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Heliothis species and their natural enemies, with their potential for biological control

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Abstract. Four egg and 24 larval parasitoids including one mermithid species have been identified from *Heliothis armigera* collected at and around ICRISAT Center. Twenty one insect and five spider species have been recorded as predators of *Heliothis*. The degree of parasitism varies according to the crop. Egg parasitism is absent on chickpea, and almost negligible on pigeonpea (0·3%). Most early larval parasitism occurs on pearl millet (50·7%), sorghum (49·5%), and chickpea (31·4%), whereas late larval parasitism occurs on pigeonpea (16·4%), and groundnut (11·5%).

The egg parasitoids, mostly *Trichogramma chilonis* Ishii, and the parasitoids of small larvae, mostly *Campoletis chlorideae* Uchida, are the most abundant natural enemies of *Heliothis* in the study area.

Keywords. *Heliothis* spp., parasitoids; predators; pathogens.

1. Introduction

The International Workshop on *Heliothis* Management in 1981 held at the ICRISAT, reviewed *Heliothis* work and discussed the future research strategies to combat the ever increasing menace of *Heliothis* in national and international agriculture (ICRISAT 1982). It was recognised that work is required on a regional basis to develop integrated pest management programs for *Heliothis*. At ICRISAT Center, some components of integrated pest management, particularly of *H. armigera*, are under investigation. This paper reviews the results of 11 years of monitoring of *Heliothis* and the natural enemies of this genus.

2. *Heliothis* species at ICRISAT Center and its environs

Three *Heliothis* species—*H. armigera* (Hubner), *H. peltigera* (Schiff.) and *H. assulta* Guenee damage crops in India. The most important of these is *H. armigera* (Jayaraj 1981; Jadhav *et al* 1985). This is confirmed by 11 years light trapping data from ICRISAT Center in which *H. armigera* formed 99·2% of the catch, followed by *H. assulta* (0·6%) and *H. peltigera* (0·2%).

3. Host plants and seasonal population of *H. armigera*

Of the 96 cultivated and 61 uncultivated plant species that have been reported to be hosts of *H. armigera* in the Indian literature, 50 cultivated and 48 uncultivated

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species have been recorded at and around ICRISAT Center (Bhatnagar and Davies 1978). This wide host range covers most crops, including the ICRISAT's mandate crop: sorghum, pearl millet, groundnut, pigeonpea and chickpea.

The trend of larval population of *H. armigera* on ICRISAT crops is shown against the ICRISAT cropping schedule in figure 1. ICRISAT crops provide food for *H. armigera* from July until April, when there is a closed season of 2 months (May–June). During the closed season *H. armigera* survives largely on weeds. Thus, *H. armigera* can breed throughout the year at and around ICRISAT Center (Pawar *et al* 1984).

H. armigera feeds on the foliage and flowers of groundnut; the earheads of sorghum and pearl millet; the flowers and pods of pigeonpea; and the foliage, flowers and pods of chickpea. *H. armigera,* multiplying on rainy season crops, appears to exert high population pressure on postrainy season crops, principally pigeonpea and

