOSTS

Data on alternative hosts of parasitoids of H. armigera should be treated with utmost caution, because misidentifications are frequent. This is best illustrated with Palexorista laxa Curran, an important tachinid parasitoid of H. armigera which has been recorded from many alternative hosts covering several lepidopterous families. However, according to Crosskey (1967), H. armigera is the only proven host of P. laxa. Palexorista is a particularly difficult genus, and several closely related species have been confused under the name P. laxa. The alternative host records may therefore include several Palexorista species which have other host-associations. Such cases have significant consequences for defining host specificity of parasitoids of H. armigera, and thus for implementing biological control.

Furthermore, records alone do not indicate preference of parasitoids. A parasitoid might show a preference for one particular host, and use other species as hosts only to bridge periods of absence of its preferred host. Hence, it may be necessary to identify principal and alternative hosts of parasitoids.

Table 6 is a summary of the host range for a number of parasitoids of H. armigera. Note that partially identified parasitoid species, some of which are very important, cannot be included here.

Within the Tachinidae, the subfamily Tachininae seem to be parasitoids of noctuids. The important subfamily Goniinae has more generalist species, recorded from non-noctuid hosts. Exceptions are Goniophthalmus halli Mesnil, Paradrino halli Curran, and probably also Palexorista laxa, common parasitoids in Africa, which are probably specific parasitoids of H. armigera. Again, records of alternative hosts in such taxonomically difficult groups as Carcelia, Exorista and Pales, must be regarded with caution.

Most braconid parasitoids of H. armigera are polyphagous, with the exception of Cardiochiles spp. Although based on few records for each species, none of the five Cardiochiles spp. has been recorded from a host

Table 6. Parasitoids of H. armigera and their host range in Africa. **I**, recorded from H. armigera only; **II**, recorded from Noctuidae only; **III**, recorded from several families of Lepidoptera.

	I	II	III
Tachinidae:			
Subfamily Tachininae			
Dejeania bombylans (1)		+	
Hystricovoria bakeri			+
Linnaemya agilis		+	
Linnaemya albifrons		+	
Linnaemya longirostris		+	
Nemoraea capensis		+	
Nemoraea rubellana		+	
Subfamily Goniinae			
Carcelia illota (1)		+	
Ceromya cibdela			+
Exorista sorbillans			+
Exorista xanthaspis			+
Gonia bimaculata			+
Goniophthalmus halli	+		
Pales blepharipus			+
Pales coerulea			+
Pales nigronitens			+
Pales seminitida			+
Palexorista idonea			+
Palexorista laxa (4)	+		
Paradrino halli (3)	+		
Peribaea mitis			+
Peribaea orbata		+	
Pseudogonia rufifrons		+	
Sturmia convergens			+
Thelairosoma angustifrons			+
Winthemia dasyops (1)		+	
Zygobothria ciliata			+
Ichneumonidae:			
Barylypa rufae (1)		+	
Charops ater			+
Enicospilus capensis (2)		+	
Metopius discolor (1)	+		
Netelia opaculus		+	
Netelia testacea			+
Braconidae:			
Apanteles diparopsidis			+
Apanteles maculitarsis			+
Apanteles ruficrus			+
Bracon brevicornis			+
Cardiochiles nigricollis (1)	+		
Cardiochiles nigromaculatus (1)	+		
Cardiochiles trimaculatus (1)	+		

Table 6 (contd.).

	I	II	III
Cardiochiles variegatus (1)	+		
Chelonus curvimaculatus			+
Chelonus versatilis (1)			+
Meteorus laphygmarum		+	
Scelionidae:			
Telenomus ullyetti (2)	+		
Eulophidae:			
Euplectrus laphygmae			+
Trichogrammatidae:			
Trichogrammatoidea lutea			+

(1) Based on few records
(2) Occasionally recorded from Pyralidae
(3) Only once recorded from another Noctuidae (Cetola sp.)
(4) H. armigera is the only proven host (see text)

other than H. armigera. Cardiochiles nigriceps Viereck, a well-studied species from North America, has shown a high degree of specificity to the host Heliothis virescens Fabricius (Part II).

In scelionid egg parasitoids of the genus Telenomus a combination of several physical cues as well as chemical cues (contact kairomones) leads to host acceptance (Part II), and allows them to select host age and host species; they generally are host specific. Trichogrammatid parasitoids on the other hand are generally less specific, and often attack a range of Lepidoptera host eggs available in a specific habitat.

4.3 DISTRIBUTION

Information on geographical distribution of African parasitoids of Helicoverpa armigera is patchy. Parasitoids from the Afrotropical Region recorded from other regions as well are presented in Table 7. It can be seen that the African parasitoid complex is most closely related to that of the Oriental Region.

Within the African continent, striking differences exist between the parasitoid complexes reported from different areas (Table 8). When comparing H. armigera parasitoids from the two best-studied areas, southern Africa (Botswana, South Africa and Zimbabwe) and East Africa (Kenya, Tanzania and Uganda), only three species are important in both areas; these are Palexorista laxa, Paradrino hálli and Chelonus curvimaculatus Cameron. All of the other species are important in only one of the areas, although they might be present in both. An example of the latter is Apanteles diparopsidis Lyle, which is an important parasitoid of H. armigera in Tanzania (Nyambo 1986), while in southern Africa it is found only on Diparopsis spp. and Earias spp. (Noctuidae).

When comparing parasitoid guild structures of the two areas (see Table 4) it is apparent that egg parasitoids are important in southern Africa whereas they are rare in East Africa. This may however be attributable to

Table 7. Distribution of widespread parasitoids, recorded from H. armigera in Africa, outside the Afrotropical Region.

	Oriental Region	Palaearctic Region	Nearctic Region	Neotropical Region
Tachinidae:				
Carcelia illota	+			
Exorista sorbillans	+	+		
Exorista xanthaspis	+	+		
Gonia bimaculata	+	+		
Goniophthalmus halli	+			
Hystricovoria bakeri	+			
Palexorista laxa	+			
Peribaea orbata	+			
Pseudogonia rufifrons	+	+		
Sturmia convergens	+			
Voria ruralis	+	+	+	+
Zygobothria ciliata	+			
Ichneumonidae:				
Enicospilus capensis	+			
Netelia testacea		+		
Sraconidae:				
Apanteles ruficrus	+			
Bracon brevicornis	+	+	+	+
Cardiochiles nigromaculatus	+			

the lack of attention being paid to egg parasitoids in East Africa. Ichneumonids, on the other hand, are among the principal parasitoids of H. armigera only in East Africa. Similarly, Tachinidae are better represented in the parasitoid complex in southern Africa than in East Africa, while hymenopterous larval parasitoids were the major group in East Africa (Table 4).

4.4 HOST-PLANT ASSOCIATIONS

Host-plant associations of natural enemies of H. armigera have not been studied experimentally in Africa. However, some trends appear from field collections of parasitoids. The most extensive data set in this respect is the work by Nyambo in Tanzania (Nyambo 1986; Nyambo, unpublished). From these data it appears that there is a parasitoid guild, composed of Palexorista laxa, Chelonus curvimaculatus and Apanteles diparopsidis, attacking H. armigera on sorghum, but not to a significant degree on other crops. Consequently, H. armigera on sorghum suffers much higher parasitism levels than on other crops.

By contrast, Cardiochiles spp. seem to be generally associated more with cotton than with other crops. In Tanzania, Cardiochiles spp. were associated with cotton and the weed cleome, and were rare on sorghum and maize (Nyambo 1986). Parsons (1940) reared C. nigricollis Cameron mostly from larvae collected on cotton in South Africa. Moreover, Greathead (1966) found C. trimaculatus Cameron to be the most important parasitoid of H. armigera on cotton in Uganda.

Table 8. Major parasitoids of H. armigera in East Africa and southern Africa. **(a)** indicates the species that are important in East Africa as well as in southern Africa.

Parasitoid species	Country**	(a)	Crop	* Reported Occurrence
		--EAST AFRICA--		
Tachinidae:				
Carcelia illota	T	-	Cotton	7%
Goniophthalmus halli	K,T	-	Cotton	Up to 12%
Palexorista laxa	T,U	+	Mainly sorghum	Up to 42%
Paradrino halli	T	+	Various	Common
Ichneumonidae:				
Charops sp.	T	-	Various	Up to 23%
Charops sp.	U	-	Various	Up to 10%
Enicospilus sp.	U	-	Mainly cotton	11%
Braconidae:				
Apanteles diparopsidis	T	-	Sorghum	Up to 26%
Apanteles ultor-group	U	?	Maize/groundnut	Up to 20%
Apanteles vitripennis-group	T	-	Various	Common
Cardiochiles trimaculatus	U	-	Mainly cotton	8%
Cardiochiles sp.	T	?	Mainly cotton	Up to 18%
Chelonus curvimaculatus	T,U	+	Various	Up to 12%
		--SOUTHERN AFRICA--		
Tachinidae:				
Linnaemya longirostris	SA	-	Various	Important
Gonia bimaculata	SA	-	Citrus	Important
Palexorista laxa	B,SA,Z	+	Cotton	20-30%
Paradrino halli	Z	+	Citrus	Up to 25%
Braconidae:				
Apanteles maculitarsis	SA	-	Various	Common
Apanteles nr. aethiopicus	SA	?	Peas	Important
Bracon brevicornis	SA	-	Antirrhinum	Common
Cardiochiles nigricollis	B,SA	-	Mainly cotton	Common
Chelonus curvimaculatus	SA	+	Maize, citrus	Common
Scelionidae:				
Telenomus ullyetti	SA,Z	-	Various	Up to 70%
Trichogrammatidae:				
Trichogrammatoidea lutea	SA,Z	-	Maize, cotton	Up to 60%

* Percent parasitism

** B, Botswana; K, Kenya; SA, South Africa; T, Tanzania; U, Uganda; Z, Zimbabwe

Nyambo (1986) commonly reared Charops sp. from H. armigera on tomato, cleome and chickpea, whereas it was rare in collections from cotton and maize.

In South Africa, Taylor (1934) and Parsons (1940) reported that H. armigera was attacked by Bracon brevicornis only on antirrhinum plants,

while the pest was present on various host plants.

Citrus in southern Africa seems to have its own parasitoid guild which attacks H. armigera, during flowering, early in the season. The tachinids Gonia bimaculata Wiedemann (Cuthbertson 1934), Gonia sp. (Hall & Ford 1933; Jones 1939) and Paradrino halli (Jones 1939) were important parasitoids of H. armigera on citrus, but were rare on cotton and food crops, usually grown later in the season (Parsons & Ullyett 1934; Parsons 1940; Jones 1939). It is unclear whether this difference is caused by seasonal occurrence of the parasitoids or host-plant associations.

4.5 SEASONALITY

In tropical Africa, the occurrence of H. armigera and its natural enemies is influenced by rainfall. Rainfall in Uganda is relatively uniform throughout the year. Coaker (1959) found that H. armigera populations in Uganda remained at relatively stable low levels over four years, which he attributed to a well-balanced parasitoid-host relationship. In western Tanzania on the other hand, H. armigera enters diapause to survive the well-defined dry season. Reed (1965) stated that H. armigera populations were able to build up rapidly after this period because of the absence of natural enemies, which increased more slowly; later in the season, natural enemies seemed to reduce pest populations. Nyambo's (1986) work in Tanzania shows that Palexorista laxa, Chelonus curvimaculatus and Apanteles diparopsidis were absent during the dry season, whereas Charops sp. and Cardiochiles sp. (or spp.) were common throughout the year. During the growing season, the occurrence of Chelonus curvimaculatus and A. diparopsidis was irregular (Nyambo 1986).

These results suggest that augmentation and other means to encourage natural enemies to build up early in the season, before pest infestation becomes severe, deserve consideration.

4.6 RECOMMENDATIONS

Despite the amount of natural enemy data presented in Part II, our knowledge of the role that predators, parasitoids and pathogens play in regulating H. armigera populations in agricultural food and cash crops remains inadequate. Local in-depth studies are needed on the dynamics and natural mortality factors of H. armigera populations. Studies on the role of natural enemies should pay special attention to the inadequately studied predators, and try to assess their seasonal occurrence, and impact on H. armigera populations. In addition, detailed studies on egg parasitoid populations are needed in East Africa. Experimental studies on host-plant associations of natural enemies may help to identify key natural enemies in different crops, and form the basis for their augmentation or encouragement in integrated pest management programmes.

PART II

5. NATURAL ENEMIES OF *H. ARMIGERA* IN AFRICA

In this chapter, all parasitoids, predators and pathogens recorded from *Helicoverpa armigera* in Africa are reviewed. Depending on the information available, the following aspects are described for each species.

a. Name in current taxonomy, with synonyms. Author's names are not parenthesized (Crosskey *et al*. 1985). Synonyms are limited to those that refer to *H. armigera* records from Africa.
b. Taxonomic comment, including misidentifications and commentary on the reliability of records. Bracketed references refer to taxonomists' comments as follows:

    (1) R.W. Crosskey, pers. comm.
    (2) A.K. Walker, pers. comm.
    (3) T. Huddleston, pers. comm.
    (4) A. Polaszek, pers. comm.
    (5) Z. Bouček, pers. comm.

c. Distribution; within the Afrotropical Region by country, other regions by region.
d. Biology; relevant notes on adults, oviposition (including host location/recognition), development, and host stages attacked.
e. Alternative hosts or prey. Host records are not exhaustive; noctuids are given by species (African records only), non-noctuid lepidopterans by family, and non-lepidopterans by order (worldwide records).
f. Host-plant associations.
g. Secondary natural enemies.
h. *H. armigera* records; including country, host plant, occurrence (or percent parasitism or predation) and source. The initials 'BMNH' are given for specimens in the British Museum (Natural History) collection.

Families and orders are arranged in accordance with recent classification. Within each family species are listed alphabetically.

5.1 PARASITOIDS

DIPTERA

Bombyliidae

Sp. indet
H. armigera records:

South Africa	Maize	Important	Parsons & Ullyett 1934

Phoridae

Dohrniphora paolii Schmitz
Diploneura paolii Schmitz (Risbec 1960).
Biology: Dubious record as a true parasitoid; might well be a general saprozoic species.
Distribution: Afrotropical Region: Somalia.
H. armigera records:

Somalia	-	-	Risbec 1960

Sarcophagidae

The majority of species of Sarcophaginae are opportunist saprophages depositing their larvae in wounds, corpses and damaged tissues of animals and plants. Most Sarcophaga spp. sensu lato fall into this catogory but a few, chiefly Neotropical species, have been shown to be obligate parasitoids. Thus, records of Sarcophaga spp. as parasitoids of H. armigera should be treated with caution and careful observation made on the circumstances under which larvae and pupae are fed on by the fly larvae before they are accepted as true parasitoids (Greathead 1963).

Amobia signata Meigen
Pachyophthalmus signatus Meigen (Hall & Ford 1933)
Distribution: Afrotropical Region: southern Africa, West Africa; Nearctic Region; Oriental Region; Palaearctic Region.
Biology: This is possibly a hyperparasitoid.
Alternative hosts: HYMENOPTERA; ORTHOPTERA.
H. armigera records:

Zimbabwe	Citrus	Common	Hall & Ford 1933

Sarcophaga hirtipes Wiedemann
Distribution: Widespread mainland Afrotropical Region; Mediterranean Subregion; Oriental Region.
H. armigera records:

Tanzania	-	-	Robertson 1965

Sarcophaga sp.
H. armigera records:

Somalia	Maize	-	Chiaromonte 1933

Sarcophaga sp.
H. armigera records:

Senegal	Maize, millet	Rare	Bhatnagar 1987

Tachinidae

The biology of Tachinidae is reviewed by Clausen (1940) and Herting (1960).

Subfamily Tachininae

Dejeania bombylans Fabricius

Taxonomic comment: Records are regarded as reliable (1).

Distribution: Afrotropical Region: widespread from Ethiopia to South Africa, Angola, Sierra Leone, Zaire.

Alternative hosts: LEPIDOPTERA Noctuidae: Cucullia terrensis Felder.

H. armigera records:

Tanzania	-	-	Robertson 1965
Zimbabwe	Cotton	Abundant	Cuthbertson 1934

Hystricovoria bakeri Townsend

Distribution: Afrotropical Region: Botswana, Ghana, Kenya, South Africa; Oriental Region.

Alternative hosts: LEPIDOPTERA Noctuidae: Xanthodes graellsi Feisthamel; Arctiidae; Lymantriidae; Tortricidae.

H. armigera records: Although this species occurs in the Afrotropical Region, host records on H. armigera have been reported only from the Oriental Region (Crosskey 1976).

Genus Linnaemya Robineau-Desvoidy

Limited information exists on the biology of this genus. Strickland (1923) reported that Bonnetia (=Linnaemya) compta Fallen deposits its incubated eggs on the plant, in the vicinity of a host. Eggs hatch immediately and larvae attach to the passing host to bore through its integument. Many parasitoid larvae are actively killed by the host while entering the host's body, or die inside the host. The parasitoid pupates outside the host.

Linnaemya agilis Curran

Taxonomic comment: Records are regarded as reliable (1).

Distribution: Afrotropical Region: Benin, Kenya, Malawi, Nigeria, South Africa, Tanzania, Uganda, Zaire, Zimbabwe.

Alternative hosts: LEPIDOPTERA Noctuidae: Diparopsis castanea Hampson, Earias biplaga Walker, E. insulana Boisduval.

H. armigera records:

South Africa	Cotton	-	Curran 1934
Tanzania	Cotton	-	Curran 1934
Uganda	Cotton	-	Nyiira 1970a
Uganda	-	-	Coaker 1959

Linnaemya albifrons Smith

Micropalpus affinis Corti (Taylor 1932)

Taxonomic comment: Records are regarded as reliable (1).

Distribution: Afrotropical Region: widespread West Africa to East Africa, north-east Africa & southern Africa, Zaire.

Alternative hosts: LEPIDOPTERA Noctuidae: Leucania leucosticha Hampson.

H. armigera records:

South Africa	Cotton	-	Taylor 1932
Zimbabwe	-	-	Risbec 1960

Linnaemya longirostris Macquart

Taxonomic comment: Records are regarded as reliable (1).

Distribution: Afrotropical Region: widespread eastern Africa from Sudan and

Ethiopia to South Africa, Zaire.

Biology: The larval period of L. longirostris is 10-12 d, the pupal period 14-19 d. Occurs mostly during the fifth and sixth larval stages of the host H. armigera, and often emerges from the host pupa (Parsons 1940).

Host-plant associations: L. longirostris occurs on a variety of food crops and wild plant species. It appears from Parsons' (1940) data that L. longirostris, together with Palexorista sp., is more abundant on maize than on cotton.

Alternative hosts: LEPIDOPTERA Noctuidae: Cucullia sp., Plusia limbirena Guenée.

H. armigera records:

Kenya	Tomato	-	BMNH (Cock Coll 1987)
Kenya	Cotton	-	Le Pelley 1959
Kenya	-	-	Rens 1977
Kenya	-	-	van Emden 1960
South Africa	Various crops	Important	Parsons 1940
South Africa	Cotton	-	Taylor 1932
South Africa	Cotton	-	Simmonds 1960
Tanzania	Cotton	Rare	Robertson 1973
Uganda	-	-	Coaker 1959

Linnaemya sp.

H. armigera records:

Zimbabwe	Tobacco	-	Bünzli & Büttiker 1957

Nemoraea capensis Robineau-Desvoidy

Taxonomic comment: Records are regarded as reliable (1).

Distribution: Afrotropical Region: widespread north-east Africa, East Africa and southern Africa, Nigeria, Zaire.

Biology: Occurs in the fifth and sixth instars of H. armigera (Parsons 1940).

Alternative hosts: LEPIDOPTERA Noctuidae: Agrotis segetum Schiffermüller, Diparopsis castanea, Spodoptera exempta Walker.

H. armigera records:

Botswana	Cotton, sorghum	Rare	Roome 1971a
South Africa	Peas, citrus	Rare	Parsons 1940
South Africa	Cotton	-	Simmonds 1960

Nemoraea rubellana Villeneuve

Taxonomic comment: Records are regarded as reliable (1).

Distribution: Afrotropical Region: Cameroun, Ethiopia, Kenya, Rwanda, South Africa, Tanzania, Uganda, Zaire, Zimbabwe.

Alternative hosts: LEPIDOPTERA Noctuidae: Spodoptera exempta.

H. armigera records:

Kenya	-	-	Rens 1977

Paratachina obliqua Loew

Paratachina ingens Brauer & Bergenstamm (Taylor 1932)

Taxonomic comment: The record is regarded as reliable (1).

Distribution: Afrotropical Region: South Africa.

H. armigera records:

South Africa	Cotton	-	Taylor 1932

Subfamily Goniinae

Carcelia evolans Wiedemann

Taxonomic comment: There is a complex of sibling or semi-sibling species around 'evolans'. The record below is regarded as doubtful (1).

Distribution: Afrotropical Region: Ivory Coast, Senegal, Sierra Leone.

Biology: Jacquemard (1969) described the biology of C. evolans parasitizing Diparopsis watersi Rothschild in Cameroun. The females oviposit on cotton bolls that have been infested with bollworms. The eggs hatch almost immediately. First instars attack and enter the host, and remain inside for about 12 d. The host is killed in its fifth instar, and mature parasitoid larvae leave the dead host to pupate outside. Pupal period: 10 d. C. evolans enters diapause simultaneously with the host.

Alternative hosts: LEPIDOPTERA Noctuidae: Busseola fusca Hampson, Diparopsis spp.; Lasiocampidae; Papilionidae.

H. armigera records:

Tanzania	Cotton	Rare	Robertson 1973

Carcelia illota Curran

Taxonomic comment: This is probably a complex of sibling or semi-sibling species (1).
Misidentified as C. evolans in Reed (1965).

Distribution: Afrotropical Region: Nigeria, Tanzania, South Africa; Oriental Region.

Alternative hosts: LEPIDOPTERA Noctuidae: Acontia sp., Spodoptera littoralis Boisduval; Limacodidae.

H. armigera records:

Nigeria	-	-	BMNH (Beeden Coll 1974)
Tanzania	Cotton	7%	Robertson 1973
Tanzania	Cotton	Low numbers	Reed 1965, BMNH
Tanzania	Cotton, pigeon pea	-	BMNH (Ritchie Coll 1923)

Carcelia sp.

H. armigera records:

Senegal	-	Rare	Bhatnagar 1987

Carcelia sp.

H. armigera records:

Tchad	Cotton	-	Silvie pers. comm. 1988

Ceromya cibdela Villeneuve

Actia cibdela Villeneuve (Cuthbertson 1934)

Taxonomic comment: Reliable record (1).

Distribution: Afrotropical Region: Mozambique, Nigeria, Tanzania, Zaire.

Alternative hosts: LEPIDOPTERA Noctuidae; Sphingidae.

H. armigera records:

South Africa	Cotton	-	Cuthbertson 1934

Chetogena sp.

H. armigera records:

Senegal	Various crops	-	Bhatnagar 1987

?Drino sp.

H. armigera records:

Uganda	Cotton	-	Nyiira 1970a

Exorista sorbillans Wiedemann

Tricholyga sorbillans Wiedemann (Taylor 1932)

Taxonomic comment: Records must be regarded as suspect (1). Many undescribed species have been confused under E. sorbillans (Crosskey 1984).

Distribution: Afrotropical Region: Cameroun, Kenya, Malawi, Sierra Leone, Uganda; Mediterranean Subregion; Oriental Region.

Biology: Datta & Mukherjee (1978) studied the biology of Exorista ?sorbillans (as Tricholyga sorbillans) on Bombyx mori Linnaeus (Lep.: Bombycidae).

Oviposition: Macrotype eggs are laid on the host, mostly on inter segmental regions, with an average of 2 eggs per host.

Development: Eggs hatch within 2-3 d, larvae enter the host and feed inside for 5-6 d. The third instar emerges from the host to pupate outside. Egg+larval period: 8-12 d; pupal period: 10 d.

Alternative hosts: LEPIDOPTERA Lasiocampidae; Limacodidae; Lymantriidae; Noctuidae; Papilionidae; Psychidae; Saturniidae; HYMENOPTERA.

H. armigera records:

South Africa	Cotton	-	Taylor 1932

Exorista xanthaspis Wiedemann

Exorista fallax Meigen (Lazarevic 1971)

Taxonomic comment: Records are regarded as reliable (1).

Distribution: Afrotropical Region: widespread (incl. Madagascar, Seychelles, Socotra); Oriental Region; Palaearctic Region.

Biology: Achan et al. (1968) described the life-history of this parasitoid, under its synonym E. fallax, parasitizing H. armigera.

Adult: Mating occurs soon after emergence. The pre-oviposition period is 7-10 d.

Oviposition: Females attack the late instars of the host. Eggs are attached to the host near its head region, and hatch after 3-8 d. The parasitoids emerge from the host after 7-10 d (Herting 1960).

Alternative hosts: LEPIDOPTERA Noctuidae: Agrotis segetum, Earias sp., Plusia orichalcea Fabricius, Serrodes partita Fabricius, Spodoptera exempta, S. exigua Hübner, Xanthodes intersepta Guenée; Arctiidae; Lasiocampidae; Lymantriidae; Pieridae; Pyralidae; Sphingidae.

H. armigera records:

Senegal	Millet	Rare	Bhatnagar 1987
Sudan	Cotton	-	Lazarévic 1971

Gonia bimaculata Wiedemann

Taxonomic comment: Records are regarded as reliable (1).

Distribution: Afrotropical Region: widespread (excl. West Africa); Oriental Region; Palaearctic Region.

Biology: Gonia spp. oviposit microtype eggs on the plant, to be ingested by late instar host larvae.

Alternative hosts: LEPIDOPTERA Noctuidae: Agrotis segetum, Apopestes limbata Staudinger; Arctiidae.

H. armigera records:

Somalia	Maize	-	Chiaromonte 1933
South Africa	Cotton	Rare	Parsons 1940
South Africa	Cotton	2%	Parsons & Ullyett 1934
South Africa	Cotton	-	Simmonds 1960
South Africa	Citrus	Important	Cuthbertson 1934

?Gonia sp.

H. armigera records:

Zimbabwe	Citrus	V. important	Hall & Ford 1933

?Gonia sp.

H. armigera records:

Zimbabwe	Citrus	Important	Jones 1939

Goniophthalmus halli Mesnil

Taxonomic comment: All records below are regarded as reliable (1).

Distribution: Afrotropical Region: Botswana, Kenya, Namibia, Sudan, Tanzania, West Africa, Zimbabwe; Oriental Region.

Biology: Patel & Singh (1972) described the biology of G. halli parasitizing H. armigera.

Adults: Mating occurs generally on the day of emergence. Pre-oviposition period: 5-7 d. Fecundity: 5,000 eggs per female.

Oviposition: Numerous microtype eggs (0.18x0.1 mm) are attached to the host plant, near the edges of feeding spots of the target host, in order to be ingested together with the plant material.

Development: Eggs hatch in the host gut and the parasitoid larvae inhabit the haemolymph until they reach the third instar; they then attack other organs. Mortality of parasitoid eggs or larvae is generally high (Muck 1985). Parasitized hosts are not easily distinguishable from unparasitized and will continue feeding. Although several larvae can be found per host, no more than one parasitoid will eventually emerge, due to strong intraspecific competition. The parasitoid usually pupates within the host pupa, but sometimes the parasitoid larva leaves the host pupa to pupate outside.

Egg+larval period: variable, 9-17 d; pupal period: 8-16 d (27°C). In Tanzania this species has been reported to diapause for 130 d within its host pupa during the dry season (Reed 1965).

Host stages: The fourth, fifth or sixth instars of H. armigera are attacked. The adult parasitoid usually emerges from the host pupa.

Alternative hosts: No records from Africa. G. halli is regarded as a parasitoid specific on H. armigera. Out of 19 host records of this parasitoid worldwide only 2 are records of hosts (Lepidoptera) other than H. armigera.

H. armigera records:

Botswana	Cotton	0.1%	Roome 1971a, BMNH
Cape Verde	-	-	Mück 1985
Kenya	Cotton	-	BMNH (Rens Coll 1970)
Kenya	-	-	Dewhurst unpubl. 1985
Senegal	Maize, millet	Up to 2%	Bhatnagar 1987
Sudan	-	-	BMNH (Wood Coll 1933)
Tanzania	Cotton	Up to 12%	Reed 1965, BMNH
Tanzania	Cotton	Rare	Robertson 1973
Tchad	Cotton	-	Silvie pers. comm. 1988
Zimbabwe	-	-	Mesnil 1956
Zimbabwe	Citrus	-	BMNH (Jones Coll 1938)
Zimbabwe	-	-	BMNH (Hall Coll 1929)

Pales blepharipus Brauer & Bergenstamm

Phorocera blepharipus Brauer & Bergenstamm (Taylor 1932)

Taxonomic comment: The specific name must be regarded as doubtful (1).

Distribution: Afrotropical Region: South Africa, Zaire.

Alternative hosts: LEPIDOPTERA Noctuidae: Anomis auragoides Guenée, Cucullia terrensis, Plusia sp., Spodoptera exempta, Xanthodes graellsi; Lasiocampidae; Lymantriidae; Pyralidae; Saturniidae; Sphingidae.

H. armigera records:

South Africa	Cotton	-	Cuthbertson & Munro 1941
South Africa	Cotton	-	Taylor 1932

Pales coerulea Jaennicke

Taxonomic comment: The specific name must be regarded as doubtful (1).

Distribution: Afrotropical Region: north-east Africa to southern Africa; ?Oriental Region.

Alternative hosts: LEPIDOPTERA Noctuidae: Spodoptera littoralis; Hesperiidae; Lasiocampidae; Lycaenidae; Lymantriidae; Papilionidae.

H. armigera records:

South Africa	Various crops	Rare	Parsons 1940
Zimbabwe	Citrus	-	BMNH (Jones Coll 1938)

Pales nigronitens Villeneuve

Taxonomic comment: The specific name must be regarded as doubtful (1). Parsons (1940) recorded P. nigronitens as well as P. pavida Meigen, but according to Cuthbertson & Munro (1941) they were both P. nigronitens.

Distribution: Afrotropical Region: South Africa, Zaire.

Biology: Occurs in the second to the sixth instar of H. armigera and emerges from its pupa. Development egg-adult: 29-40 d (Parsons 1940).

Alternative hosts: LEPIDOPTERA Limacodidae.

H. armigera records:

South Africa	Citrus, vegetables	Rare	Parsons 1940

Pales seminitida Villeneuve

Taxonomic comment: The specific name must be regarded as doubtful (1).

Distribution: Afrotropical Region: Malawi, Nigeria, Zaire.

Alternative hosts: LEPIDOPTERA Lasiocampidae; Thaumetopoeidae.

H. armigera records:

Zimbabwe (from ?H. armigera)	Malvaceae	-	Cuthbertson & Munro 1941

Palexorista idonea Brauer & Bergenstamm

Sturmia partitor Curran (Cuthbertson 1939).

Taxonomic comment: The specific name below must be regarded as suspect (1).

Distribution: Afrotropical Region: Mozambique, South Africa.

Alternative hosts: LEPIDOPTERA Lasiocampidae.

H. armigera records:

Zimbabwe	Cotton	-	Cuthbertson 1939

Palexorista imberbis Wiedemann

Taxonomic comment: Records from Africa must be regarded as suspect. Despite many records in literature, there is no evidence that 'imberbis' occurs in the Afrotropical Region (1). All BMNH specimens from Africa, that were recorded as 'imberbis', are Palexorista laxa.

Distribution: Djibouti, Egypt, Israel.

Alternative hosts: LEPIDOPTERA Noctuidae: Spodoptera exigua, S. littoralis, Xylina exoleta Linnaeus; Lasiocampidae.

H. armigera records:

Sudan	Cotton	V. important	Tunstall 1958
Sudan	Cotton	Important	Lazarévic 1971
Tchad	Cotton	-	Silvie pers. comm. 1988
Uganda	Cotton	Rare	Greathead 1966

Palexorista laxa Curran

Sturmia laxa Curran (Taylor 1932; Cuthbertson & Munro 1941)

Taxonomic comment: This is probably a complex of sibling or semi-sibling species (1), and is currently being studied at the BMNH. In current taxonomy, P. laxa has been misidentified as Sturmia (=Palexorista) inconspicua Meigen (Jones 1939) and Drino (=Palexorista) imberbis (Reed 1965; Robertson 1973), neither occurring in the Afrotropical Region. H. armigera records are reliable for specimens present in the BMNH collection only; other records must be regarded as doubtful.

Distribution: Afrotropical Region: Botswana, Malawi, Senegal, South Africa, Sudan, Tanzania, Uganda, Zimbabwe; Oriental Region.

Biology: Jackson et al. (1976) described the biology of P. ?laxa parasitizing Helicoverpa zea Boddie.

Adults: Mating occurs soon after emergence. Pre-oviposition period: 6.9 d (25°C), 4.6 d (30°C); oviposition period: 24.5 d (25°C), 17.5 d (30°C).

Oviposition: Female attaches the incubated, macrotype eggs to the host body from a position standing beside the host.

Development: Eggs hatch immediately after oviposition and the emerging larvae enter the host. During development of the parasitoid larvae the host feeds normally, until the larvae emerge. Depending on the size of the host, one to seven parasitoid larvae emerge per host; they pupate outside.

Egg+larval period: 6.0 d (25°C), 4.6 d (30°C); pupal period: 9.4 d (25°C), 6.7 d (30°C) (Jackson et al. 1976), 12 d (Reed 1965).

Host stages: Mostly, fourth to sixth instars are attacked. The parasitoid emerges from the sixth instar or from the prepupa.

Alternative hosts: LEPIDOPTERA Noctuidae: Anomis auragoides, Busseola fusca, Leucania leucosticha, L. loreyi Duponchel, Lycophotia oliveata Hampson, Spodoptera exempta, S. exigua, Tarache nitidula Fabricius, Xanthodes graellsi; Arctiidae; Lasiocampidae; Pyralidae; Sphingidae.
According to Crosskey (1967) H. armigera is the only proven host of P. laxa. In this respect, the above alternative host records must be regarded as suspect. Gerling & Rotary (1973) demonstrated that P. laxa failed to develop in the noctuid Spodoptera littoralis. The parasitoids died at an early stage, together with their hosts. In the Sudan, Tunstall (1958) reported that P. ?laxa, an important parasitoid of H. armigera, did not parasitize Diparopsis watersi to any extent.

Host-plant associations: Data from Tanzania reveal a strong association of P. laxa with sorghum, compared with maize, cotton or cleome (Nyambo 1986). It was observed that H. armigera on sorghum feeds in a more exposed position than on other crops. This phenomenon might explain the differences in parasitism levels. See also Palexorista sp. below.

H. armigera records:

Botswana	Sorghum	-	BMNH (Roome Coll 1970)
Botswana	-	14.5%	Roome 1971a
Mali	-	-	BMNH (Doumbia Coll 1978)
Senegal	-	-	Risbec 1960
Senegal	Sorghum	Rare	Bhatnagar 1987
South Africa	Cotton	-	Cuthbertson & Munro 1941
South Africa	Cotton	-	Taylor 1932
Sudan	-	-	BMNH (Wood Coll 1933)
Tanzania	Cotton	Up to 25%	Reed 1965, BMNH
Tanzania	Various crops	Up to 42%	Nyambo 1986, BMNH
Tanzania	Cotton	14%	Robertson 1973, BMNH
Tanzania	-	-	BMNH (Ritchie Coll 1923)
Tanzania	-	-	BMNH (Disney Coll 1949)
Uganda	-	-	BMNH (Mubbin Coll 1939)
Zaire	-	-	Risbec 1960
Zimbabwe	-	-	BMNH (Gatuma Coll 1969)
Zimbabwe	-	-	Jones 1939, BMNH

Palexorista quadrizonula Thomson

Distribution: Afrotropical Region: widespread (incl. São Tome, Seychelles).

H. armigera records:

Senegal	Various crops	Up to 10%	Bhatnagar 1987

Palexorista sp. nr. inconspicua Meigen

H. armigera records:

Somalia	Maize	-	Chiaromonte 1933

Palexorista sp. nr. laxa Curran

H. armigera records:

Botswana	Abutilon	-	BMNH (Ingram Coll 1968)

(from Heliothis sp.)

Palexorista sp.

Taxonomic comment: Misidentified as Sturmia (=Palexorista) inconspicua, which is not Afrotropical (1). This might well be P. laxa.

Biology: Larval period: 10-14 d; pupal period: 8-17 d. Occurs mainly in the fifth and sixth instars of H. armigera (Parsons 1940).

Host-plant associations: In South Africa, higher parasitism by this species was observed on maize than on cotton. This might have been a density response; densities were higher on maize (Parsons & Ullyett 1934; Parsons 1940).

H. armigera records:

South Africa	Various crops	V. important	Parsons 1940
South Africa	Cotton	-	Simmonds 1960
South Africa	Cotton	20-30%	Parsons & Ullyett 1934
South Africa	Maize	Important	Parsons & Ullyett 1934
Sudan	-	-	Balla 1982

Palexorista sp.

H. armigera records:

Senegal	Various crops	Rare	Bhatnagar 1987

Paradrino halli Curran

Drino halli Curran (Robertson 1973)
Sturmia halli Curran (1939)
Sturmia rhodesiensis Jones (1939)

Taxonomic comment: This is a distinctive species; records are therefore regarded as reliable (1).

Distribution: Afrotropical Region: Botswana, Tanzania, Uganda, Zimbabwe.

Biology: Jones (1939) studied the biology of P. halli as the most important parasitoid of H. armigera on citrus in Zimbabwe.

Adult: Males can copulate directly after emergence, females only after 3 d. Pre-oviposition period is 7 d. Longevity: 12-33 d for females, 6-22 d for males; without food longevity is 5 d shorter for both sexes.

Oviposition: The adult female alights on the host to oviposit; oviposition occurs very quickly to prevent defence by the host. The ovipositor is short. Fully incubated macrotype eggs (0.7x0.23 mm) are attached to the integument of the host. The number of eggs per host varies with the abundance of hosts, most commonly 1-3 eggs are laid per host.

Development: Within 15 min after oviposition eggs hatch and the first instars enter the host by boring through the integument. The parasitoid larvae enter the host's fat bodies and create a hole for respiration in one of the tracheae; they place their spiracles in the opening. A funnel of wound tissue is formed around the parasitoid. Fully grown parasitoid larvae emerge from the host to pupate outside. When emerging from the host pupal stage they do so from between the segments of the pupa; this species bores no hole in the host pupa. In Tanzania, usually one parasitoid emerged per host (Robertson 1973). Egg+larval period: 16-20 d; pupal period: 7-16 d (Robertson 1973).

Host stages: The mostly attacked of H. armigera is the fourth. Parasitoid larvae emerge from the sixth instar or pupa of the host.

Host-plant associations: Parasitism is rather low on different crops. Jones (1939) however found high levels of parasitism on citrus during spring, much higher than on maize or vegetable crops later in the season. This could be attributable to a seasonal rather than a host plant effect.

Alternative hosts: LEPIDOPTERA Noctuidae: occasionally Busseola fusca and Cetola sp.; no other record. This species is regarded as a specialist parasitoid of H. armigera.

H. armigera records:

Botswana	Various crops	Rare	Roome 1971a
Tanzania	Cotton	Rare	Robertson 1973
Tanzania	Various crops	Common	Nyambo 1986
Zimbabwe	Citrus	Up to 25%	Jones 1939, BMNH
Zimbabwe	Various crops	Up to 5%	Jones 1939
Zimbabwe	Cotton	-	Bünzli & Büttiker 1957
Zimbabwe	-	-	Curran 1939

Peribaea mitis Curran

Taxonomic comment: Records are regarded as reliable (1).

Distribution: Afrotropical Region: Kenya, South Africa, Sudan.

Alternative hosts: LEPIDOPTERA Noctuidae: Spodoptera exigua; Geometridae.

H. armigera records:

Sudan	Clover	-	BMNH (Johnston Coll 1927)
Sudan	-	-	BMNH (Bedford Coll 1929)

Peribaea orbata Wiedemann

Actia aegyptia Villeneuve (Ismael & Swailem 1975)

Taxonomic comment: Records are regarded as reliable (1).

Distribution: Afrotropical Region: East Africa & southern Africa, Congo basin, West Africa to north-east Africa; Oriental Region.

Biology: This parasitoid attacks mostly the second or third instar of the host Spodoptera littoralis. Pupal period: 7-10 d (Hegazi, Hammad & El-Minshawy 1977).

Alternative hosts: LEPIDOPTERA Noctuidae: Spodoptera exempta, S. exigua, S. littoralis.

H. armigera records:

Egypt	-	-	Ismael & Swailem 1975

Plagiomima rufolateralis Crosskey

Taxonomic comment: Records are regarded as reliable (1).

Distribution: Afrotropical Region: Botswana, Namibia.