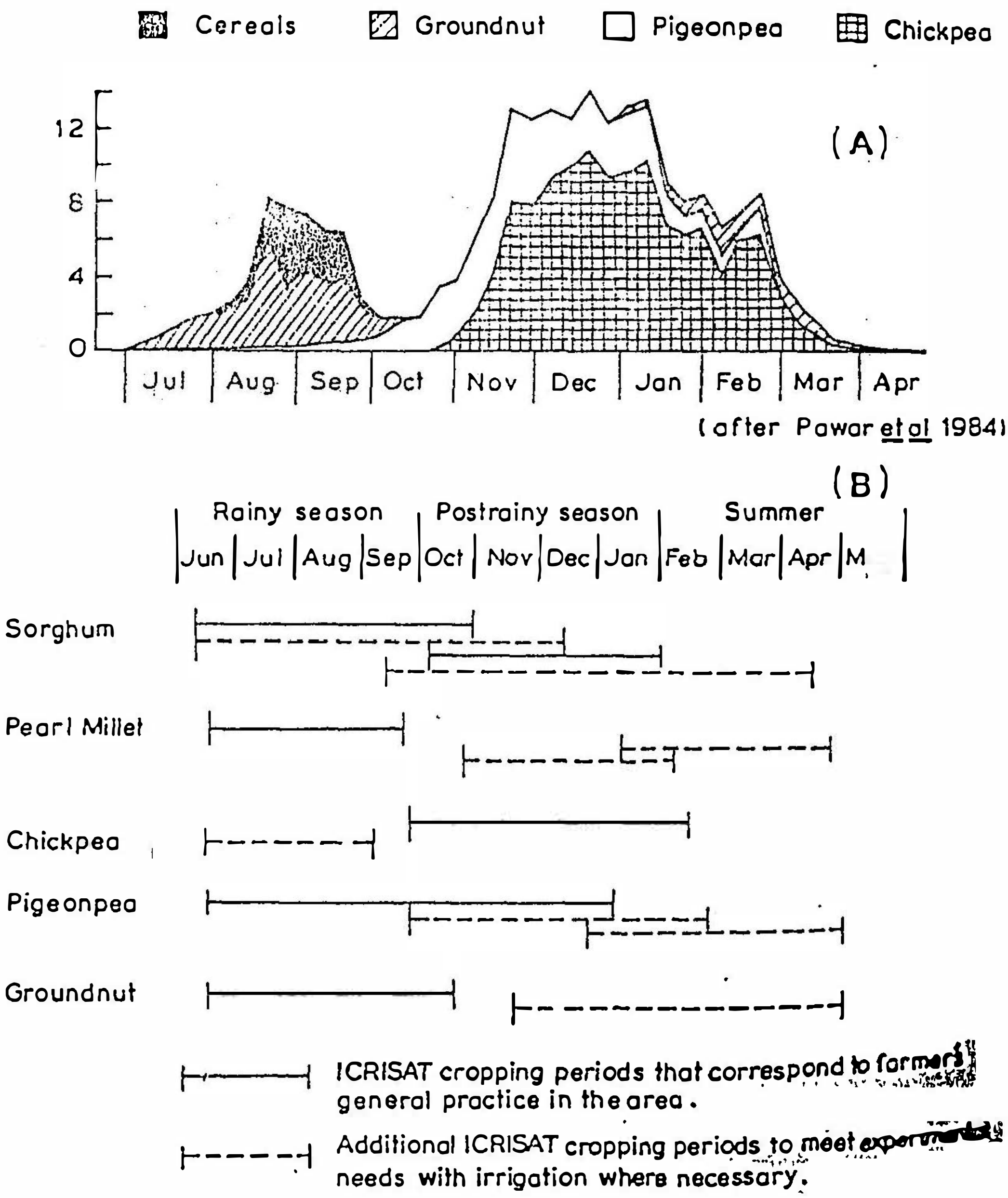


Figure 1. **A.** Trend of populations of *H. armigera* larvae on crops in the pesticide-treated areas of ICRISAT Centre, between 1979–80—1982–83. **B.** ICRISAT Centre's cropping schedule.

chickpea. The role of long distance migration within India and Africa in determining levels of infestation by *H. armigera* on different crops is now being investigated.

4. Natural enemies of *Heliothis* spp.

4.1 *Parasitoids*

The egg and larval parasitoids and their effect on *Heliothis* populations have been studied in relation to many plant species. Four egg and 24 larval parasitoids including one mermithid species have been recovered from over 80,000 eggs and 200,000 larvae of *H. armigera* collected from the ICRISAT Center farm and from farmers' fields (table 1). The parasitoids also recorded from *H. peltigera* and *H. assulta* are included in the table.

Of the egg parasitoids, *Trichogramma chilonis* Ishii is the most common. Hymenoptera and Diptera have been recovered from the larvae. Most Hymenoptera emerge from 1–3 instar larvae and from collections on cereals, whereas most Diptera emerge from 4–6 instar larvae from legumes. Among the Hymenoptera *Campoletis chlorideae* Uchida, and among the Diptera *Carcelia illota* Curran are most important; they occur on many crops throughout the year. The mermithid *Ovomermis albicans* (Sieb.) is active only during the rainy season, and only on groundnut and other short statured crops and weeds growing on red soils (Bhatnagar *et al* 1985).