H. armigera records:

Botswana	Carnations, sunflower (from Heliothis sp.)	-	Crosskey 1984

Pseudogonia rufifrons Wiedemann

Gonia ritchiei Cuthbertson & Munro (1941)

Isomera cinerascens Rondani (Lazarevic 1971)

Pseudogonia cinerascens Rondani (Parsons 1940; Simmonds 1960)

Taxonomic comment: Records are regarded as reliable (1).

Distribution: Afrotropical Region: widespread (incl. Cape Verde Islands, Socotra); Oriental Region; Palaearctic Region.

Biology: The biology of P. rufifrons, under its synonym Gonia cinerascens, has been extensively studied on the host Galleria mellonella Linnaeus (Lep.: Pyralidae) by Campadelli and others in Italy.

Adult: Mating occurs on the day of emergence. Pre-oviposition period: 16 d at 24°C. Longevity : 22 d for females, 15 d for males at 24°C (Campadelli & Baronio 1979). Fecundity: several thousands of eggs (Gardenghi & Mellini 1980).

Oviposition: Numerous microtype eggs are attached to the leaves to be ingested by the host together with the plant material.

Development: Eggs hatch in the fore- or mid-gut; hatching is mainly induced by digestive enzymes of the host (Mellini & Campadelli 1979). The first instar develops within the abdominal muscles of the host. Ecdysteroid hormones of the host act directly on parasitoid development (Barinio & Sehnal 1980). The second instar moves to the space between the old larval skin and the developing pupa. The mature third instar pupates inside the cocoon of the host. No more than one parasitoid will emerge per host, due to intraspecific competition. Pupal period: 10 d (27°C). Total development period: 30-37 d (Parsons 1940).

Host stages: Most commonly, fourth to sixth instars of H. armigera are attacked. The adult parasitoid emerges from the host pupa (Parsons 1940).

Host-plant associations: Parsons (1940) found P. rufifrons more frequently on H. armigera on peas, than on other crops.

Alternative hosts: LEPIDOPTERA Noctuidae: Leucania loreyi, Spodoptera exempta, S. exigua.

H. armigera records:

Senegal	Maize	Up to 14%	Bhatnagar 1987
South Africa	Various crops	Rare	Parsons 1940
South Africa	Cotton	-	Simmonds 1960

South Africa (from ?H. armigera)	Citrus	-	Cuthbertson & Munro 1941
Sudan	Cotton, beans	-	Lazarévic 1971

Sturmia convergens Wiedemann

Sturmia flavohalterata Bischof (Milner 1967)

Taxonomic comment: Records are regarded as reliable (1).

Distribution: Afrotropical Region: Ethiopia, Kenya, Malawi, Nigeria, Sierra Leone, South Africa, Tanzania, Zambia, Zimbabwe; Oriental Region.

Biology: The female deposits microtype eggs in the vicinity of the host, mostly on the underside of the leaves. First instar larvae find and enter the host. Mature larvae leave the host pupae and pupate in the soil (Herting 1960).

Alternative hosts: LEPIDOPTERA Danaidae; Nymphalidae.

H. armigera records:

Tanzania	Striga	-	Milner 1967

?Sturmia sp.

Taxonomic comment: This might well be Palexorista sp.

H. armigera records:

Zimbabwe	Citrus	V. important	Hall & Ford 1933

Thelairosoma angustifrons Villeneuve

Taxonomic comment: Records must be regarded as doubtful (1).

Distribution: Afrotropical Region: Malawi, Nigeria, South Africa, Tanzania, Uganda, Zaire.

Alternative hosts: LEPIDOPTERA Bombycidae; Sphingidae.

H. armigera records:

Zimbabwe	Cotton	-	Pearson 1958

Voria capensis Villeneuve

Taxonomic comment: The record below is regarded as reliable (1).

Distribution: Afrotropical Region: widespread eastern Africa from Kenya to South Africa, Ghana, Nigeria.

H. armigera records:

South Africa	-	-	Cuthbertson & Munro 1941

Voria ruralis Fallen

Taxonomic comment: This species is very near to V. capensis.

Distribution: Afrotropical Region: from Kenya to South Africa; Nearctic Region; Neotropical Region; Oriental Region; Palaearctic Region.

Biology: This cosmopolitian species has been studied extensively as a parasitoid of the noctuid Trichoplusia ni Hübner in North America.

Adults: Mating occurs soon after emergence. Pre-oviposition period: 9 d; oviposition period: 14 d (Brubaker 1968). Fecundity: 60 eggs per female (Elsey & Rabb 1970). Longevity: 28 d for females, 20 d for males (Grant & Shepard 1983).

Oviposition: Fully incubated eggs are laid on the host and hatch immediately.

Development: First instar larvae bore into the host body and settle in the muscle fibre. After a few days, the parasitoid larvae create a hole for respiration in the integument of the host and place their abdominal spiracles in the opening (Elsey & Rabb 1970). The parasitoids pupate inside the host larva or pupa. This species is gregarious, with an average of 2.2 pupae emerging per T. ni host. Egg+larval period: 7-9 d; pupal period: 7-8 d (27°C) (Grant & Shepard 1983); see also Jackson, Butler & Bryan (1969).

Host stages: Late host instars are preferred for oviposition. Adult parasitoids emerge from the host larval or pupal stage.

Alternative hosts: LEPIDOPTERA Noctuidae: Plusia chalcites Esper, P. limbirena, P. orichalcea. Worldwide, V. ruralis is mainly a parasitoid

of Noctuidae.

H. armigera records: Although this species occurs in the Afrotropical Region, host records on H. armigera have been reported only from the Oriental Region.

Winthemia dasyops Wiedemann

Taxonomic comment: Records are regarded as reliable (1).

Distribution: Afrotropical Region: Ethiopia, Ghana, Kenya, Madagascar, Malawi, Mozambique, Nigeria, South Africa, Tanzania, Uganda, Zaire; South Yemen.

Biology: It has been recorded that Winthemia species have a short pre-oviposition period (2-3 d). They inject their eggs in the host larva or attach the eggs to the host integument. Eggs hatch in about one week. The larval period is very short (Clausen 1940).

H. armigera records:

South Africa	Cotton	-	Cuthbertson & Munro 1941

Zygobothria ciliata van der Wulp

Sturmia munroi Curran (Cuthbertson 1934; Jones 1939)

Taxonomic comment: Records are regarded as reliable (1).

Distribution: Afrotropical Region: widespread mainland; Oriental Region.

Alternative hosts: LEPIDOPTERA Noctuidae: Diparopsis castanea, Spodoptera exigua; Geometridae; Lasiocampidae; Psychidae; Sphingidae.

H. armigera records:

South Africa	Citrus	-	Cuthbertson 1934
Zimbabwe	Citrus	Rare	Jones 1939

HYMENOPTERA

Ichneumonidae

Barylypa humeralis Brauns

Distribution: Palaearctic Region.

Alternative hosts: LEPIDOPTERA Noctuidae.

H. armigera records:

Egypt	Predom. Tomato	Up to 16%	Megahed et al. 1977

Barylypa rufa Holmgren

Distribution: Palaearctic Region.

Alternative hosts: LEPIDOPTERA Noctuidae.

H. armigera records:

Egypt	-	Common	Ismael & Swailem 1975

Campoplex xanthostoma Gravenhorst

Distribution: Palaearctic Region.

Alternative hosts: LEPIDOPTERA Gelechiidae; Noctuidae; Pyralidae.

H. armigera records:

Egypt	-	Rare	Megahed et al. 1977

Genus Charops Holmgren

The African fauna in this genus is still largely undescribed. Likewise, very limited information exists on the biology of Charops spp. Duodu & Lawson (1983) studied C. diversipes Roman on the nymphalid host Acraea terpsicore Linnaeus. Charops spp. generally attack exceptionallly young host larvae (mostly first instars), although a Charops sp. has been reported to attack the third instar of Orgyia mixta Snellen (Lymantriidae) more than the first or second instar (Migunda 1970). The development of C. diversipes, from egg to adult, is 13-17 d. The mature

larva emerges from the host larva and starts spinning a cocoon. The cocoon remains on the plant during pupation. Pupae of Charops spp. are commonly hyperparasitized by Brachymeria spp. (Chalcididae). The records below might include many different species.

Charops ater Szepligeti
Taxonomic comment: Records are regarded as reliable (2).
Distribution: Afrotropical Region: Madagascar, Mozambique, Nigeria.
Alternative hosts: LEPIDOPTERA Noctuidae: Spodoptera littoralis; Nymphalidae.
H. armigera records:

Mozambique	-	-	BMNH (Umbeluzi Coll 1982)

Charops sp.
H. armigera records:

Tanzania	Legumes	Common	Reed 1965

Charops sp.
Biology: This species is common year-round in Tanzania. The parasitoid larva emerges from the third or fourth instar of the host (Nyambo 1986).
Host-plant associations: Common on tomato, cleome and chickpea; rare on cotton and maize (Nyambo 1986).
H. armigera records:

Tanzania	Various crops	Up to 23%	Nyambo 1986

Charops sp.
H. armigera records:

Tanzania	Cotton	2.1%	Robertson 1973

Charops sp.
H. armigera records:

Tanzania	Pigeon pea	-	BMNH (Disney Coll 1949)

Charops sp.
H. armigera records:

Tanzania	Striga	-	Milner 1967

Charops sp.
H. armigera records:

Uganda	Various crops	10%	Coaker 1959

Charops sp.
H. armigera records:

Uganda	Cotton	-	Nyiira 1970a

Charops sp.
H. armigera records:

Botswana	Cotton, cleome	-	Roome 1975a

Charops sp.
H. armigera records:

Tchad	Cotton	-	Silvie pers. comm. 1988

Charops spp.
Alternative hosts: LEPIDOPTERA Noctuidae: Plusia orichalcea.
H. armigera records:

South Africa	Cotton, tomato	V. rare	Parsons 1940

Charops sp.
H. armigera records:

Nigeria	-	-	BMNH (Beeden Coll 1974)

Charops sp.
H. armigera records:

Senegal	Sorghum, acanthospermum	Rare	Bhatnagar 1987

Diadegma sp.
Angitia sp. (Parsons 1940)
Taxonomic comment: Probably many undescribed species in Africa (2).
Biology: Larval period: 7-11 d; pupal period: 12-15 d. Attacks mostly the third host instar (Parsons 1940).
H. armigera records:

South Africa	Peas, maize	Rare	Parsons 1940

Genus Enicospilus Stephens
Moutia & Courtois (1952) report that Enicospilus sp. has a pre-ovipostition period of 8-10 d and a fecundity of 8-14 eggs per female. The female deposits one egg in the body cavity of the host, and the egg hatches after 2 d. The larva develops in the haemolymph of the host. When fully grown, it emerges from the host and spins a cocoon on the plant. Oviposition is probably most frequent in the third and fourth instars of the host. In general, Enicospilus spp. are parasitoids of Noctuidae; many are thought to be host specific. Some species are adapted to dry conditions, e.g. E. capensis Thunberg, is known as a dry season parasitoid of noctuids in India (Gauld & Mitchell 1978).

Enicospilus capensis Thunberg
Distribution: Afrotropical Region: throughout (incl. Madagascar); Oriental Region.
Alternative hosts: LEPIDOPTERA Noctuidae: Sesamia sp., Spodoptera exempta, many other Noctuidae; occasionally Pyralidae.
H. armigera records: Although this species occurs throughout Africa, host records on H. armigera have been reported only from the Oriental Region.

Enicospilus ?communis Szepligeti
H. armigera records:

Uganda	Cotton	11%	Coaker 1959

Enicospilus sp.
H. armigera records:

Tanzania	Cotton	Rare	Robertson 1973

Metopius discolor Tosquinet
Distribution: Afrotropical Region: South Africa, Tanzania.
Biology: Endoparasitoid. Attacks late host instars. Egg-adult period: 32-39 d (Parsons 1940). Metopius spp. are the only ichneumonids that emerge from the host pupal stage.
Alternative hosts: No records.
H. armigera records:

South Africa	Various crops	Rare	Parsons 1940
South Africa	Cotton	-	Taylor 1932
South Africa	Cotton	-	Simmonds 1960
Tanzania	Cotton	Rare	Reed 1965

Netelia ?capensis Holmgren
Distribution: Afrotropical Region: Ethiopia, Kenya, South Africa, Uganda.
Biology: Netelia spp. oviposit one black egg with a hard shell on the host. Usually full-grown host larvae (fifth and sixth) are attacked. The host

is killed before it pupates.

H. armigera records:

Uganda	-	Rare	Coaker 1959

Netelia opacula Schrank

Taxonomic comment: Specific name must be regarded as doubtful (2).

Distribution: Afrotropical Region: Ethiopia, Kenya, South Africa, Uganda; Palaearctic Region.

Alternative hosts: LEPIDOPTERA Noctuidae: records from Palaearctic Region only.

H. armigera records:

Kenya	-	-	Le Pelley 1959

Netelia testacea Gravenhorst

Taxonomic comment: Record below is regarded as reliable (2).

Distribution: Afrotropical Region: Zimbabwe; Palaearctic Region.

Alternative hosts: LEPIDOPTERA Noctuidae, records from outside the Afrotropical Region only; Arctiidae; Lasiocampidae; Notodontidae; Sphingidae.

H. armigera records:

Zimbabwe	-	-	BMNH (Gatooma Coll 1969)

Netelia sp.

H. armigera records:

Kenya	Tomato	-	BMNH (Cock Coll 1987)

Netelia sp.

H. armigera records:

Tanzania	Cotton	Up to 3%	Reed 1965

Netelia sp.

H. armigera records:

Tanzania	Various crops	Rare	Nyambo 1986

Netelia sp.

H. armigera records:

Tanzania	Cotton	Rare	Robertson 1973

Netelia sp.

H. armigera records:

Uganda	Cotton	-	Nyiira 1970a

Pristomerus sp. nr. fumipennis Wilkinson

H. armigera records:

Uganda	-	Rare	Coaker 1959

Pristomerus sp.

Taxonomic comment: Many undescribed Pristomerus spp. in Africa.

Biology: Solitary endoparasitoid. Occurs mainly in second and third host instars. Larval period: 7-9 d; pupal period: 9-11 d (Parsons 1940). The fully grown larva spins a cocoon near the host remains.

H. armigera records:

South Africa	Various crops	Rare	Parsons 1940

Pristomerus sp.

H. armigera records:

Tanzania	Cotton	Rare	Reed 1965

Pristomerus sp.

H. armigera records:

Tanzania	Various crops	Rare	Nyambo 1986

Pristomerus sp.
H. armigera records:

Botswana	Various crops	-	Roome 1975a

Pristomerus sp.
H. armigera records:

South Africa	Cotton	-	Simmonds 1960

Pristomerus sp.
H. armigera records:

Senegal	Sorghum	-	Bhatnagar 1987

Braconidae

Aleiodes sp.
Taxonomic comment: Recorded as Rogas sp.; the genus Rogas was later transferred to Aleiodes.
H. armigera records:

Uganda	Cotton	-	Nyiira 1970a

Aleiodes sp.
H. armigera records:

Senegal	Various crops	Up to 7%	Bhatnagar 1987

Genus Apanteles Foerster
Taxonomic comment: This huge genus was classified in species-groups by Nixon (1965), and has been reclassified by Mason (1981) in a number of new genera. Because Mason's reclassification is based only on American species, excluding species from all other parts of the world, it is not generally accepted. We therefore use Nixon's classification.
Biology: Species in this genus are larval, in some cases egg-larval, endoparasitoids of Lepidoptera. Mature larvae emerge from the host and pupate in cocoons alongside the host remains. Some species emerge from very young host larvae, some from the host's final instar. Species are either solitary or gregarious (Le Masurier 1987). Although some species attack a wide variety of host species of different lepidopterous families, most are restricted to a small number of closely related hosts.

Apanteles diparopsidis Lyle
Taxonomic comment: The record below is regarded as reliable (2).
Distribution: Afrotropical Region: Malawi, Rwanda, South Africa, Sudan, Tanzania, Uganda, West Africa, Zaire.
Biology: Attacks the first and emerges from the second instar of H. armigera. Pupal period: 5-8 d (Nyambo 1986).
Host-plant associations: Common on sorghum, rare on cotton (Nyambo 1986).
Alternative hosts: Mainly known as a parasitoid of Diparopsis and Earias spp.; LEPIDOPTERA Noctuidae: Diparopsis castanea, D. watersi, Earias biplaga, E. insulana; Gelechiidae; Lyonetiidae; Pyralidae.
H. armigera records:

Tanzania	Various crops	Up to 26%	Nyambo 1986

Apanteles maculitarsis Cameron
Taxonomic comment: The records below are regarded as doubtful (2).
Distribution: Afrotropical Region: Kenya, Malawi, Senegal, South Africa.
Biology: Larval period: 8-10 d; pupal period: 6-8 d. Mostly, it attacks the first instar and emerges from the third instar of H. armigera (Parsons 1940).
Alternative hosts: LEPIDOPTERA Noctuidae: Spodoptera exempta; Lasiocampidae;

Saturniidae.

Host-plant associations: Most frequent on peas (Parsons 1940).

H. armigera records:

Senegal	-	-	Risbec 1950
South Africa	Various crops	Common	Parsons 1940
South Africa	Various crops	-	de Saeger 1944

Apanteles ruficrus Haliday

Taxonomic comment: Recognizable species; records are regarded as reliable (2).

Distribution: Afrotropical Region: Cameroun, Madagascar, Senegal, Somalia, South Africa, Sudan, Uganda; Oriental Region; Palaearctic Region; introduced in North America and New Zealand.

Biology: Gregarious species. Hafez (1947) described the biology of A. ruficrus parasitizing Agrotis ipsilon Rottenburg.

Mating occurs directly after emergence. There is no pre-oviposition period, because eggs are fully developed upon emergence. Fecundity: 220 eggs per female. Longevity of female: 6.3 d (26°C). Sex ratio 2:1, in favour of males.

Oviposition: The female deposits a large number of eggs per host, just under the host integument. During the next 5 d the eggs swell up from 0.13x0.04 mm to 0.56x0.25 mm, and hatch. The larvae feed within the host during their development. The host gradually becomes inactive and stops feeding. The fully grown third instar parasitoids leave the host almost simultaneously and start spinning their white cocoons alongside the host remains. Hafez reported that about 60 parasitoids emerge per Agrotis host. Egg+larval period: 11-18 d; pupal period: 3-6 d (28°C) (McCutcheon, Salley & Turnipseed 1983).

Alternative hosts: LEPIDOPTERA Noctuidae: Agrotis ipsilon, Euxoa spinifera Hübner, Leucania loreyi, Plusia circumflexa Linnaeus, P. gamma Linnaeus, Sesamia cretica Lederer, Spodoptera exempta, S. exigua, S. littoralis; Arctiidae; Geometridae; Hesperiidae; Lycaenidae; Lymantriidae; Nymphalidae; Pyralidae; Yponomeutidae.

Secondary natural enemies: A pteromalid has been recorded from A. ruficrus cocoons in Egypt (Hafez 1947).

H. armigera records:

Egypt	-	Common	Ismail & Swailem 1975
Egypt	-	Rare	Megahed et al. 1977
Senegal	-	-	Risbec 1950
Somalia	Maize	-	de Saeger 1944
Sudan	Cotton	-	Greathead 1966

Apanteles sesamiae Cameron

Taxonomic comment: Distinct species; records are regarded as reliable (2).

Distribution: Afrotropical Region: Cameroun, Kenya, Malawi, Mozambique, Senegal, South Africa, Sudan, Uganda, Zaire.

Biology: Ullyett (1935) described the biology of A. sesamiae parasitizing Busseola fusca.

Adult: Mating occurs shortly after emergence. Longevity: 3-4 d.

Development: Egg+larval period: 14-21 d; pupal period: 5-7 d (26°C, 80%RH). High humidity seems to be essential for development. Commonly, 60-100 larvae emerge per host larva.

Host stages: Mature parasitoid larvae emerge from the fifth or sixth instar of the host.

Alternative hosts: Known mainly as a stemborer parasitoid; LEPIDOPTERA Noctuidae: Busseola fusca, Sesamia spp.; Pyralidae. The stout body and short appendages suggest the adaptation of this species to parasitize stemborers (see Ullyett 1935).

H. armigera records:

Zaire	-	-	de Saeger 1944
(from Heliothis sp.)			

Apanteles sp. nr. aethiopicus (ultor-group of Nixon (1965))
Biology: Occurs in the first to the third host instar of H. armigera. Larval period: 7-10 d; pupal period: 6-8 d (Parsons 1940).
Host-plant associations: Frequent on peas (Parsons 1940).
H. armigera records:

South Africa	Peas	Important	Parsons 1940

Apanteles sp. ultor-group of Nixon (1965)
H. armigera records:

Uganda	Various crops	Up to 20%	Coaker 1959

Apanteles sp. vitripennis-group of Nixon (1965)
Biology: This species attacks the first instar of the host (Nyambo, unpublished). A. vitripennis is a solitary species (Le Masurier 1987).
H. armigera records:

Tanzania	Various crops	Common	Nyambo 1986

Apanteles sp.
H. armigera records:

Uganda	Cotton	-	Nyiira 1970a

Apanteles sp.
H. armigera records:

Kenya	Pigeon pea	-	BMNH (KARI Coll 1985)

Apanteles sp.
H. armigera records:

Botswana	Sorghum, sunflower	-	Roome 1975a

Apanteles sp.
H. armigera records:

Somalia	Cotton	-	Russo 1940

Apanteles sp.
H. armigera records:

Tchad	Cotton	-	Silvie pers. comm. 1988

Apanteles sp.
H. armigera records:

Egypt	Various plants	Up to 27%	Megahed et al. 1977

Apanteles sp.
H. armigera records:

Madagascar	Cotton	Important	Vaissayre 1977

Ascogaster ?cava de Saeger
Distribution: Afrotropical Region: Zaire.
H. armigera records:

Uganda	-	Rare	Coaker 1959

Bracon brevicornis Wesmael
Microbracon brevicornis Wesmael (in all references below)
Taxonomic comment: Bracon brevicornis is now thought to be a synonym of B. hebetor Say (2).
Distribution: Afrotropical Region: South Africa, Sudan, West Africa; Nearctic Region; Neotropical Region; Oriental Region; Palaearctic Region.
Biology: Gregarious larval ectoparasitoid. Taylor (1932) described the biology of B. brevicornis parasitizing H. armigera in South Africa. Adult: Pre-oviposition period less than a day. Fecundity: 200 eggs per

female. Longevity: 25 d for females; 9 d for males. Arrhenotokous. Host feeding by adult females has been recorded.

Oviposition: The host is paralysed and 3-8 eggs, depending on the size of the host, are deposited on the integument. Eggs hatch after 1.5-2 d.

Development: Larvae develop outside the host. Mature larvae spin a cocoon and pupate alongside the host remains. Larval period: 4-5 d; pupal period: 6-8 d.

Alternative hosts: Wide host range; LEPIDOPTERA Noctuidae: Busseola fusca, Diparopsis watersi, Earias insulana, Leucania sp., Spodoptera exempta, S. exigua; Gelechiidae; Pieridae; Pyralidae; Stenomidae; Tortricidae; COLEOPTERA.

Host-plant associations: In South Africa, B. brevicornis was found associated almost exclusively with H. armigera on Antirrhinum majus, a garden plant, while H. armigera was present on various crops (Taylor 1932; Parsons 1940).

H. armigera records:

Egypt	Various plants	Up to 17%	Megahed et al. 1977
South Africa	Exclusively on antirrhinum	-	Taylor 1932
South Africa	Cotton	-	Simmonds 1960
South Africa	Maize	10%	Ullyett 1933
South Africa	Various crops	Rare	Parsons 1940
South Africa	Antirrhinum	V. common	Parsons 1940
South Africa	Lucerne, antirrhinum	Common	Pettey 1948
Tchad	Cotton	-	Silvie pers. comm. 1988

Bracon hebetor Say

Taxonomic comment: Bracon brevicornis is now thought to be a synonym of B. hebetor (2).

Distribution: Afrotropical Region; Neotropical Region; Oriental Region; Palaearctic Region.

Alternative hosts: Wide host range; LEPIDOPTERA Blastoblasidae; Gelechiidae; Hesperiidae; Lycaenidae; Noctuidae; Oecophoridae; Pyralidae; Stenomidae; Tineidae; Yponomeutidae; HYMENOPTERA.

H. armigera records:

Senegal	Maize, millet	Rare	Bhatnagar 1987

Bracon kirkpatricki Wilkinson

Microbracon kirkpatricki Wilkinson (Balla 1982)

Distribution: Afrotropical Region: Congo, Egypt, Ivory Coast, Malawi, Senegal, Somalia, Sudan; Oriental Region; introduced in North America in 1969.

Biology: Engroff & Watson (1975) described the biology of B. kirkpatricki parasitizing Pectinophora gossypiella Saunders (Gelechiidae).

Alternative hosts: LEPIDOPTERA. Mainly known as a parasitoid of Pectinophora gossypiella (Gelechiidae); Pyralidae.

H. armigera records:

Sudan	-	-	Balla 1982

Bracon sp.

H. armigera records:

Tanzania	Cotton	-	Le Pelley 1959

Bracon sp.

H. armigera records:

Senegal	Millet	Rare	Bhatnagar 1987

Braunsia sp.

H. armigera records:

Tanzania	Cotton	-	Le Pelley 1959

Genus Cardiochiles Nees

Taxonomic comment: There are several undescribed species in Africa. Species from the Sahelian Subregion have recently been revised (Huddleston & Walker in press). Revision for tropical Africa is underway.

Biology: Cardiochiles spp. are solitary endoparasitoids of Lepidoptera. They usually attack their host during early host instars and emerge from the fourth, fifth or sixth instar, depending on the parasitoid species. The North American Cardiochiles nigriceps is the best studied species in this genus, and is regarded as a highly specific parasitoid of Heliothis virescens. It has been shown that the females locate their host by close range chemoreception. They examine areas contaminated with mandibular gland secretions of H. virescens (Vinson 1968; Vinson & Lewis 1965; Vinson et al. 1975). The active chemical compounds are specific to H. virescens; the parasitoid will show a weaker response to frass of the closely related Helicoverpa zea (Vinson et al. 1975). The latter is an unsuitable host for C. nigriceps, because it will encapsulate the parasitoid egg (Lynn & Vinson 1977). C. nigriceps deposits one egg per host larva. Oviposition temporarily paralyses the host. The egg hatches within 1.5-2 d, and the new larva develops and remains inside the host until the host enters the soil to pupate (Danks, Rabb & Southern 1979). When the larva emerges from the host it feeds externally on the host remains, and starts spinning a cocoon to pupate in the ground (Lewis & Vinson 1968). Compare also Singh & Parshad (1970) for the biology of Cardiochiles hymeniae Fisher & Parshad.

Although there is no evidence that the African Cardiochiles spp., which parasitize H. armigera, are host specific, none of the species presented below has been found on a host other than H. armigera.

It has been reported that C. nigriceps is associated with tobacco plants (Vinson 1975; Martin et al. 1981). In Tanzania, Cardiochiles spp. seem to be associated with cotton more than other crops (Nyambo 1986).

Cardiochiles nigricollis Cameron

Taxonomic comment: Records are regarded as reliable (2).

Distribution: Afrotropical Region: Botswana, South Africa, Zaire.

Biology: Larval period: 10-13 d; pupal period: 9-12 d. Mainly, second and third instars of H. armigera are attacked (Parsons 1940).

Host-plant associations: In South Africa, C. nigricollis was mostly found in cotton-bred hosts (Parsons 1940).

H. armigera records:

Botswana	Cotton, maize, cleome	-	Roome 1975a
South Africa	Predom. cotton	Common	Parsons 1940
South Africa	Cotton, maize	-	de Saeger 1948

Cardiochiles nigromaculatus Cameron

Taxonomic comment: Reliable records (2).

Distribution: Afrotropical Region: Malawi, South Africa, Uganda, Zaire; Oriental Region.

H. armigera records:

Tanzania	-	-	Reed 1965, BMNH
Uganda	Cotton	-	Nyiira 1970a

Cardiochiles trimaculatus Cameron

Taxonomic comment: Records are regarded as reliable (2).

Distribution: Afrotropical Region: Equatorial Guinea, South Africa, Tanzania, Uganda, Zaire.

Biology: According to Greathead (1966), C. trimaculatus was the most important parasitoid of H. armigera on cotton in Uganda.

H. armigera records:

Tanzania	Cotton	Rare	Robertson 1973
Uganda	Various crops	8%	Coaker 1959

Uganda	Cotton	Important	Greathead 1966

Cardiochiles sp. nr. trimaculatus Cameron
Cardiochiles sp.
Taxonomic comment: These are two separate species.
Host-plant associations: These species seem to be associated with cotton and cleome; they are rare on sorghum (Nyambo 1986).
H. armigera records:

Tanzania	Various crops	Important	Nyambo 1986

Cardiochiles sp. nr. trimaculatus Cameron
H. armigera records:

Uganda	Cotton	-	Greathead 1966

Cardiochiles variegatus Szepligeti
Taxonomic comment: Reliable records (2).
Distribution: Afrotropical Region: Gambia, Niger, Nigeria, Senegal, Tanzania, Zaire.
H. armigera records:

Nigeria	-	-	BMNH (Beeden Coll 1975)
Senegal	Maize, millet, acanthospermum	Up to 40%	Bhatnagar 1987, BMNH

Cardiochiles sp.
H. armigera records:

South Africa	Cotton	-	Simmonds 1960

Cardiochiles sp.
H. armigera records:

Tchad	Cotton	-	Silvie pers. comm. 1988

Chelonus bifoveolatus Szepligeti
Taxonomic comment: Record below is regarded as reliable (2).
Distribution: Afrotropical Region: Tanzania, Zaire.
H. armigera records:

Tanzania	-	-	Robertson 1970

Chelonus curvimaculatus Cameron
Chelonella curvimaculatus Cameron (Parsons 1940)
Neochelonella curvimaculatus Cameron (Coaker 1959)
Taxonomic comment: Probably a complex of species. In current taxonomy records are regarded as reliable (2).
Distribution: Afrotropical Region: Madagascar, Mauritius, Somalia, South Africa, Sudan, Tanzania, Uganda, Zaire, Zimbabwe.
Biology: Solitary egg-larval parasitoid. Broodryk (1969) described the biology of C. curvimaculatus.
Adult: Copulation occurs soon after emergence. No pre-oviposition period. The fecundity is high (520 eggs per female at 26.5°C). Longevity: 8.2 d for females, 6.4 d for males at 26.5°C; longevity at 32°C is only 1.5 d for both sexes.
Oviposition: Females attack the host in its egg stage. They deposit one egg (0.2x0.05 mm) per host, and do not distinguish between parasitized and unparasitized host eggs. Also, freshly laid eggs are attacked to about the same extent as are older eggs. In young host eggs the parasitoid deposits its egg in the yolk, in older host eggs the parasitoid oviposits directly into the haemocoel of the host embryo. Adult females of Chelonus sp. nr. curvimaculatus respond to kairomones of their host; the kairomones are emitted by the scales the moths leave at oviposition sites (Chiri & Legner 1982).
Development: Eggs hatch after 1-1.5 d (26.5°C). Larvae emerging in the yolk of the host egg will soon enter the haemocoel of the embryo.

Parasitized larvae of H. armigera are arrested in their third larval instar and start spinning their cocoon; spinning normally takes place in the host's sixth instar. The parasitoid larva consumes the host and pupates outside. According to Nyambo (1986) parasitoid larvae emerge from the second or third instar of the host. Broodryk demonstrated that C. curvimaculatus adjusts its development period to the host species. Consequently, this parasitoid can synchronize its life-cycle with that of different host species. On H. armigera the egg-to-adult period is 29 d (26.5°C) (Broodryk 1969). Larval period: 8-10 d; pupal period: 9-12 d (Parsons 1940). Also, diapause synchronization has been reported from C. curvimaculatus (Broodryk 1969).

Alternative hosts: LEPIDOPTERA Noctuidae: Celama squalida Staudinger, Earias insulana; Gelechiidae; Pyralidae; COLEOPTERA.
Broodryk (1969) reports that Spodoptera littoralis encapsulated the larva of C. curvimaculatus in 78% of the cases, whereas H. armigera did not encapsulate the parasitoid.

H. armigera records:

Madagascar	Cotton	Important	Vaissayre 1977
South Africa	Maize	Common	Parsons 1940
South Africa	Citrus	-	Prinsloo 1984
Tanzania	Various crops	Up to 12%	Nyambo 1986
Uganda	-	Rare	Coaker 1959

Chelonus pilosulus Szepligeti

Taxonomic comment: Probably correct identification in current taxonomy (2).
Distribution: Afrotropical Region: Sudan, Tanzania.

H. armigera records:

Sudan	Cotton	-	Lazarévic 1971

Chelonus versatilis Wilkinson

Chelonella versatilis Wilkinson (1932)
Microchelonus versatilis Wilkinson (Robertson 1970)

Taxonomic comment: Probably correct identification in current taxonomy (2).
Distribution: Afrotropical Region: Botswana, Sudan, Tanzania; Mediterranean Subregion.
Biology: Adults emerge from the third or fourth instar of H. armigera.
Alternative hosts: LEPIDOPTERA Gelechiidae: Pectinophora gossypiella; Pyralidae.

H. armigera records:

Botswana	-	0.6%	Roome 1971a
Sudan	Cotton	-	Wilkinson 1932
Tanzania	Various crops	-	Robertson 1970

Chelonus sp.

H. armigera records:

South Africa	Cotton	-	Simmonds 1960

Chelonus sp.

H. armigera records:

Zimbabwe	Citrus	V. rare	Hall & Ford 1933

Disophrys lutea Brullé

Taxonomic comment: Record is regarded as reliable (2).
Distribution: Afrotropical Region: widespread; Palaearctic Region.
Alternative hosts: LEPIDOPTERA Noctuidae: Spodoptera exempta.

H. armigera records:

Senegal	Sorghum	Rare	Bhatnagar 1987

Disophrys nigricornis Brullé

Taxonomic comment: Record must be regarded as doubtful (3).
Distribution: Afrotropical Region: Senegal, Tanzania, Zaire.

H. armigera records:

Senegal	-	-	Risbec 1950

Disophrys sp.
Taxonomic comment: Record must be regarded as doubtful (3).
H. armigera records:

Sudan	Cotton, beans	-	Lazarévic 1971

Meteorus clytes Nixon
Taxonomic comment: Record is regarded as reliable (3).
Distribution: Afrotropical Region: South Africa, Tanzania.
Alternative hosts: No records.
H. armigera records:

Tanzania	Groundnut	-	BMNH (Disney Coll 1952)

Meteorus laphygmarum Brues
Taxonomic comment: All the records below are regarded as reliable (3).
Distribution: Afrotropical Region: Madagascar, Nigeria, South Africa, Sudan, Uganda, Zimbabwe.
Alternative hosts: LEPIDOPTERA Noctuidae: Earias biplaga, Spodoptera exempta, S. exigua.
H. armigera records:

Madagascar	-	-	Brenière 1965
Nigeria	-	-	BMNH (Beeden Coll 1974)
Sudan	-	-	BMNH (Bedford Coll 1927)
Sudan	-	Rare	Nixon 1943
Tanzania	Cotton	Rare	Robertson 1973
Tchad	Cotton	-	Silvie pers. comm. 1988
Uganda	-	Rare	Coaker 1959

Meteorus sp.
H. armigera records:

Tanzania	Cotton	Rare	Reed 1965
Tanzania	Various crops	Rare	Nyambo 1986

Meteorus sp.
H. armigera records:

Botswana	-	-	Roome 1975a

Meteorus sp.
H. armigera records:

Senegal	-	-	BMNH

(from Heliothis sp.)

Meteorus sp.
H. armigera records:

Tchad	Cotton	-	Silvie pers. comm. 1988

Microplitis sufiventris Kokujev
H. armigera records:

Egypt	Various plants	Up to 50%	Megahed et al. 1977

Ceraphronidae

Genus Ceraphron Jurine

Gregarious endoparasitoids. Most species are recorded in the literature as hyperparasitoids, especially through Apanteles spp. on Lepidoptera. Chaudhary & Chand (1973) described the biology of C. fijiensis Ferriere

from India. Newly formed cocoons or mature Apanteles larvae which had emerged from the phytophagous host, were attacked. Larval period: 7-8 d; pupal period: 8-9 d at 30°C.

Ceraphron sp.
H. armigera records:

Uganda	-	Rare	Coaker 1959

?Ceraphron sp.
H. armigera records:

Uganda	-	-	Nyiira 1970a

Scelionidae

Platytelenomus busseolae Gahan
Taxonomic comment: This is probably a misidentification (4).
Distribution: Afrotropical Region: Nigeria, Tanzania.
Alternative hosts: LEPIDOPTERA Noctuidae: Busseola fusca, Sesamia sp.; Pyralidae.
H. armigera records:

Uganda	Cotton	-	Coaker 1959

Telenomus ullyetti Nixon
Phanurus ullyetti Nixon (Parsons & Ullyett 1936)
Taxonomic comment: The records below are regarded as reliable (4). Parsons & Ullyett (1934) recorded Phanurus sp., which was later considered to be P. ullyetti (Parsons & Ullyett 1936), a synonym of T. ullyetti.
Distribution: Afrotropical Region: Cameroun, South Africa, Tanzania, Zimbabwe.
Biology: Jones (1937) described the biology of this species parasitizing H. armigera.
Adults: Mating occurs immediately after emergence. No pre-oviposition period. Fecundity: 30-90 eggs per female. Sex ratio: 7:3, in favour of females. Arrhenotokous. Longevity: 18 d for females, 14 d for males (22°C); non-oviposition extends the female life-span.
Oviposition: Eggs are deposited in the yolk of young host eggs (1 egg per host). Females can distinguish between parasitized and unparasitized hosts. Detailed studies on the related Telenomus heliothidis Ashmead, a parasitoid of Helicoverpa zea in North America, have revealed that several physical cues as well as chemical cues (contact kairomones) are involved in recognizing and accepting the host egg (Strand & Vinson 1982, 1983).
Development: The parasitoid remains for a comparatively long period passively as a first instar in the yolk of the host egg. There is evidence that the female of T. heliothidis injects an arrestment factor in the host egg at oviposition. Consequently, the host ceases development (Strand et al. 1986).
The second instar attacks the host embryo. If the embryo has grown beyond a certain size, the parasitoid larva will not be able to attack, and starves. Egg-adult period: 25 d at 19.4°C or 14 d at 26°C.
Alternative hosts: LEPIDOPTERA Pyralidae: Chilo sp., Scirpophaga sp.
Host-plant associations: Parsons (1940) observed higher egg parasitism levels, mainly by T. ullyetti, on tomato, and to a lesser extent on cucumber and marrow, than on legumes. He attributed this to the distribution of host eggs which are aggregated near the flowers on the former crops.
H. armigera records:

South Africa	Cotton	Up to 70%	Parsons 1940

South Africa	Maize	Up to 16%	Parsons & Ullyett 1934
South Africa	Cotton	Up to 2%	Parsons & Ullyett 1934
South Africa	Winter crops	Up to 50%	Parsons & Ullyett 1936
Tanzania	-	-	BMNH (Tapley Coll 1955)
Zimbabwe	Cotton	Up to 25%	Jones 1937
Zimbabwe	Citrus	<1%	Jones 1936, 1937

Telenomus sp.
H. armigera records:

Zimbabwe	Citrus	-	Hall & Ford 1933

Telenomus sp.
H. armigera records:

Botswana	Various crops	-	Roome 1975a

Telenomus sp.
H. armigera records:

South Africa	Cotton	Up to 19%	van Hamburg 1981

Telenomus sp.
Phanurus sp. (Taylor 1932).
H. armigera records:

South Africa	Bean, tomato	Up to 80%	Taylor 1932

Chalcididae

Genus Brachymeria Westwood in Stephens
Little is known about this genus in the Afrotropical Region. Brachymeria spp. are pupal parasitoids, many species attack the pupae of beneficial hymenopterans.