Parasitoids have their preferences for crops irrespective of their host insect. This has been observed not only with sole crops but also with intercrops. Bhatnagar *et al* (1979) observed that parasitoids do not transfer with *H. armigera* from sorghum to pigeonpea in the sorghum/pigeonpea intercrop, but that each crop exhibits its own parasitoid complex.

The average rates of egg and larval parasitism recorded for *H. armigera* over the past eight years on ICRISAT mandate crops at ICRISAT Center are given in table 2. Egg mortalities of up to 33·2% on sorghum, 10·5% on pearl millet, 14·8% on groundnut, 0·3% on pigeonpea, have been recorded. On chickpea, no egg parasitism has ever been recorded.

Most early larval parasitism occurs on pearl millet (50·7%), sorghum (49·5%), and chickpea (31·9%), whereas late larval parasitism occurs chiefly on pigeonpea (16·4%) and groundnut (11·5%). Among larval parasitoids, *C. chlorideae* contributes predominantly to the mortality of 1–3 instar and *C. illota* much to the mortality of 4–6 instar larvae on all crops except groundnut, where, besides these parasitoids, the mermithid *O. albicans* is an equally or more important parasitoid (Bhatnagar *et al* 1985). Although, as a foliage feeder, *H. armigera* causes little or no yield loss in groundnut, the crop may act as an important reservoir for *Heliothis* populations when other hosts are not available or attractive.

The overall rates of egg and larval parasitism of *Heliothis* at ICRISAT Center by month, irrespective of plant species, are given in figure 2. In general, higher rates of parasitism were recorded during the rainy season when *H. armigera* is largely on groundnut, sorghum and pearl millet, whereas lower rates of parasitism were recorded during the postrainy season when *Heliothis* is largely on pigeonpea and chickpea.

Table 1. Parasitoids recovered from *Heliothis* spp. in Andhra Pradesh Maharashtra and Karnataka 1977–1985.