Brachymeria bottegi Masi
Taxonomic comment: Record below must be regarded as suspect (5).
H. armigera records:

Zimbabwe	Tobacco	Rare	Bünzli & Büttiker 1957

Brachymeria cowani Kirkby
Taxonomic comment: Record below must be regarded as suspect (5).
H. armigera records:

Tanzania	Cotton	Rare	Reed 1965

Brachymeria sp.
Biology: Recorded as a secondary parasitoid.
H. armigera records:

Uganda	-	-	Coaker 1959

Brachymeria sp.
H. armigera records:

Tanzania	Cotton	Rare	Robertson 1973

Hyperchalcidia soudanensis Steffan
Distribution: Afrotropical Region: Cameroun, Kenya, Nigeria, Sudan, Uganda.
Biology: Pupal ectoparasitoid.
Alternative hosts: LEPIDOPTERA Noctuidae: Busseola fusca; Psychidae; Pyralidae.
H. armigera records:

Sudan	-	-	Balla 1982

Eurytomidae

Eurytoma sp.
Biology: Hyperparasitoid of Apanteles sp.
H. armigera records:

Uganda	-	-	Coaker 1959

Eurytoma spp.
Biology: Hyperparasitoid of Apanteles sp.
H. armigera records:

Zimbabwe	Tobacco	Rare	Bünzli & Büttiker 1957

Eulophidae

Euplectrus laphygmae Ferrière
Distribution: Afrotropical Region: Ethiopia, Kenya, Malawi, Senegal, South Africa, Sudan, Tanzania, Uganda, Zimbabwe.
Biology: Neser (1973) studied E. sp. nr. laphygmae parasitizing the noctuid Plusia acuta Walker. Gerling & Limon (1976) described the biology of E. laphygmae parasitizing Spodoptera littoralis.
Adult: Males emerge before females. Most females are arrhenotokous. Sex ratio is about 1:1 (Gerling & Limon 1976). Longevity: 45 d for females, 29 d for males (26°C). Fecundity: 165 eggs per female (Gerling & Limon 1976). Host feeding by adult females has been recorded.
Oviposition: Females briefly paralyse the host during oviposition and attach their eggs (0.2x0.1 mm) to the host integument, mostly to the first three abdominal segments. Females can discriminate between host species and host instars. The number of eggs deposited per host depends on the host size. Eggs hatch after 1-2 d (Neser 1973).
Development: The first instar larvae start feeding while still contained in the eggshell. The host stops feeding within 2 d after emergence of the parasitoid larvae and its body gradually collapses during the next 3 d. The entire parasitoid development takes place at the oviposition site. When mature, the larvae move underneath the dead host and spin their cocoons. Larval period: 3-5 d; total development (egg-adult): 7.5-9 d (30°C) (Neser 1973); compare also Parsons (1940). 3-5 larvae develop per Spodoptera littoralis host (Hegazi, Hammad & El-Minshawy 1977).
Host stages: According to Neser (1973) the first and sixth instars of Plusia are rejected for oviposition. Gerling & Limon (1976) found that only the first four instars of Spodoptera littoralis were attacked. E. laphygmae oviposited normally on H. armigera, but failed to complete development on this host.
Secondary natural enemies: Multiparasitism by E. laphygmae and the endoparasitoids Microplitis sp., Meteorus laphygmarum and Copidosoma sp. was found on Plusia acuta (Neser 1973).
Alternative hosts: LEPIDOPTERA Noctuidae: Achaea catella Guenée, Anomis leona, Plusia gamma, P. orichalcea, Spodoptera exempta, S. exigua; Arctiidae; Geometridae; Pyralidae.
H. armigera records:

Senegal	-	-	Risbec 1960
Sudan (from Heliothis sp.)	-	-	Ferrière 1941
Sudan	-	-	BMNH Coll 1976
Tanzania	-	-	Robertson 1970

Euplectrus sp.
H. armigera records:

South Africa	Peas	-	Parsons 1940

Euplectrus sp.
H. armigera records:

Tchad	Cotton	-	Silvie pers. comm. 1988

?Euplectrus sp.
H. armigera records:

Uganda	Cotton	-	Nyiira 1970a

Pediobius furvus Gahan
Distribution: Afrotropical Region: Cameroun, Ghana, Ivory Coast, Kenya, Mali, Nigeria, Senegal, Sudan, Tanzania, Uganda, Zimbabwe.
Biology: Gregarious pupal endoparasitoid. Mohyuddin (1968) described the biology of P. furvus parasitizing Chilo partellus Swinhoe (Pyralidae). 17-330 adults emerge per host pupa. Development egg-adult: 25-29 d (25°C).
Alternative hosts: Mainly known as a graminaceous stemborer parasitoid. LEPIDOPTERA Noctuidae: Busseola spp., Sesamia spp.; Pyralidae.
H. armigera records:

Sudan	-	-	Balla (1982)

Pediobius mediopunctatus Waterston
Distribution: Afrotropical Region: Ivory Coast, Senegal.
Biology: Often recorded as a hyperparasitoid.
Alternative hosts: LEPIDOPTERA Noctuidae: Anomis leona (hyper), Eublemma gayneri Rothschild, Spodoptera littoralis (hyper); Arctiidae; Hesperiidae; Lycaenidae; HYMENOPTERA.
H. armigera records:

Senegal	-	-	Risbec 1960

Elasmidae

Elasmus johnstoni Ferrière
Distribution: Afrotropical Region: Sudan, Uganda, Zimbabwe; Oriental Region.
Biology: Larval ectoparasitoid. Haroon Khan & Verma (1946) described the biology of E. johnstoni parasitizing Earias spp. Fecundity: 18 eggs per female. Longevity female: 7-46 d. Arrhenotokous. 1-2 eggs are deposited per host larva. Development egg-adult: 10-28 d.
Alternative hosts: Mainly recorded from Earias spp. (Noctuidae). and Pectinophora gossypiella (Gelechiidae). Facultative hyperparasitoid.
H. armigera records:

Sudan	-	-	Balla 1982

Encyrtidae

Copidosoma sp.
Biology: Gregarious egg-larval parasitoid. El-Heneidy & Abbas (1983) described the biology of this particular Copidosoma sp.
Adults: Mating occurs within a few hours of emergence. Sex ratio: 3:2, in favour of females. Longevity: 3-6 d (25°C).
Development: Eggs are deposited in the host egg. Copidosoma sp. has a

polyembryonic mode of reproduction. The parasitoids develop inside the host larva, pupate, and emerge as adults from the sixth instar of H. armigera. 20-600 adults emerge per host. Diapause of the parasitoid, in its prepupal stage, occurs inside the host remains.

Host-plant associations: El-Heneidy & Abbas (1983) report that this species was found only on weeds, not on cotton or tomato, and attributed this to the seasonal occurrence of the parasitoid.

H. armigera records:

Egypt	Various plants	Rare	Megahed et al. 1977

Copidosoma sp.

H. armigera records:

Senegal	Various crops	-	Bhatnagar 1987

Copidosoma sp.

H. armigera records:

Egypt (from Heliothis sp.)	-	Common	Ismael & Swailem 1975

Mymaridae

Sp. indet

H. armigera records:

Zimbabwe	-	Rare	Jones 1937

Trichogrammatidae

Trichogramma pretiosum Riley

Distribution: Introduced and established in South Africa in 1975; Nearctic Region.

Alternative hosts: LEPIDOPTERA Geometridae; Pyralidae; Tortricidae; NEUROPTERA.

H. armigera records:

South Africa	Cotton	Rare	van Hamburg 1981

Trichogramma sp. nr. evanescens Westwood

H. armigera records:

Madagascar	Cotton	Important	Vaissayre 1977

?Trichogramma sp.

H. armigera records:

Tanzania	Cotton	Up to 5%	Reed 1965

?Trichogramma sp.

H. armigera records:

Uganda	Cotton	-	Coaker 1959

?Trichogramma sp.

H. armigera records:

Uganda	Cotton	-	Nyiira 1970a

?Trichogramma spp.

H. armigera records:

Botswana	Various crops	-	Roome 1975a

?Trichogramma sp.
H. armigera records:

South Africa	-	-	Taylor 1932

?Trichogramma sp.
H. armigera records:

South Africa	-	Rare	Jones 1937

Trichogrammatoidea lutea Girault
Trichogramma lutea Girault
Taxonomic comment: The records below are regarded as reliable (4).
Distribution: Afrotropical Region: Cape Verde, South Africa, Zaire, Zambia, Zimbabwe.
Biology: Jones (1937) studied the biology of T. lutea parasitizing H. armigera.
Adults: Mating occurs soon after emergence. Mated females are fertilized for life, males can mate many times. No pre-oviposition period. Fecundity: 32 eggs per female; 0-15 eggs are laid per day. Longevity: 2-9 d (26°C). Arrhenotokous.
Oviposition: Females oviposit 1-5 eggs into the host egg. Eggs are often superparasitized, in which case they yield no offspring (Mück 1985). Eggs are deposited in the central yolk of the host egg and are often enclosed by the embryo during its development.
Development: Parasitoid eggs swell up, and hatch after one day. The first instar feeds on the yolk, the second instar starts feeding on the organs of the host embryo. Development of the host is arrested. T. lutea is less restricted to young host eggs than is Telenomus ullyetti. One to four adults (mostly 2) emerge per host. If more than one progeny of mated females develop per host, usually only one is male (Kfir 1982). Egg-adult period: 19 d at 19.4°C or 9 d at 26°C.
Alternative hosts: LEPIDOPTERA Noctuidae: Anomis leona Schaus, Diparopsis castanea, Earias biplaga; Pyralidae; Tortricidae.
H. armigera records:

Cape Verde	-	-	Mück 1985
South Africa	Cotton	Up to 60%	Parsons 1940
South Africa	Citrus	-	Prinsloo 1984
South Africa	Cotton	-	Taylor 1932
South Africa	Cotton	Up to 19%	van Hamburg 1981
South Africa	Maize	Up to 44%	Parsons & Ullyett 1934
South Africa	Cotton	Up to 17%	Parsons & Ullyett 1934
South Africa	Maize	41%	Parsons & Ullyett 1936
South Africa	Cotton	Up to 50%	Parsons & Ullyett 1936
Zambia	Maize, cotton	Important	Bebbington & Allen 1935
Zimbabwe	Cotton	Up to 50%	Peat 1935
Zimbabwe	Cotton	Up to 48%	Jones 1937
Zimbabwe	Maize	Up to 75%	Jones 1937
Zimbabwe	Citrus	<1%	Jones 1936, 1937

Trichogrammatoidea sp.
H. armigera records:

Senegal	Acanthospermum	Up to 17%	Bhatnagar 1987
	Maize	Up to 27%	
	Sorghum	Up to 32%	
	Tomato	Up to 80%	

Bethylidae

Goniozus sp.

Biology: Gregarious ectoparasitoid. The biology of Goniozus spp. is described by Gordh & Hawkins (1981).

H. armigera records:

Senegal	Maize, millet	-	Bhatnagar 1987

5.2 PREDATORS AND PATHOGENS

HEMIPTERA

Anthocoridae

Genus Orius Wolff, J.F.

Taxonomic comment: Little is known about Afrotropical Orius species (Gauri 1980). It is doubtful whether the African species recorded as O. insidiosus Say is the same as the Nearctic species.

Biology: Orius spp. have been extensively studied in North America (Ryerson & Stone 1979). Mating can occur directy after moulting from the last nymphal stage. In O. tristicolor White, the pre-oviposition period is 2-3 d, the oviposition period 22 d, the fecundity 130 eggs per female (25°C) (Askari & Stern 1972) and the longevity 15 d (Iglinsky & Rainwater 1950). Eggs (0.42x0.4 mm) are deposited in the plant tissue, sometimes in clusters, and hatch after 3-5 d (25.5°C). The five nymphal stages of O. tristicolor will develop in 14.4 d at 25.5.C or 8.4 d at 33°C (Askari & Stern 1972). In small laboratory containers at 27°C, O. insidiosus consumed 0.7 eggs, or 4.4 first instar larvae, of Heliothis spp. per day per predator (Lingren, Ridgway & Jones 1968).

Alternative food: Orius spp. feed on a wide variety of arthropod prey (Marshall 1930); they are in particular important predators of spider mites, thrips and noctuid pests. Besides arthropods they also feed on plant tissues, such as pollen (Salas-Aguilar & Ehler 1977), and a coincidence in population build-up of O. insidiosus and the period of pollen-shed has been reported from maize (Dicke & Jarvis 1962) and soybean (Isenhour & Yeargan 1981). Alternative food may also be provided as floral or extrafloral nectaries. Trelease (1879) suggested that extrafloral nectaries of cotton can provide an alternative food source during the absence of insect prey. Although O. tristicolor has been observed feeding on extrafloral nectaries (van den Bosch & Hagen 1966) populations did not increase until their insect prey became abundant (Yokoyama 1978).

Host-plant associations: Orius insidiosus occurs on many wild plant species (Barber 1936). In North America it has been shown that O. insidiosus was more abundant in soybean fields with grass and mixed weeds, than in weed-free or broadleaf-weed soybean habitats (Shelton & Edwards 1983); it was suggested that predators are likely to be attracted to weedy habitats as a result of alternative food sources and favourable microclimatic conditions.

Orius albidipennis Reuter

H. armigera records:

Egypt	-	-	Megahed et al. 1977

Orius ?insidiosus Say

H. armigera records:

South Africa	Cotton	Important	Pearson 1958
Uganda	Cotton	-	Nyiira 1970a

Orius laevigatus Fieb.

H. armigera records:

Egypt	-	-	Megahed et al. 1977

Orius sp. nr. insidiosus Say

H. armigera records:

South Africa	Cotton, maize	40%	Parsons & Ullyett 1934

Orius sp.
H. armigera records:

Zimbabwe	Cotton	V. important	Peat 1935

Orius sp.
H. armigera records:

South Africa	Cotton	-	Parsons 1940

Orius sp.
H. armigera records:

Senegal	Maize, millet	-	Bhatnagar 1987

Orius spp.
H. armigera records:

Egypt	-	-	Ismael & Swailem 1975

Reduviidae

Coranus papillosus Thunberg
H. armigera records:

South Africa	Cotton	-	Taylor 1932

Ectomocoris fenestratus Klug
H. armigera records:

Senegal	Various crops	Rare	Bhatnagar 1987

Rhinocoris albopunctatus Stål
Distribution: Afrotropical Region: Cameroun, South Africa, Uganda.
Biology: Nyiira (1970b) studied the biology of this species in Uganda. Oviposition: Brown eggs (1.5x0.5 mm) are deposited in a cluster (5-250 eggs per cluster) on the foliage or stems, mostly on the underside of leaves. Eggs are brooded by the male parent. Nymphs hatch after 5-15 d (21-28°C). Nymphal development (5 stages) takes 54-92 d (21-28°C). Nyiira reports that adults consumed 1-3 H. armigera larvae per day in the laboratory.
Alternative prey: Rhinocoris spp. are polyphagous. Nyiira reported their feeding on Earias spp. (Noctuidae) and several Coleoptera, Hemiptera and Hymenoptera species, among which beneficial insects including Orius sp. (Anthocoridae), nymphs of Rhinocoris sp. (Reduviidae) and ants.
Secondary natural enemies: In Uganda, Odhiambo (1959) found that the related Rhinocoris albopilosus Signoret, despite parental care, suffered 10-20% egg parasitism by two Hadronotus species (Hym.: Scelionidae).
H. armigera records:

South Africa	Cotton	-	Taylor 1932
Uganda	Cotton	-	Nyiira 1970b

Rhinocoris segmentarius Stål
H. armigera records:

South Africa	Cotton	-	Taylor 1932
Uganda	Cotton	-	Nyiira 1970a

Cosmolestes pictus Klug
H. armigera records:

Uganda	Cotton	-	Nyiira 1970a

Pentatomidae

Glypsus conspicuus Westwood

Distribution: Afrotropical Region: Central Africa, Kenya, South Africa, Uganda.

Biology: Reed (1965) reported that G. conspicuus attacked the eggs and all larval stages of H. armigera.

H. armigera records:

South Africa	Cotton	-	Taylor 1932
Tanzania	Cotton	Regular	Reed 1965

Macrorhaphis acuta Dallas

Macrorhaphis spurcata Walker (Nyiira 1970b)

Microrhaphis spurcata Walker (Taylor 1932)

Biology: Reed (1965) reported that M. acuta attacked the eggs and all larval stages of H. armigera.

Distribution: Afrotropical Region: Malawi, South Africa, Uganda.

H. armigera records:

South Africa	Cotton	-	Taylor 1932
Tanzania	Cotton	Common	Reed 1965
Uganda	Cotton	-	Nyiira 1970a

THYSANOPTERA

Scolothrips sexmaculatus Pergande

Distribution: Afrotropical Region: Nearctic Region; Neotropical Region; Oriental Region; Palearctic Region.

Biology: Adults are bisexual. Low capacity of increase; fecundity: 4-5 eggs per female; longevity: 7-14 d (Bailey 1939). The eggs are inserted in the plant tissue and hatch after 6-10 d. Egg+nymphal period: 17-37 d (Lewis 1973).

Alternative prey: S. sexmaculatus is known as a mite predator; it can become cannibalistic when crowded (Bailey 1939).

H. armigera records:

Egypt	-	-	Ismael & Swailem 1975

NEUROPTERA

Chrysopidae

Chrysopidae are known for their predacious habits during the larval stages and have been recorded feeding on a wide variety of arthropods, including many agricultural pests. It has been demonstrated that larvae of Chrysoperla carnea Stephens respond to kairomones in the scales of Helicoverpa zea moths (Lewis et al. 1977; Nordlund et al. 1977); moths leave scales at their oviposition sites. Adult chrysopids are nocturnal and feed on soft plant parts. In cotton, extrafloral nectaries encourage population build-up of C. carnea (Schuster, Lukefahr & Maxwell 1976). Chrysopids, especially C. carnea, are commonly mass-reared and released against various insect pests, including Helicoverpa spp. (Hassan 1974).

Chrysopa congrua Walker

Distribution: Afrotropical Region: Tanzania, Zimbabwe.

Biology: Brettell (1982) described the biology of C. congrua. Oviposition period: 35 d. Fecundity: 177 eggs per female. Longevity of

adults: 50 d (25°C). In the laboratory, the number of H. armigera eggs consumed during larval development was 20 during the first instar, 55 during the second instar and 219 during the third instar. Development period egg: 4 d; larva 11.9 d; pupa: 8.9 d (25°C), when fed on H. armigera eggs.

Alternative prey: In the laboratory, a wide variety of prey is consumed (Brettell 1982).

H. armigera records:

Zimbabwe	Cotton	Common	Brettell 1982

Chrysopa pudica Navas

Biology: Brettell (1982) described the biology of C. pudica. Adult: Oviposition period: 39 d. Fecundity: 139 eggs per female. Longevity: 55 d (25°C). Development period egg: 4 d; larva 10.5 d; pupa: 9.9 d (25°C) when fed on H. armigera eggs.

Alternative prey: In the laboratory, a wide variety of prey is consumed (Brettell 1982).

H. armigera records:

Zimbabwe	Cotton	Common	Brettell 1982

Chrysopa sp.

Biology: Feeds on eggs and larvae of H. armigera. In the laboratory, predator larvae consumed up to 14 eggs per day and were able successfully to attack third instars (Reed 1965).

H. armigera records:

Tanzania	Cotton	Common	Reed 1965

Chrysopa sp.

H. armigera records:

South Africa	Cotton	-	Pearson 1958

Chrysopa sp.

H. armigera records:

South Africa	Cotton	-	Parsons 1940

Chrysopa sp.

H. armigera records:

Uganda	Cotton	-	Nyiira 1970a

Chrysoperla carnea Stephens

Chrysopa carnea Stephens (Ismael & Swailem 1975; Balla 1982)

Distribution: Mediterranean Subregion; Nearctic Region; Neotropical Region; Oriental Region; Palaearctic Region.

Biology: Adult: Pre-oviposition period 9 d. Longevity 36 d. Fecundity 39 eggs per female at 27.4°C, when fed on H. armigera (Awadallah, Abou-Zeid & Tawfik 1975). Incubation period egg: 3 d; larval period: 10 d; pupal period 6.7 d (27-30°C), when fed on H. armigera. Predation: daily consumption of the third instar of the predator is 26 eggs or 90 first instars of H. armigera (El-Dakroury et al. 1977). C. carnea responds to kairomones emitted by Helicoverpa zea (Nordlund et al. 1977).

Alternative prey: A wide variety of prey is consumed.

H. armigera records:

Egypt	-	-	Ismael & Swailem 1975
Egypt	-	-	Megahed et al. 1977
Sudan	-	-	Balla 1982

Mallada boninensis Okamoto

Chrysopa boninensis Okamoto (Brettell 1979)

Distribution: Afrotropical Region: Cape Verde, Guinea, Kenya, Mozambique, South Africa, Tanzania, Zaire, Zimbabwe; Oriental Region.

Biology: Brettell (1979) described the biology of M. boninensis.

Longevity of adults: 25 d (25°C). In the laboratory, the number of H. armigera eggs consumed during development was 20 during the first instar, 40 during the second instar and 240 during the third instar. Larvae of this species carry debris of dead prey on their back. Development period, egg: 3.7 d; larva 10.6 d; pupa: 9.5 d (25°C), when fed on H. armigera eggs. Lee & Shih (1983) describe the biology and predation of this predator from China.

Alternative prey: In the laboratory, a wide variety of prey is consumed (Brettell 1979).

H. armigera records:

Zimbabwe	Cotton	Common	Brettell 1979

COLEOPTERA

Carabidae

Genus Chlaenius Bonelli

African Chlaenius spp. feed on a variety of arthropods (Larochelle 1974). Adults of this carabid genus are ground-dwelling and nocturnal. Eggs are laid singly in the soil (David, Banerji & Kalra 1973). Larvae move up and down the plants in search of prey and feed on first to third instars of noctuids (Katiyar et al. 1976). According to Chen & Chen (1982), larvae of C. bioculatus Chaudoir consume about 30 young lepidopterous larvae during their development.

Chlaenius boisduvali Dejean

H. armigera records:

Senegal	Various crops	-	Bhatnagar 1987

Chlaenius dusaultii Dufour

H. armigera records:

Senegal	Various crops	-	Bhatnagar 1987

Graphipterus obsoletus Olivier

H. armigera records:

Senegal	Various crops	-	Bhatnagar 1987

Pheropsophus sp. nr. lafertei Arrow

H. armigera records:

Senegal	Various crops	-	Bhatnagar 1987

Staphilinidae

Paederus alfierii Koch

H. armigera records:

Egypt	-	-	Megahed et al. 1977

Coccinellidae

Coccinella undecimpunctata Linnaeus

Biology: Ibrahim (1955) described the biology of C. undecimpunctata.

H. armigera records:

Egypt	-	-	Megahed et al. 1977

Scymnus spp.

H. armigera records:

Egypt	-	-	Megahed et al. 1977

DIPTERA

Asilidae

Asilid larvae are well known as predators of egg-pods of locusts in the soil (Greathead 1963).

Promachus sp.

H. armigera records:

Senegal	Various crops	-	Bhatnagar 1987

HYMENOPTERA

Vespidae

Polistes sp.

Biology: Adults collect prey larvae and fly them to their nest, and feed them to their offspring.

H. armigera records:

Senegal	Maize, millet	-	Bhatnagar 1987

Eumenidae

Delta sp.

Biology: Adults collect H. armigera larvae and fly them to their nest, and feed them to their offspring.

H. armigera records:

Senegal	-	-	Bhatnagar 1987

Eumenes maxillosus De Geer

H. armigera records:

Madagascar	-	-	Brenière 1965
South Africa	Cotton	-	Taylor 1932
Sudan	-	-	Balla 1982

Sphecidae

The majority of sphecids are predators. Their biology and behaviour is reviewed by Bohart & Menke (1976).

Ammophila sp.

Biology: Adults collect H. armigera larvae and fly them to their nest, and feed them to their offspring.

H. armigera records:

Tanzania	-	Common	Reed 1965

Chlorion sp.

H. armigera records:

Zimbabwe	Citrus	-	Jones 1936

Formicidae

The ant fauna in tropical agroecosystems is usually well developed, and ants have been shown to play a significant role in the control of insect pests (e.g. Leston 1973). Although research has mainly been concentrated on tree crops (Leston 1973; Room 1975), it is believed that ants are also important control agents of insect pests in annual cropping systems, because ant faunas can develop very rapidly (Carroll & Risch 1983). The ant fauna and its impact in African annual cropping systems is still poorly understood. Some observations in South Africa indicate that Dorylus sp., a ground-dwelling species, has a great impact on populations of H. armigera pupae in the soil (P.J. Guest pers. comm.). On the other hand, ants have been reported to carry away parasitized H. armigera larvae (Taylor 1932). The ecology of foraging by ants is reviewed by Carroll & Janzen (1973).

Myrmicaria sp.

H. armigera records:

Tanzania	Cotton	Common	Reed 1965

Pheidole megacephala Fabricius

H. armigera records:

South Africa	-	-	Steyn 1955

Pheidole sp.

H. armigera records:

South Africa	Maize, cotton	V. important	Parsons & Ullyett 1934
Tanzania	Cotton	Common	Reed 1965
Uganda	Cotton	-	Nyiira 1970a

Sp. indet.

H. armigera records:

Botswana	-	Common	Roome 1975a

NEMATODA

Mermithidae

Hexamermis sp.

Biology: In India, Achan et al. (1968) found that Hexamermis-infested larvae of Helicoverpa armigera turned green and subsequently yellow in colour before they stopped feeding. After 4-5 d the nematodes emerged from the host.

H. armigera records:

Senegal	Groundnut, acanthospermum	Up to 2%	Bhatnagar 1987

Nuclear Polyhedrosis Virus (NPV)

Biology: Diseased larvae are yellow and eventually turn brown-black. First and second instars of H. armigera are most susceptible to NPV (Ripper & George 1965; Daoust 1974); mortality occurs shortly after infestation, while larvae are still in a young stage (Whitlock 1974). North American strains of this biocontrol agent have been introduced and applied as a biological insecticide against H. armigera in Africa (Angelini & Labonne 1970; McKinley 1971; Roome 1971b, 1975b).

H. armigera records:

Botswana	Sorghum	Up to 61%	Roome 1971a,b
Senegal	Various crops	-	Bhatnagar 1987
Sudan	-	-	Bergold & Ripper 1957
Tanzania	Various crops	V. important	Nyambo 1986
Tanzania	-	-	Reed 1965
Uganda	Cotton	-	Coaker 1958
Zimbabwe	-	-	McKinley 1971

Bacteria

Biology: Probably only young larvae are susceptible to bacterial disease. Mortality occurs at later instars, often when larvae are fully grown (Nyambo 1986).

H. armigera records:

Tanzania	Various crops	V. important	Nyambo 1986

Fungi

Nomuraea rileyi (Farlow) Samson

Biology: In the laboratory, Mohamed, Sikorowski & Bell (1977) found that first and second instars and of H. zea were less susceptible to infection by the fungus than were third to fifth instars. This fungus has been reviewed by Ignoffo (1981). In general, the occurrence of fungi in the field is irregular and unpredictable, mainly determined by weather conditions (rainfall).

Alternative hosts: LEPIDOPTERA: species from various families; some Coleoptera.

H. armigera records:

Tanzania	-	-	Nyambo, unpublished

Sp. indet.

Tanzania	-	Rare	Reed 1965

BIBLIOGRAPHY

Achan, P.D.; Mathur, K.C.; Dharmadikari, P.R.; Manjunath, T.M. (1968) Parasites of Heliothis spp. in India. Technical Bulletin, Commonwealth Institute of Biological Control **10**, 129-147.

Angelini, A.; Labonne, V. (1970) Sur une technique d'élévage d'Heliothis armigera (Hb.) et une possibilité de production de virose nucleaire en Côte d'Ivoire. Coton et Fibres Tropicales **25**, 501-504.

Askari, A.; Stern, V.M. (1972) Biology and feeding habits of Orius tristicolor (Hemiptera: Anthocoridae). Annals of the Entomological Society of America **65**, 96-100.

Awadallah, K.T.; Abou-Zeid, N.A.; Tawfik, M.F.S. (1975) Development and fecundity of Chrysopa carnea Stephens. Bulletin de la Société Entomologique d'Egypte **59**, 323-329.

Bailey, S.F. (1939) The six-spotted thrips, Scolothrips sexmaculatus (Perg.). Journal of Economic Entomology **32**, 43-47.

Balla, A.N. (1982) Progress in research and development for Heliothis management in the Sudan.

Barber, G.W. (1936) Orius insidiosus (Say), an important natural enemy of the cotton earworm. Technical Bulletin, United States Department of Agriculture **504**, 24 pp.

Baronio, P.; Sehnal, F. (1980) Dependence of the parasitoid Gonia cinerascens on the hormones of its lepidopterous hosts. Journal of Insect Physiology **26**, 619-626.

Barry, R.M.; Hatchett, J.H.; Jackson, R.D. (1974) Cage studies with predators of the cabbage looper, Trichoplusia ni, and corn earworm, Heliothis zea, in soybean. Journal of the Georgia Entomological Society **9**, 71-78.

Bebbington, A.G.; Allen, W. (1935) Mazabuka, Northern Rhodesia. In: Progress Reports from Experiment Stations, Season 1933-34. London; Empire Cotton Growing Corporation, pp. 75-80.

Bechinski, E.J.; Pedigo, L.P. (1982) Evaluation of methods for sampling predatory arthropods in soybeans. Environmental Entomology **11**, 756-761.

Beeden, P. (1974) Boll worm oviposition of cotton in Malawi. Cotton Growing Review **5**, 52-61.

Bergold, C.H.; Ripper, W.E. (1957) The polyhedral virus of Heliothis armigera (Hbn.). Nature, London **180**, 764.

Bhatnagar, V.S. (1987) Rapport de synthèse (1981-86) et récommandations, sous-programme de lutte biologique, Projet CILSS de Lutte Intégrée, Sénegal. FAO, Rome, 168 pp.

Bohart, R.M.; Menke, A.S. (1976) Sphecid wasps of the world: a generic revision. Berkeley, University Press, 696 pp.

Bosch, R. van den; Hagen, K.S. (1966) Predacious and parasitic arthropods in

California cotton fields. California Agricultural Experiment Station Bulletin **820**, 32 pp.

Bosch, R. van den; Leigh, T.F.; Gonzalez, D.; Stinner, R.E. (1969) Cage studies on predators of the bollworm in cotton. Journal of Economic Entomology **62**, 1486-1489.

Brenière, J. (1965) Liste des parasites et prédateurs des principaux insectes nuisibles aux cultures a Madagascar. l'Agronomie tropicale **20**, 344-349.

Brettell, J.H. (1979) Green lacewings (Neuroptera: Chrysopidae) of cotton fields in central Rhodesia. 1. Biology of Chrysopa boninensis Okamoto and toxicity of certain insecticides to the larvae. Rhodesia Journal of Agricultural Research **17**, 141-150.

Brettell, J.H. (1982) Green lacewings (Neuroptera: Chrysopidae) of cotton fields in central Zimbabwe. 2. Biology of Chrysopa congrua Walker and C. pudica Navas and toxicity of certain insecticides to their larvae. Zimbabwe Journal of Agricultural Research **20**, 77-84.

Broodryk, S.W. (1969) The biology of Chelonus (Microchelonus) curvimaculatus Cameron (Hymenoptera: Braconidae). Journal of the Entomological Society of Southern Africa **32**, 169-189.

Brubaker, R.W. (1968) Seasonal occurrence of Voria ruralis, a parasite of the cabbage looper in Arizona, and its behavior and development in laboratory culture. Journal of Economic Entomology **61**, 306-309.

Bünzli, G.H.; Büttiker, W.W. (1957) Insects in Southern Rhodesian tobacco culture. Acta Tropica **14**, 236-253.

Byerly, K.F.; Gutierrez, A.P.; Jones, R.E.; Luck, R.F. (1978) A comparison of sampling methods for some arthropod populations in cotton. Hilgardia **46**, 257-282.

Campadelli, G.; Baronio, P. (1979) Ciclo biologico di Gonia cinerascens Rond. (Dipt. Tachinidae) allevata in ambiente condizionato sull'ospite di sostuizione Galleria mellonella L. (Lep. Galleriidae). Bollettino dell'Istituto de Entomologia della Università degli Studi di Bologna **34**, 35-54.

Carroll, C.R.; Janzen, D.H. (1973) Ecology of foraging by ants. Annual Review of Ecology and Systematics **4**, 231-251.

Carroll, C.R.; Risch, S.J. (1983) Tropical annual cropping systems: ant ecology. Environmental Management **7**, 51-57.

Chaudhary, J.P.; Chand, N. (1973) First record of Ceraphron fijiensis Ferrière (Ceraphronidae: Hymenoptera) from India. Indian Journal of Entomology **34**, 179-180.

Chen, Y.H.; Chen, Y.M. (1982) Studies on the predatory two-spotted ground beetle. Fijian Agricultural Science and Technology **4**, 25-27.

Chiaromonte, A. (1933) Considerazioni entomologiche sulla coltura delle cereali nella Somalia Italiana. l'Agricoltura Coloniale **27**, 484-487.

Chiri, A.A.; Legner, E.F. (1982) Host-searching kairomones alter behavior of Chelonus sp. nr. curvimaculatus, a hymenopterous parasite of the pink bollworm, Pectinophora gossypiella (Saunders). Environmental Entomology

11, 452-455.

Clausen, C.P. (1940) Entomophagous insects. London; MacGraw-Hill Ltd, 688 pp.

Coaker, T.H. (1958) Experiments with a virus disease of the cotton bollworm Heliothis armigera (Hb.). Annals of Applied Biology **46**, 536-541.

Coaker, T.H. (1959) Investigations on Heliothis armigera (Hb.) in Uganda. Bulletin of Entomological Research **50**, 487-506.

Collins, M.D. (1986) Pyrethroid resistance in the cotton bollworm, Heliothis armigera: a case study from Thailand. 1986 British Crop Protection Conference, Brighton, pp. 583-590.

Crosskey, R.W. (1967) A revision of the Oriental species of Palexorista Townsend (Dipt.: Tachinidae Sturmiini). Bulletin of the British Museum (Natural History) Entomology, Supplement **21**, 97 pp.

Crosskey, R.W. (1976) Taxonomic conspectus of the Tachinidae of the Oriental Region. Bulletin of the British Museum (Natural History) Entomology, Supplement **26**, 357 pp.

Crosskey, R.W. (1980) Family Tachinidae. In: Crosskey, R.W. (ed) Catalogue of the Diptera of the Afrotropical Region. Trustees of the British Museum (Natural History) Entomology, London, Monograph **906**, 822-882.

Crosskey, R.W. (1984) Annotated keys to the genera of Tachinidae (Diptera) found in tropical and southern Africa. Annals of the Natal Museum **26**, 189-337.

Crosskey, R.W. (1985) Comments on the proposed amendment to article 51c of the code Z.N.(S.)2474. Bulletin of Zoological Nomenclature **42**, 209-211.

Curran, C.H. (1934) African Tachinidae I. American Museum Novitatae **751**, 25 pp.

Curran, C.H. (1939) African Tachinidae II. American Museum Novitatae **1022**, 1-5.

Cuthbertson, A. (1934) Biological notes on some Diptera in Southern Rhodesia. Proceedings of the Rhodesia Science Association **33**, 32-50.

Cuthbertson, A. (1939) Biological notes on some Diptera in Southern Rhodesia. Transactions of the Rhodesia Science Association **37**, 135-151.

Cuthbertson, A.; Munro, H.K. (1941) Some records of tachinid parasites and their insect hosts in Southern Africa. Transactions of the Rhodesia Science Association **38**, 88-118.

Danks, H.V.; Rabb, R.L.; Southern, P.S. (1979) Biology of insect parasites of Heliothis larvae in North Carolina. Journal of the Georgia Entomological society **14**, 36-64.

Daoust, R.A. (1974) Weight-related susceptibility of larvae of Heliothis armigera to a crude nuclear-polyhedrosis virus preparation. Journal of Invertebrate Pathology **23**, 318-324.

Datta, R.K.; Mukherjee, P.K. (1978) Life-history of Tricholyga bombycis (Diptera: Tachinidae), a parasite of Bombyx mori (Lepidoptera:

Bombycidae). Annals of the Entomological Society of America **71**, 767-770.

David, H.; Banerji, D.K.; Kalra, A.N. (1973) Record of a carabid predator Chlaenius bioculatus Chaud. on the leaf-roller, Neomarasmia suspicalis Wlk., a pest of sugarcane. Indian Journal of Entomology **34**, 175-177.

Dicke, F.F.; Jarvis, J.L. (1962) The habits and seasonal abundance of Orius insidiosus (Say) (Hemiptera-Heteroptera: Anthocoridae) on corn. Journal of the Kansas Entomological Society **35**, 339-344.

Dietrick, E.J. (1961) An improved backpack motor fan for suction sampling of insect populations. Journal of Economic Entomology **54**, 394-395.

Driesche, R.G. van (1983) Meaning of 'percent parasitism' in studies of insect parasitoids. Environmental Entomology **12**, 1611-1622.

Duodu, Y.A.; Lawson, B.W.L. (1983) Natural enemies of Acraea terpsicore (Lep.: Nymphalidae) in Ghana, with particular reference to the parasite Charops diversiceps (Hym.: Ichneumonidae). Entomophaga **28**, 271-276.

El-Dakroury, M.S.I.; Abbas, M.S.T.; Heneidy, A.H.; Awadallah, K.T. (1977) The efficiency of Chrysopa carnea Stephens on eggs and larvae of Heliothis armigera Hb. (Neuroptera: Chrysopidae; Lepidoptera: Noctuidae). Agricultural Research Review **55**, 151-156.

El-Heneidy, A.H.; Abbas, M.S.T. (1983) Biological notes on Copidosoma sp. (Hym., Encyrtidae), an egg-larval parasite of Heliothis armigera Hb. (Lep., Noctuidae) in Egypt. Zeitschrift für Angewandte Entomologie **96**, 74-77.

Elsey, K.D.; Rabb, R.L. (1970) Biology of Voria ruralis (Diptera: Tachinidae). Annals of the Entomological Society of America **63**, 216-222.

Emden, F.I. van (1960) Keys to the Ethiopian Tachinidae. III. Macquartiinae. Proceedings of the Zoological Society of London **134**, 313-487.

Engroff, B.W.; Watson, T.F. (1975) Influence of temperature on adult biology and population growth of Bracon kirkpatricki. Annals of the Entomological Society of America **68**, 1121-1125.

Ferrière, C. (1941) New species of Euplectrini (Hymenoptera: Chalcidoidea) from Europe, Africa and Asia. Bulletin of Entomological Research **32**, 17-48.

Gardenghi, G.; Mellini, E. (1980) Sulla formazione dell'uovo microtipico e del relativo apparato di fissazione in Gonia cinerascens Rond. Bollettino dell'Istituto di Entomologia della Università degli Studi di Bologna **35**, 215-230.

Gauri, M.S.K. (1980) Notes on Anthocoridae (Heteroptera) with descriptions of two new species of economic importance from Africa. Bulletin of Entomological Research **70**, 287-291.

Gauld, I.D.; Mitchell, P.A. (1978) The taxonomy, distribution and host preferences of African parasite wasps of the subfamily Ophioninae (Hymenoptera: Ichneumonidae). Farnham Royal, UK; Commonwealth Agricultural Bureaux, 287 pp.

Gerling, D.; Limon, D. (1976) A biological review of the genus Euplectrus (Hym.: Eulophidae) with special emphasis on E. laphygmae as a parasite of Spodoptera littoralis (Lep.: Noctuidae). Entomophaga **21**, 179-187.

Gerling, D.; Rotary, N. (1973) Hypersensitivity, resulting from host-unsuitability, as exemplified by two parasite species attacking Spodoptera littoralis (Lep.: Noctuidae). Entomophaga **18**, 391-396.

Gledhill, J.A. (1982) Progress and problems in Heliothis management in tropical southern Africa. In: Proceedings of the International Workshop on Heliothis Management. ICRISAT, Patancheru, India, 15-20 November 1981, pp. 375-384.

Gonzalez, D.; Ramsay, D.A.; Leigh, T.F.; Ekbom, B.S.; Bosch, R. van den (1977) A comparison of vacuum and whole-plant methods for sampling predaceous arthropods on cotton. Environmental Entomology **6**, 750-760.

Goodenough, J.L. (1986) Efficacy of entomophagous arthropods. In: Johnson, S.J.; King, E.G.; Bradley, J.R. (eds) (1986) Theory and tactics of Heliothis population management. I. Cultural and biological control. Proceedings of a Workshop held at Tifton, GA, March 15, 1983, Southern Cooperative series Bulletin **316**, 75-91.

Goodyer, G.J.; Wilson, A.G.L.; Attia, F.I.; Clift, A.D. (1975) Insecticide resistance in Heliothis armigera (Hübner) (Lepidoptera: Noctuidae) in the Namoi Valley of New South Wales, Australia. Journal of the Australian Entomological Society **14**, 171-173.

Gordh, G.; Hawkins, B. (1981) Goniozus emigratus (Rohwer), a primary external parasite of Paramyelois transitella (Walker), and comments on bethylids attacking Lepidoptera (Hymenoptera: Bethylidae; Lepidoptera: Pyralidae). Journal of the Kansas Entomological Society **54**, 787-803.

Grant, J.F.; Shepard, M. (1983) Biological characteristics of a South American population of Voria ruralis (Diptera: Tachinidae), a larval parasitoid of the soybean looper (Lepidoptera: Noctuidae). Environmental Entomology **12**, 1673-1677.

Greathead, D.J. (1963) A review of the insect enemies of Acridoidea (Orthoptera). Transactions of the Royal Entomological Society of London **114**, 437-517.