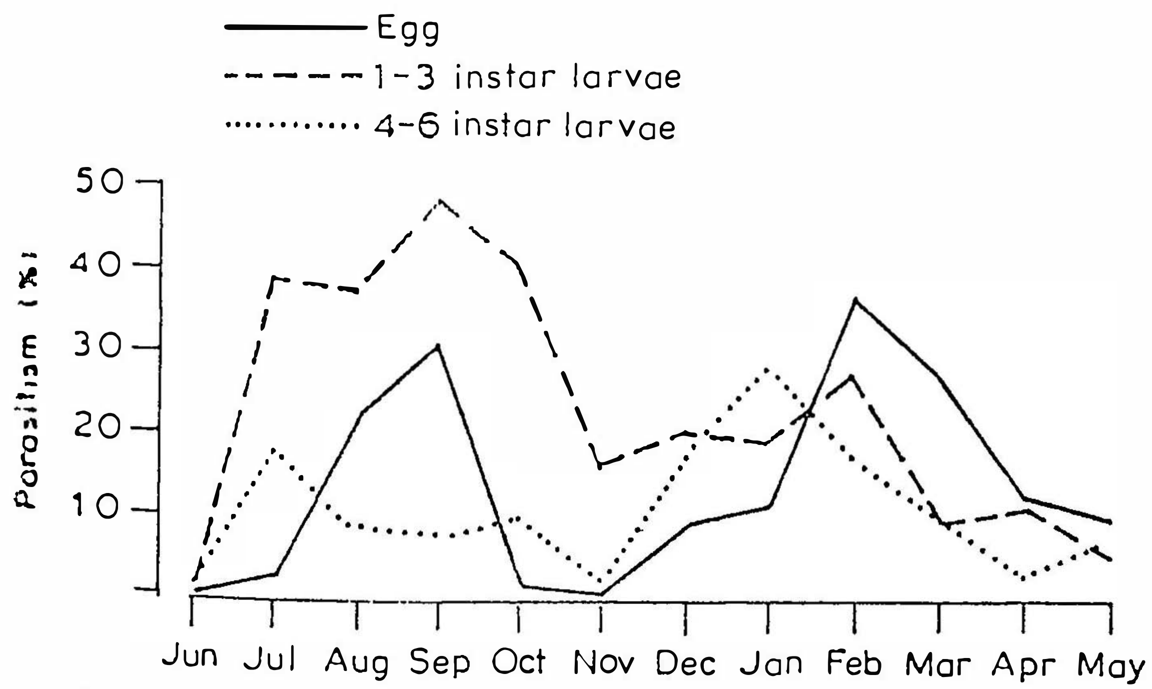
Species	Recovered from		
	H. armigera	*H. peltigera*	*H. assulta*
Insects			
Diptera			
Tachinidae			
Carcelia illota Curran[d]	√	√	√
Exorista xanthaspis Wied[c]	√		
Goniophthalmus halli Mes[d]	√	√	√
Palexorista laxa Curran[c]	√		
Palexorista solennis Walker[c]	√		√
Palexorista sp.[c]	√	√	
Sturmiopsis inferens Tns[c]	√	√	
Hymenoptera			
Bethylidae			
Goniozus sp[c]	√		
Braconidae			
Apanteles sp.[c]	√		
Bracon sp.[c]	√		
Chelonus sp[b]	√		
Microchelonus curvimaculatus Cameron[b]	√	√	√
Rogas sp[c]	√		
Ichneumonidae			
Barichneumon sp.[d]	√		
Campoletis chlorideae Uchida[c]	√	√	
Disophrys[c]	√		
Enicospilus sp. nr. *shinkanus* Uchida[c]	√		
Eriborus argenteopilosus Cameron[c]	√	√	
Eriborus trochanteratus Morley[c]	√		
Ichneumon sp.[c]	√		
Metopius rufus Cam.[c]	√		
Temelucha sp.[c]	√		
Xanthopimpla stemmator Thun.[c]	√		
Trichogrammatidae			
Trichogramma chilonis Ishii[a]	√	√	
Trichogramma sp.	√		
Trichogrammatoidea sp.[a]	√		
Trichogrammatoidea bactrae sp. *fumata* Nagaraja[a]	√		
Mermithid			
Ovomermis albicans (Sieb.)[c]	√	√	√

[a,b,c,d] Egg, egg-larval, larval and larval/ex-larval parasitoids respectively.

Table 2. Average parasitism (%) of *H. armigera* eggs and larvae on ICRISAT mandate crops at ICRISAT Center, 1977–1985.

Crops	Egg parasitism (%)	Larval parasitism (%): in 1–3 instars by *Campoletis*: Total	Chlorideae alone	in 4–6 instars by *Carcelia*: Total	Illota alone
Sorghum	33·2 (23511)[a]	49·5 (7877)[a]	45·7	5·8 (8537)[a]	3·9
Pearl millet	10·5 (2986)[a]	50 7 (584)[a]	39·9	5·1 (355)[a]	4·8
Groundnut	14 8 (2778)[a]	14·3[7·4][b] (3492)[a]	6 5	11·5[7·7][b] (3230)[a]	1·5
Pigeonpea	0·3 (21787)[a]	9 9 (10354)[a]	3·4	16·4 (28171)[a]	8·1
Chickpea	0 0 (3700)[a]	31 9 (12969)[a]	31·6	6·1 (13283)[a]	5 7

[a]Total number of collections of eggs or larvae over the years
[b]Nematode parasitism alone (%)



Larval instar	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Egg	1827	2381	10450	9463	2111	10647	8747	6887	4097	3611	2528	2332
1-3	717	2915	4963	6862	3844	7417	3616	5092	3155	1778	1465	1672
4-6	215	3152	5875	6532	4703	14713	6658	8367	4819	2208	3226	2092

Figure 2. Mean egg and larva parasitism (%) of *H. armigera* at ICRISAT Centre, 1976–85.

4.2 *Predators*

Although 21 insects and 5 spider species have been recorded as predators of *Heliothis* eggs and larvae (table 3) their effect on *H. armigera* population has not yet been quantified. Their activity, however, has been observed to differ with the crop and the soil type. We reared wasps, *Delta* spp., in a field cage and found them active when provided with a pool of water and the sucrose, as a substitute for flowering plants (ICRISAT 1983). Birds have often been recorded feeding on larvae from crops like chickpea in areas where there are trees to serve as roosting sites.