Greathead, D.J. (1966) Memorandum on the parasites and possibilities of biological control of East African bollworms. Unpublished Report of the Commonwealth Institute of Biological Control, 21 pp.

Greadhead, D.J.; Girling, D.J. (1988) Distribution and economic importance of Heliothis spp. in southern and eastern Africa including a listing and assessment of the importance of their natural enemies and host plants. Proceedings of the Second International Workshop on Heliothis Management. Delhi, 1985 (in press).

Hafez, M. (1947) The biology and life-history of Apanteles ruficrus Hal. Bulletin de la Société Fouad 1er Entomologie **31**, 225-249.

Haggis, M.J. (1982) Distribution of Heliothis armigera eggs on cotton in the Sudan Gezira: spatial and temporal changes and their possible relation to weather. Proceedings of the International Workshop on Heliothis Management. ICRISAT, Patancheru, India, 15-20 November 1981, pp. 87-99.

Hall, W.J.; Ford, W.K. (1933) Notes on some citrus insects of southern Rhodesia. Publication of the British South Africa Company **2**, 1-51.

Hamburg, H. van (1981) The inadequacy of egg counts as indicators of threshold levels for control of Heliothis armigera on cotton. Journal of the Entomological Society of South Africa **44**, 289-295.

Hansen, J.D.; Owens, J.C.; Huddleston, E.W. (1981) Relation of head capsule width to instar development in larvae of the range caterpillar, Hemileuca diviae Cockerell (Lepidoptera: Saturniidae). Journal of the Kansas Entomological Society **54**, 1-7.

Hardwick, D.F. (1965) The corn earworm complex. Memoirs of the Entomological Society of Canada **40**, 247 pp.

Haroon Khan, M.; Verma, P.M. (1946) Studies on Earias species (the spotted bollworms of cotton) in the Punjab. Part III. The biology of the common parasites of E. fabia Stoll, E. insulana Boisd. and E. cupreoviridis Walker. Indian Journal of Entomology **7**, 41-63.

Hassan, S.A. (1974) Die Massenzucht und Verwendung von Chrysopa-Arten (Neuroptera, Chrysopidae) zur Bekämpfung von Schädinsekten. Zeitschrift für Pflanzenkrankheiten und Pflanzenschütz **81**, 620-637.

Hegazi, E.M.; Hammad, S.M.; El-Minshawy, A.M. (1977) Field and laboratory observations on the parasitoids of Spodoptera littoralis (Boisd.) (Lep.: Noctuidae) in Alexandria. Zeitschrift für Angewandte Entomologie **84**, 316-321.

Henrard, P. (1937) Les insectes parasites du cottonnièr dans la région de Lisala. Bulletin Agriculture de Congo Belge **28**, 609-624.

Herting, B. (1960) Biologie der westpalaärktischen Raupfliegen, Dipt., Tachinidae. Monographien zur Angewandte Entomologie **16**, 188 pp.

Hogg, D.B.; Nordheim, E.V. (1983) Age-specific survivorship analysis of Heliothis spp. populations on cotton. Researches on Population Ecology **25**, 280-297.

Holloway, J.D.; Bradley, J.D.; Carter, D.J. (1987) CIE guides to insects of importance to man. 1. Lepidoptera. London; C.A.B International Institute of Entomology, British Museum Natural History, 262 pp.

Huddleston, T.; Walker, A.K. (in press) Cardiochiles (Hymenoptera: Braconidae) in the Sahel Region of Africa. Bulletin of Entomological Research.

Ibrahim, M.M. (1955) Studies on Coccinella undecimpunctata aegyptiaca Reiche. 2. Biology and life-history. Bulletin de la Société Entomologique d'Egypte **39**, 395-423.

Iglinsky, W.; Rainwater, C.F. (1950) Orius insidiosus, an enemy of a spider mite on cotton. Journal of Economic Entomology **43**, 567-568.

Ignoffo, C.M. (1981) The fungus Nomuraea rileyi as a microbial insecticide. In Burges, H.D. (ed) Microbial control of pest and plant diseases, 1970-1980. London, Academic Press, pp. 513-538.

Irwin, M.E.; Shepard, M. (1980) Sampling predaceous Hemiptera on soybean. In: Kogan, M.; Herzog, D.C. (eds) Sampling methods in soybean entomology. New York; Springer-Verlag, pp. 503-531.

Isenhour, D.J.; Yeargan, K.V. (1981) Effect of crop phenology on Orius insidiosus populations on strip-cropped soybean and corn. Journal of the Georgia Entomological Society **16**, 310-322.

Ismael, I.I.; Swailem, S.M. (1975) On the biology of the bollworm Heliothis armigera (Lep.: Noctuidae). Bulletin de la Société Entomologique d'Egypte **59**, 207-216.

Jackson, C.G.; Butler, G.D.; Bryan, D.E. (1969) Time required for development of Voria ruralis and its host, the cabbage looper, at different temperatures. Journal of Economic Entomology **62**, 69-70.

Jackson, C.G.; Bryan, D.E.; Neemann, E.G.; Patana, R. (1976) Palexorista laxa: development, longevity and production of progeny on Heliothis spp. Environmental Entomology **5**, 431-434.

Jacquemard, P. (1969) Contribution à l'étude de la biologie d'Eucarcelia evolans (Wied.), parasite de Diparopsis watersi (Rots.) au Cameroun Féderal. Coton et Fibres Tropicales **24**, 415-417.

Jayaraj, S. (1982) Biological and ecological studies of Heliothis. Proceedings of the International Workshop on Heliothis Management. ICRISAT, Patancheru, India, 15-20 November 1981, pp. 17-28.

Johnson, S.J.; King, E.G.; Bradley, J.R. (eds) (1986) Theory and tactics of Heliothis population management. I. Cultural and biological control. Proceedings of a Workshop held at Tifton, GA, March 15, 1983, Southern Cooperative series Bulletin **316**, 161 pp.

Jones, E.P. (1936) Investigations on the cotton bollworm, Heliothis obsoleta Fabr. Publication of the British South Africa Company **4**, 21-82.

Jones, E.P. (1937) The egg parasites of the cotton bollworm Heliothis armigera Hübn. in Southern Rhodesia. Publication of the British South Africa Company **6**, 37-105.

Jones, E.P. (1939) The biology of a tachinid parasite, Sturmia rhodesiensis sp. n., of the cotton bollworm, Heliothis armigera Hübn., in Southern Rhodesia. Publication of the British South Africa Company **7**, 11-34.

Joyce, R.J.V. (1982) A critical review of the role of chemical pesticides in Heliothis management. Proceedings of the International Workshop on Heliothis Management. ICRISAT, Patancheru, India, 15-20 November 1981, pp. 173-188.

Katiyar, R.R.; Misra, B.P.; Upadhyay, K.D.; Prasad, N. (1976) Laboratory evaluation of a carabid larva Chlaenius bioculatus (Col.: Carabidae) as a predator of lepidopterous pests. Entomophaga **21**, 349-351.

Kfir, R. (1982) Reproduction characteristics of Trichogramma brasiliensis and T. lutea, parasitizing eggs of Heliothis armigera. Entomologia Experimentalis et Applicata **32**, 249-255.

Kogan, J; Pitre, H.N. (1980) General sampling methods for above-ground populaions of soybean arthropods. **In:** Kogan, M.; Herzog, D.C. (eds) Sampling methods in soybean entomology. New York, Springer-Verlag, pp. 30-60.

Kogan, J.; Sell, D.K.; Stinner, R.E.; Bradley, J.R.; Kogan, M. (1978) The literature of arthropods associated with soybean. V. A bibliography of Heliothis zea (Boddie) and H. virescens (F.) (Lepidoptera: Noctuidae).

International Agricultural Publications INTSOY Series **17**, 242 pp.

Larochelle, A. (1974) A world list of prey of Chlaenius (Coleoptera: Carabidae). Great Lakes Entomologist **7**, 137-142.

Lazarévic, B. (1971) A contribution to the study of the cotton bollworm in the Sudan. Zastita Bilja **22**, 115-141 (in Serbo-Croat).

Lee, S.J.; Shih, C.I.T. (1983) Biology, predation and field-cage release of Chrysopa boninensis Okamoto on Paurocephala psylloptera Crawford and Corcyra cephalonica Stainton. Chinese Journal of Entomology **1**, 123-124 (in Chinese).

Le Masurier, A.D. (1987) A comparative study of the relationship between host size and brood size in Apanteles spp. (Hymenoptera: Braconidae). Ecological Entomology **12**, 383-393.

Le Pelley, R.H. (1959) Agricultural insects of East Africa. East African High Commision; Nairobi, Kenya, 307 pp.

Leston, D. (1973) The ant mosaic: tropical tree crops and the limiting of pests and diseases. Pest Abstracts and News Summaries **19**, 311-341.

Lewis, T. (1973) Thrips, their biology, ecology and economic importance. London, Academic Press, 349 pp.

Lewis, W.J.; Vinson, S.B. (1968) Egg and larval development of Cardiochiles nigriceps Viereck. Annals of the Entomological Society of America **61**, 561-565.

Lewis, W.J.; Nordlund, D.A.; Gross, H.R.; Jones, R.L.; Jones, S.L. (1977) Kairomones and their use for management of entomophagous insects. V. Moth scales as a stimulus for predation of Heliothis zea (Boddie) eggs by Chrysopa carnea Stephans larvae. Journal of Chemical Ecology **3**, 483-487.

Lingren, P.D.; Ridgway, R.L.; Jones, S.L. (1968) Consumption by several common arthropod predators of eggs and larvae of two Heliothis species that attack cotton. Annals of the Entomological Society of America **61**, 613-618.

Luck, R.F.; Shepard, B.M.; Kenmore, P.E. (1988) Experimental methods for evaluating arthropod natural enemies for integrated pest management. Annual Review of Entomology **33**, 367-391.

Lynn, D.C.; Vinson, S.B. (1977) Effects of temperature, host age, and hormones upon encapsulation of Cardiochiles nigriceps eggs by Heliothis spp. Journal of Invertebrate Pathology **29**, 50-55.

Marshall, G.E. (1930) Some observations on Orius (Triphleps) insidiosus (Say). Journal of the Kansas Entomological Society **3**, 29-30.

Marstom, N.L. (1980) Sampling parasitoids of soybean insect pests. **In:** Kogan, M.; Herzog, D.C. (eds) Sampling methods in soybean entomology. New York; Springer-Verlag, pp. 481-504.

Martin, P.B.; Lingren, P.D.; Greene, G.L.; Grissell, E.E. (1981) The parasitoid complex of three noctuids (Lep.) in a northern Florida cropping system: seasonal occurrence, parasitization, alternate hosts, and influence of host-habitat. Entomophaga **26**, 401-419.

Mason, W.R.M. (1981) The polyphyletic nature of Apanteles Foerster (Hymenoptera: Braconidae): a phylogeny and reclassification of Microgastrinae. Memoirs of the Entomological Society of Canada **115**, 147 pp.

McCutcheon, G.S.; Salley, W.Z.; Turnipseed, S.G. (1983) Biology of Apanteles ruficrus, an imported parasitoid of Pseudoplusia includens, Trichoplusia ni and Spodoptera frugiperda (Lepidoptera: Noctuidae). Environmental Entomology **12**, 1055-1058.

McKinley, D.J. (1971) Nuclear polyhedrosis virus of the cotton bollworm in Central Africa. Cotton Growing Review **48**, 297-303.

Megahed, M.M.; Abou-Zaid, N.A.; El-Dakroury, M.S.I.; Abbas, M.S.T. (1977) On the natural enemies of the American bollworm Heliothis armigera Hb. in Egypt. Journal of Agricultural Research, Tanta University **3**, 187-207.

Mellini, E.; Campadelli, G. (1979) Sulla schiusura delle uove microtipiche di Gonia cinerascens Rond. in condizioni sperimentali. Bollettino dell'Istituto di Entomologia della Università degli Studi di Bologna **34**, 153-189.

Mesnil, L. (1956) Larvaevorinae (Tachininae). Part I - Salmaciinae. Die Fliegen der Palaearktischen Region **10**, 548 pp.

Metcalfe, J.R.; Brenière, J. (1969) Egg parasites (Trichogramma spp.) for control of sugar cane moth borers. In: Williams, J.R.; Metcalfe, J.R.; Mungomery, R.W.; Mathes, R. (eds) Pests of sugar cane. Amsterdam; Elsevier, pp. 108-115.

Migunda, J. (1970) Charops sp. (Hymenoptera: Ichneumonidae) a larval parasite of Orgia mixta Snell. East African Agriculture and Forestry Journal **36**, 231-233.

Milner, J.E.D. (1967) Report on a survey of the natural enemies of Striga spp. (Scrophulariaceae) in East Africa. Unpublished Report of the Commonwealth Institute of Biological Control, 57 pp.

Mohamed, A.K.A.; Sikorowski, P.P.; Bell, J.V. (1977) Susceptibility of Heliothis zea larvae to Nomuraea rileyi at various temperatures. Journal of Invertebrate Pathology **30**, 414-417.

Mohyuddin, A.I. (1968) Notes on the distribution and biology of Pediobius furvus (Gah.) (Hym., Eulophidae), a parasite of graminaceous stemborers. Bulletin of Entomological Research **59**, 681-689.

Moutia, L.A.; Courtois, C.M. (1952) Parasites of the moth-borers of sugar-cane in Mauritius. Bulletin of Entomological Research **43**, 325-359.

Mück, O. (1985) Biologie, Verhälten und wirtschäftliche Bedeutung von Parasiten schädlicher Lepidopteren auf den Kapverden. Neue Entomologische Nachrichten **18**, 168 pp.

Muma, M.H. (1975) Long term can trapping for population analysis of ground-surface, arid-land arachnids. Florida Entomologist **58**, 257-270.

Neser, S. (1973) Biology and behaviour of Euplectrus species near laphygmae Ferriere (Hymenoptera: Eulophidae). Entomology Memoir, Department of Agriculture Technical Services, Republic of South Africa **32**, 31 pp.

Nixon, G.E.J. (1943) A synopsis of the African species of Meteorus (Hym.:

Braconidae). Bulletin of Entomological Research **34**, 53-64.

Nixon, G.E.J. (1965) A reclassification of the tribe Microgastrini (Hymenoptera: Braconidae). Bulletin of the British Museum (Natural History) Entomology, Supplement **2**, 284 pp.

Nordlund, D.A.; Lewis, W.J.; Jones, R.L.; Gross, H.R.; Hagen, K.S. (1977) Kairomones and their use for management of entomophagous insects. VI. An examination of the kairomones for the predator Chrysopa carnea Stephens at the oviposition sites of Heliothis zea (Boddie). Journal of Chemical Ecology **3**, 507-511.

Nyambo, B.T. (1986) Studies in the bollworm, Heliothis armigera Hübner, the key cotton pest in Tanzania, as a basis for improved integrated pest management. PhD. thesis, University of London, 444 pp.

Nye, I.W.B. (1982) The nomenclature of Heliothis and associated taxa (Lepidoptera: Noctuidae): past and present. Proceedings of the International Workshop on Heliothis Management. ICRISAT, Patancheru, India, 15-20 November 1981, pp. 3-8.

Nyiira, Z.M. (1970a) A note on the natural enemies of lepidopterous larvae in cotton bolls in Uganda. Annals of the Entomological Society of America **63**, 1461-1462.

Nyiira, Z.M. (1970b) The biology and behavior of Rhinocoris albopunctatus (Hemiptera: Reduviidae). Annals of the Entomological Society of America **63**, 1224-1227.

Odhiambo, T.R. (1959) An account of parental care in Rhinocoris albopilosus Signoret (Hemiptera-Heteroptera: Reduviidae), with notes on its life-history. Proceedings of the Royal Entomological Society of London (A) **34**, 175-185.

Parsons, F.S. (1940) Investigations on the cotton bollworm, Heliothis armigera Hübn. II. The incidence of parasites in quantitative relation to bollworm populations in South Africa. Bulletin of Entomological Research **31**, 89-109.

Parsons, F.S.; Ullyett, G.C. (1934) Investigations on the control of the American and red bollworms of cotton in South Africa. Bulletin of Entomological Research **25**, 349-381.

Parsons, F.S.; Ullyett, G.C. (1936) Investigations on Trichogramma lutea Gir. as a parasite of the cotton bollworm, Heliothis obsoleta Fabr. Bulletin of Entomological Research **27**, 219-235.

Patel, R.C.; Singh, R. (1972) Biology and breeding method of Goniophthalmus halli Mesnil (Diptera: Tachinidae), a larval parasite of Heliothis armigera (Hbn.). Indian Journal of Agricultural Sciences **42**, 739-743.

Pearson, E.O. (1958) The insect pests of cotton in tropical Africa. London; Empire Cotton Growing Corporation and Commonwealth Institute of Entomology, 355 pp.

Peat, J.E. (1935) Gatooma, Southern Rhodesia. In: Progress Reports from Experiment Stations, Season 1933-34. London; Empire Cotton Growing Corporation, pp. 51-74.

Pettey, F.W. (1948) The biological control of pricky pears in South Africa. Science Bulletin of the Department of Agriculture, South Africa **271**, 1-

163.

Poole, R.W. (1988) Noctuidae: Catalogus Lepidoptorum. Brill Publisher (in press).

Prinsloo, G.L. (1984) An illustrated guide to the parasitic wasps associated with citrus pests in the Republic of South Africa. Science Bulletin, Department of Agriculture, Republic of South Africa **402**, 119 pp.

Reed, W. (1965) Heliothis armigera (Hb.) (Noctuidae) in Western Tanganyika. I. Biology, with special reference to the pupal stage; II. Ecology and natural and chemical control. Bulletin of Entomological Research **56**, 127-140.

Rens, G.R. (1977) Interrelations and control of insects, attacking cotton and food crops, with particular reference to Heliothis armigera. First East African Conference on Entomology and Pest Control, 6-10 Dec, 1976, Nairobi, Kenya, pp. 80-84.

Ripper, W.E.; George, L. (1965) Cotton pests of the Sudan, their habits and control. Oxford; Blackwell, 345 pp.

Risbec, J. (1950) État actuel des récherches entomologiques agricoles dans la région correspondant au secteur soudanais de récherches agronomiques. C.R. 1er Conférence International Africanistes de l'Ouest **1**, 317-375.

Risbec, J. (1960) Les parasites des insects d'importance économique en Afrique tropicale et à Madagascar. l'Agronomie tropicale **15**, 624-656.

Robertson, I.A.D. (1965) Notes on Diptera collected in Tanganyika. Journal of the Entomological Society of South Africa **28**, 80-91.

Robertson, I.A.D. (1970) Notes on Hymenoptera (Parasitica) collected in Tanzania. Journal of the Entomological Society of South Africa **33**, 59-61.

Robertson, I.A.D. (1973) Notes on the insect parasites of some lepidopteran pests in Tanzania. East Africa Agriculture and Forestry Journal **39**, 82-93.

Room, P.M. (1975) Relative distributions of ant species in cocoa plantations in Papua New Guinea. Journal of Applied Ecology **12**, 47-62.

Roome, R.E. (1971a) Field studies of Heliothis armigera (Lepidoptera: Noctuidae) in Botswana. In: Matthews, G.A. (ed) Cotton insect control conference, Proceedings of the Cotton Insect Control Conference, March 24-27, 1971, Blantyre, Malawi, pp. 32-46.

Roome, R.E. (1971b) A note on the use of biological insecticides against Heliothis armigera (Hb.) in Botswana. In: Matthews, G.A. (ed) Cotton insect control conference, Proceedings of the Cotton Insect Control Conference, March 24-27, 1971, Blantyre, Malawi, pp. 221-238.

Roome, R.E. (1975a) The control of Heliothis on subsistence crops in Botswana. Mededelingen Faculteit Landbouwwetenschappen Rijks-universiteit Gent **40**, 267-282.

Roome, R.E. (1975b) Field trials with a nuclear polyhedrosis virus and Bacillus thuringiensis against larvae of Heliothis armigera (Hb.) (Lepidoptera: Noctuidae) on sorghum and cotton in Botswana. Bulletin of Entomological Research **65**, 507-514.

Roome, R.E. (1979) Pupal diapause in Heliothis armigera Hübner (Lepidoptera: Noctuidae) in Botswana: its regulation by environmental factors. Bulletin of Entomological Research **69**, 149-160.

Russo, G. (1940) Contributo alla conoscenza degli insetti dannosi al cotone nell Africa Orientale Italiana. I. Lepidotteri. Bolletino del R. Laboratorio di Entomologia Agraria di Portici **3**, 105-246.

Ryerson, S.A.; Stone, J.D. (1979) A selected bibliography of two species of Orius: the minute pirate bug, Orius tristicolor, and Orius insidiosus (Heteroptera: Anthocoridae). Bulletin of the Entomological Society of America **25**, 131-135.

Saeger, H. de (1944) Microgastrinae (Hymenoptera Apocrita). Exploration du Parc National Albert **47**, 342pp.

Saeger, H. de (1948) Cardiochilinae et Sigalphinae (Hymenoptera Apocrita). Exploration du Parc National Albert **53**, 1-272.

Salas-Aguilar, J.; Ehler, L.E. (1977) Feeding habits of Orius tristicolor. Annals of the Entomological Society of America **70**, 60-62.

Schuster, M.F.; Lukefahr, M.J.; Maxwell, F.G. (1976) Impact of nectariless cotton on plant bugs and natural enemies. Journal of Economic Entomology **69**, 400-402.

Searle, C.M.S.L. (1964) A list of the insect enemies of citrus pests in southern Africa. Technical Communication of the Plant Protection Institute, Pretoria **30**, 18 pp.

Shelton, M.D.; Edwards, C.R. (1983) Effects of weeds on the diversity and abundance of insects in soybeans. Environmental Entomology **12**, 296-298.

Simmonds, F.J. (1960) Report on a tour of Commonwealth countries in March-June 1960. Farnham Royal, UK; Commonwealth Agricultural Bureaux.

Singh, H.; Singh, G. (1975) Biological studies on Heliothis armigera (Hübner) in the Punjab. Indian Journal of Entomology **37**, 154-164.

Singh, R.P; Parshad, B. (1970) Biological notes on Cardiochiles hymeniae Fischer & Parshad (Braconidae: Hymenoptera). Indian Journal of Entomology **32**, 127-129.

Southwood, T.R.E. (1978) Ecological methods with particular reference to the study of insect populations. New York, Halsted Press, 524 pp.

Steyn, J.J. (1955) The effect of cosmopolitan brown house ant (Pheidole megacephala F.) on the citrus red scale (Aonidiella aurantii Mask.) at Letaba. Journal of the Entomological Society of South Africa **17**, 252-264.

Stinner, R.E.; Bradley, J.R.; Duyn, J.W. van (1980) Sampling Heliothis spp. on soybean. **In:** Kogan, M.; Herzog, D.C. (eds) Sampling methods in soybean entomology. New York, Springer-Verlag, pp. 407-421.

Strand, M.R.; Meola, S.M.; Vinson, S.B. (1986) Correlating pathological symptoms in Heliothis virescens eggs with development of the parasitoid Telenomus heliothidis. Journal of Insect Physiology **32**, 389-402.

Strand, M.R.; Vinson, S.B. (1982) Source and characterization of an egg recognition kairomone of Telenomus heliothidis, a parasitoid of

Heliothis virescens. Physiological Entomology **7**, 83-90.

Strand, M.R.; Vinson, S.B. (1983) Factors affecting host recognition and acceptance in the egg parasitoid Telenomus heliothidis (Hymenoptera: Scelionidae). Environmental Entomology **12**, 1114-1119.

Strickland, E.H. (1923) Biological notes on parasites of prairie cutworms. Canada Department of Agriculture Bulletin N.S. **26**, 40 pp.

Taylor, J.S. (1932) Report on cotton insect and disease investigations. Part II. Notes on the American bollworm, Heliothis obsoleta Fabr., on cotton, and its parasite Microbracon brevicornis Wesm. Science Bulletin of the Department of Agriculture, South Africa **113**, 18 pp.

Thead, L.G.; Pitre, H.N.; Kellogg, T.F. (1987) Predation on eggs and larvae of Heliothis virescens (Lep.: Noctuidae) by an adult predator complex in cage studies on cotton. Entomophaga **32**, 197-207.

Topper, C.P. (1987a) The dynamics of the adult population of Heliothis armigera (Hübner) (Lepidoptera: Noctuidae) within the Sudan Gezira in relation to cropping pattern and pest control on cotton. Bulletin of Entomological Research **77**, 525-539.

Topper, C.P. (1987b) Nocturnal behaviour of adults of Heliothis armigera (Hübner) (Lepidoptera: Noctuidae) in the Sudan Gezira and pest control implications. Bulletin of Entomological Research **77**, 541-554.

Trelease, W. (1879) Nectar; what it is, and some of its uses. In: Comstock, J.H. (ed) Report upon cotton insects. USDA Commissioner of Agriculture, pp. 319-343.

Tunstall, J.P. (1958) The biology of the Sudan bollworm, Diparopsodis watersi (Roths.), in the Gash Delta, Sudan. Bulletin of Entomological Research **49**, 1-23.

Ullyett, G.C. (1933) The mass-rearing of Bracon brevicornis Wesm. South African Journal of Science **30**, 426-432.

Ullyett, G.C. (1935) Notes on Apanteles sesamiae Cam., a parasite of the maize stalk-borer (Busseola fusca Fuller) in South Africa. Bulletin of Entomological Research **26**, 253-262.

Vaissayre, M. (1977) Contribution à la connaissance du complexe entomophage en culture cotonnière dans le sud-ouest de Madagascar. Coton et Fibres Tropicales **32**, 35-58.

Varley, G.C.; Gradwell, G.R.; Hassell, M.P. (1973) Insect population ecology: an analytical approach. Oxford, Blackwell Scientific Publications, 212 pp.

Vinson, S.B. (1968) Source of a substance in Heliothis virescens that elicits a searching response in its habitual parasite, Cardiochiles nigriceps. Annals of the Entomological Society of America **61**, 8-10.

Vinson, S.B. (1975) Biochemical coevolution between parasitoids and their hosts. In: Price, P.W. (ed) Evolutionary strategies of parasitic insects and mites. New York, Plenum Press, pp. 14-48.

Vinson, S.B.; Lewis, W.J. (1965) A method of host selection by Cardiochiles nigriceps. Journal of Economic Entomology **58**, 869-871.

Vinson, S.B.; Jones, R.L.; Sonnett, P.E.; Bierl, B.A.; Berosa, M. (1975) Isolation, identification and synthesis of host-seeking stimulants for Cardiochiles nigriceps, a parasitoid of the tobacco budworm. Entomologia Experimentalis et Applicata **18**, 443-450.

Weseloh, R.M. (1974) Host-related microhabitat preferences of the gypsy moth larval parasitoid, Parasetigena agilis. Environmental Entomology **3**, 363-364.

Weseloh, R.M. (1982) Implications of tree microhabitat preferences of Compsilura concinnata (Diptera: Tachinidae) for its effectiveness as a gypsy moth parasitoid. Canadian Entomologist **114**, 617-622.

Whitlock, V.H. (1974) Symptomatology of two viruses infecting Heliothis armigera. Journal of Invertebrate Pathology **23**, 70-75.

Wilkinson, D.S. (1932) Some new species of Chelonella (Hym.: Braconidae). Stylops **1**, 6-10.

Wilson, A.G.L. (1974) Resistance of Heliothis armigera to insecticides in the Ord Irrigation Area, North Western Australia. Journal of Economic Entomology **67**, 256-258.

Wilson, L.T.; Gutierrez, A.P. (1980) Within-plant distribution of predators on cotton: comments on sampling and predator efficiencies. Hilgardia **48**, 3-11.

Yokoyama, V.Y. (1978) Relation of seasonal changes in extrafloral nectar and foliar protein and arthropod populations in cotton. Environmental Entomology **7**, 799-802.

INDEX OF FAMILIES AND ORDERS

ANNEX 1

LIST OF NATURAL ENEMY SPECIES

acuta, Macrorhaphis (Pentatomidae)
agilis, Linnaemya (Tachinidae, Tachininae)
albidipennis, Orius (Anthocoridae)
albifrons, Linnaemya (Tachinidae, Tachininae)
albopunctatus, Rhinocoris (Reduviidae)
Aleiodes sp. (Braconidae)
alfierii, Paederus (Staphilinidae)
Ammophila sp. (Sphecidae)
Amobia signata (Sarcophagidae)
angustifrons, Thelairosoma (Tachinidae, Goniinae)
Apanteles diparopsidis (Braconidae)
Apanteles maculitarsis (Braconidae)
Apanteles ruficrus (Braconidae)
Apanteles sesamiae (Braconidae)
Ascogaster cava (Braconidae)
ater, Charops (Ichneumonidae)
bakeri, Hystricovoria (Tachinidae, Tachininae)
Barylypa rufa (Ichneumonidae)
bifoveolatus, Chelonus (Braconidae)
bimaculata, Gonia (Tachinidae, Goniinae)
blepharipus, Pales (Tachinidae, Goniinae)
boisduvali, Chlaenius (Carabidae)
bombylans, Dejeania (Tachinidae, Tachininae)
boninensis, Mallada (Chrysopidae)
bottegi, Brachymeria (Chalcididae)
Brachymeria bottegi (Chalcididae)
Brachymeria cowani (Chalcididae)
Bracon brevicornis (Braconidae)
Bracon hebetor (Braconidae)
Bracon kirkpatricki (Braconidae)
Braunsia sp. (Braconidae)
brevicornis, Bracon (Braconidae)
busseolae, Platytelenomus (Scelionidae)
capensis, Enicospilus (Ichneumonidae)
Campoplex xanthostoma (Ichneumonidae)
capensis, Nemoraea (Tachinidae, Tachininae)
capensis, Netelia (Ichneumonidae)
capensis, Voria (Tachinidae, Goniinae)
Carcelia evolans (Tachinidae, Goniinae)
Carcelia illota (Tachinidae, Goniinae)
Cardiochiles nigricollis (Braconidae)
Cardiochiles nigromaculatus (Braconidae)
Cardiochiles trimaculatus (Braconidae)
Cardiochiles variegatus (Braconidae)
carnea, Chrysoperla (Chrysopidae)
Ceraphron sp. (Ceraphronidae)
Ceromya cibdela (Tachinidae, Goniinae)
Charops ater (Ichneumonidae)
Chelonus bifoveolatus (Braconidae)
Chelonus curvimaculatus (Braconidae)
Chelonus pilosulus (Braconidae)
Chelonus versatilis (Braconidae)
Chetogena sp. (Tachinidae, Goniinae)
Chlaenius boisduvali (Carabidae)
Chlaenius dusaultii (Carabidae)
Chlorion sp. (Sphecidae)

Chrysopa congrua (Chrysopidae)
Chrysopa pudica (Chrysopidae)
Chrysoperla carnea (Chrysopidae)
cibdela, Ceromya (Tachinidae, Goniinae)
ciliata, Zygobothria (Tachinidae, Goniinae)
clytes, Meteorus (Braconidae)
Coccinella undecimpunctata (Coccinellidae)
coerulea, Pales (Tachinidae, Goniinae)
congrua, Chrysopidae (Chrysopidae)
conspicuus, Glypsus (Pentatomidae)
convergens, Sturmia (Tachinidae, Goniinae)
Copidosoma sp. (Encyrtidae)
Coranus papillosus (Reduviidae)
Cosmolestes pictus (Reduviidae)
cowani, Brachymeria (Chalcididae)
curvimaculatus, Chelonus (Braconidae)
dasyops, Winthemia (Tachinidae, Goniinae)
Dejeania bombylans (Tachinidae, Tachininae)
Delta sp. (Eumenidae)
Diadegma sp. (Ichneumonidae)
diparopsidis, Apanteles (Braconidae)
discolor, Metopius (Ichneumonidae)
Disophrys lutea (Braconidae)
Disophrys nigricornis (Braconidae)
Dohrniphora paolii (Phoridae)
Drino sp. (Tachinidae, Goniinae)
dusaultii, Chlaenius (Carabidae)
Ectomocoris fenestratus (Reduviidae)
Elasmus johnstoni (Elasmidae)
Enicospilus capensis (Ichneumonidae)
evolans, Carcelia (Tachinidae, Goniinae)
Eumenes maxillosus (Eumenidae)
Euplectrus laphygmae (Eulophidae)
Eurytoma sp. (Eurytomidae)
Exorista sorbillans (Tachinidae, Goniinae)
Exorista xanthaspis (Tachinidae, Goniinae)
fenestratus, Ectomocoris (Reduviidae)
furvus, Pediobius (Eulophidae)
Glypsus conspicuus (Pentatomidae)
Gonia bimaculata (Tachinidae, Goniinae)
Goniophthalmus halli (Tachinidae, Goniinae)
Goniozus sp. (Bethylidae)
Graphipterus obsoletus (Carabidae)
halli, Goniophthalmus (Tachinidae, Goniinae)
halli, Paradrino (Tachinidae, Goniinae)
hebetor, Bracon (Braconidae)
Hexamermis sp. (Mermithidae)
Hyperchalcidia soudanensis (Chalcididae)
Hystricovoria bakeri (Tachinidae, Tachininae)
idonea, Palexorista (Tachinidae, Goniinae)
imberbis, Palexorista (Tachinidae, Goniinae)
insidiosus, Orius (Anthocoridae)
illota, Carcelia (Tachinidae, Goniinae)
johnstoni, Elasmus (Elasmidae)
kirkpatricki, Bracon (Braconidae)
laevigatus, Orius (Anthocoridae)
laphygmae, Euplectrus (Eulophidae)
laphygmarum, Meteorus (Braconidae)
laxa, Palexorista (Tachinidae, Goniinae)
Linnaemya agilis (Tachinidae, Tachininae)
Linnaemya albifrons (Tachinidae, Tachininae)
Linnaemya longirostris (Tachinidae, Tachininae)

Rhinocoris albopunctatus (Reduviidae)
Rhinocoris segmentarius (Reduviidae)
rileyi, Nomuraea (Fungi)
rubellana, Nemoraea (Tachinidae, Tachininae)
rufa, Barylypa (Ichneumonidae)
ruficrus, Apanteles (Braconidae)
rufifrons, Pseudogonia (Tachinidae, Goniinae)
rufolateralis, Plagiomima (Tachinidae, Goniinae)
ruralis, Voria (Tachinidae, Goniinae)
Sarcophaga hirtipes (Sarcophagidae)
Scymnus sp. (Coccinellidae)
Scolothrips sexmaculatus (Thysanoptera)
segmentarius, Rhinocoris (Reduviidae)
seminitida, Pales (Tachinidae, Goniinae)
sesamiae, Apanteles (Braconidae)
sexmaculatus, Scolothrips (Thysanoptera)
signata, Amobia (Sarcophagidae)
sorbillans, Exorista (Tachinidae, Goniinae)
soudanensis, Hyperchalcidia (Chalcididae)
Sturmia convergens (Tachinidae, Goniinae)
sufiventris, Microplitis (Braconidae)
Telenomus ullyetti (Scelionidae)
testacea, Netelia (Ichneumonidae)
Thelairosoma angustifrons (Tachinidae, Goniinae)
Trichogramma pretiosum (Trichogrammatidae)
Trichogrammatoidea lutea (Trichogrammatidae)
trimaculatus, Cardiochiles (Braconidae)
undecimpunctata, Coccinella (Coccinellidae)
ullyetti, Telenomus (Scelionidae)
variegatus, Cardiochiles (Braconidae)
versatilis, Chelonus (Braconidae)
Voria capensis (Tachinidae, Goniinae)
Voria ruralis (Tachinidae, Goniinae)
Winthemia dasyops (Tachinidae, Goniinae)
xanthaspis, Exorista (Tachinidae, Goniinae)
xanthostoma, Campoplex (Ichneumonidae)
Zygobothria ciliata (Tachinidae, Goniinae)

ANNEX 2

ALTERNATIVE NOCTUID HOSTS OF *H. ARMIGERA* PARASITOIDS

Achaea catella Guenee
Agrotis segetum Schiffermuller
Agrotis ipsilon Rottenburg
Anomis auragoides Guenee
Anomis leona Schaus
Apopestes limbata Staudinger
Busseola fusca Hampson
Celama squalida Staudinger
Cucullia terrensis Felder
Diparopsis castanea Hampson
Diparopsis watersi Rothschild
Earias biplaga Walker
Earias insulana Boisduval
Eublemma gayneri Rothschild
Euxoa spinifera Hubner
Leucania leucostiga Hampson
Leucania loreyi Duponchel
Lycophotia oliveata Hampson
Plusia chalcites Esper
Plusia circumflexa Linnaeus
Plusia gamma Linnaeus
Plusia limbirena Guenee
Plusia orichalcea Fabricius
Serrodes partita Fabricius
Sesamia cretica Lederer
Spodoptera exempta Walker
Spodoptera exigua Hubner
Spodoptera littoralis Boisduval
Tarache nitidula Fabricius
Xanthodes graellsi Feisthamel
Xanthodes intersepta Guenee
Xylina exoleta Linnaeus

ANNEX 3

RECORDED HOST PLANTS REFERRED TO IN THE CATALOGUE

List of Latin names are arranged alphabetically.

Latin name	**Family**	**Common name**
Abutilon sp.	Malvaceae	Abutilon
Acanthospermum hispidum	Compositae	Acanthospermum
Antirrhinum majus	Scrophulariacae	Antirrhinum
Arachis hypogaea	Leguminosae	Groundnut
Cajanus cajan	Leguminosae	Pigeon pea
Dianthus caryophyllus	Caryophyllaceae	Carnation
Citrus spp.	Rutaceae	Citrus
Cleome spp.	Capparidaceae	Cleome, spider flower
Eleusine coracana	Gramineae	Finger millet
Gossypium herbacaea	Malvaceae	Cotton
Helianthus annuus	Compositae	Sunflower
Lycopersicon esculentum	Solanaceae	Tomato
Medicago sativa	Leguminosae	Lucerne
Nicotianum tabacum	Solanaceae	Tobacco
Pennisetum typhoides	Gramineae	Bulrush millet
Phaseolus spp.	Leguminosae	Bean
Pisum sativum	Leguminosae	Pea
Sorghum bicolor	Gramineae	Sorghum
Striga spp.	Scrophulariaceae	Striga
Trifolium spp.	Leguminosae	Clover
Zea mays	Gramineae	Maize

ANNEX 4

CHECKLIST OF *H. ARMIGERA* PARASITOIDS RECORDED FROM EAST AFRICA (KENYA, TANZANIA, UGANDA).

Parasitoid species	Country	Crop	Occurrence
Aleiodes sp.	U	Cotton	-
Apanteles diparopsidis	T	Various	Up to 26%
Apanteles sp. *vitripennis*-group	T	Various	Common
Apanteles sp. *ultor*-group	U	Various	Up to 20%
Apanteles sp.	U	Cotton	-
Apanteles sp.	K	Pigeon pea	-
Ascogaster ?*cava*	U	-	Rare
Brachymeria ?*cowani*	T	Cotton	Rare
Brachymeria sp.	U	-	-
Bracon sp.	T	Cotton	-
Braunsia sp.	T	Cotton	-
Carcelia illota	T	Cotton	Low numbers
Cardiochiles nigromaculatus	T,U	Cotton	-
Cardiochiles trimaculatus	U	Mainly cotton	8%
Cardiochiles spp.	T,U	Various	Up to 18%
Ceraphron sp.	U	-	Rare
?*Ceraphron* sp.	T	-	-
Charops sp.	T	Various	Up to 23%
Charops sp.	U	Various	10%
Chelonus bifoveolatus	T	Cotton	-
Chelonus curvimaculatus	T,U	Various	Up to 11%
Chelonus versatilis	T	Various	-
Dejeania bombylans	T	Cotton	-
?*Drino* sp.	U	Cotton	-
Enicospilus ?*communis*	U	Mainly cotton	11%
Enicospilus sp.	T	Cotton	Rare
Euplectrus laphygmae	T	-	-
?*Euplectrus* sp.	U	Cotton	-
Eurytoma sp.	U	-	-
Goniophthalmus halli	K,T	Cotton	Up to 12%
Linnaemya agilis	T,U	Cotton	-
Linnaemya longirostris	K,T,U	Cotton	Rare
Meteorus clytes	T	Groundnut	-
Meteorus laphygmarum	T,U	Cotton	Rare
Meteorus sp.	U	Cotton	Rare
Metopius discolor	T	Cotton	Rare
Nemoraea rubellana	K	-	-
Netelia ?*capensis*	U	-	Rare
Netelia opacula	K	-	-
Netelia spp.	K,T,U	Various	Rare
Palexorista laxa	T,U	Various	Up to 42%
Paradrino halli	T	Various	Common
Pristomerus spp.	U	-	Rare
Sarcophaga hirtipes	T	-	-
Sarcophaga sp.	T	Cotton	-
Sturmia convergens	T	Striga	-
Telenomus ullyetti	T	-	-
?*Trichogramma* sp.	T	Cotton	Up to 5%
?*Trichogramma* sp.	U	-	-