4.3 *Pathogens*

Whereas bacteria, fungi and viruses have sometimes caused mortality to *Heliothis* larvae in the field, little is known about the quantitative impact of pathogens on field

Table 3. Arthropod predators on *H. armigera* (Hb.), recovered in Andhra Pradesh 1977-1985.

Coleoptera	
Coccinellidae	*Menochilus sexmaculatus* F.[ab]
Dermaptera	
Carcinophoridae	*Euborellia annulipes* (Lucas)[bc]
	Euborellia stali Dohrn[bc]
Labiduridae	*Nala lividipes* (Dufour)[b]
Dictyoptera	
Mantidae	*Humbertiella* sp.[bc]
Hemiptera	
Anthocoridae	*Orius (Dimorphella) maxidentex* Ghauri[ab]
Lygaeidae	*Paromius gracilis* (Rambur)[b]
Nabidae	*Tropiconabis capsiformis* (Germar)
Pentatomidae	*Cantheconidea furcellata* (Wolff)[b]
Reduviidae	*Catamiarus brevipennis* (Serv.)[cd]
	Ectrychotes dispar Reut.[bc]
	Rhinocoris marginatus (Fab.)[bcd]
Hymenoptera	
Eumenidae	*Delta conoideus* G. soyka[cd]
	Delta campaniforme esuriens Fabricius[bc]
	Delta pyriformae (Fabricius)[cd]
Sphecidae	*Sphex argentatus* Fabricius[bc]
Vespidae	*Polistes olivaceus* Degeer[cd]
	Ropalidia marginata Lepelticr[cd]
	Vespa orientalis Fabricius[cd]
	Vespa tropica haemotodes Bequaert[cd]
Neuroptera	
Chrysopidae	*Chrysopa* sp.[abc]
Araneida	
Aranidae	*Leucauge tessellata* (Thorb.)[bc]
	Neoseona theis (Walck.)[bc]
Clubionidae	*Clubiona* sp.[bc]
Thomisidae	*Thomisus* sp.[bc]
	Oxyptila reenae (Basu)[bc]

[a, b, c, d] Egg, small larval, medium (indicated based on observations).

populations. However, nuclear polyhedrosis virus (NPV) has severely affected a laboratory culture of *H. armigera* (Bhatnagar *et al* 1982). The potential of NPV on chickpea as a biocontrol agent has been confirmed when artificially applied to chickpea in the field (Bhatnagar *et al* 1983).

5. Scope for biological control of *H. armigera*

In the light of the above observations it could be said that, for biological control of *H. armigera* at and around ICRISAT Center and in similar situations, one must aim at a plan to benefit the crops of pigeonpea and chickpea which are highly vulnerable to *H. armigera*, perhaps for the lack of adequate natural control. Egg parasitism is preferable because the insect is killed before the larva emerges to damage the crop. For example, weekly releases of the egg parasitoid, *T. chilonis*, as practiced by the sugarcane growers in Tamil Nadu, is giving good control of the internode borer, *Chilo sacchariphagous indicus*, of sugarcane (Solayappan 1980). However, it is known that egg parasitoids are not active on pigeonpea and chickpea, so releasing them in these crops is unlikely to be effective. However, releases to increase populations in sorghum, pearl millet, or groundnut to encourage natural control before *H. armigera* transfers to pigeonpea or chickpea may be a possibility. Finding exotic parasitoids which would also prefer *H. armigera* on pigeonpea and chickpea and breeding for crop varieties which are more attractive to natural enemies could also be considered.

Among the larval parasitoids, *C. chlorideae* is a potential candidate for biological control because it parasitises 1–3 instar larvae and is active on almost all crop and weed hosts of *H. armigera* (ICRISAT 198[illegible]). Nagarkatti (1982) reported that it is not amenable to mass rearing. A closely related species, *C. fasciata* Ashm. is being considered for introduction into India from the neotropical region (Sankaran 1983). The introduction of such species, however, may not prove wise. When *C. chlorideae* was introduced into the USA it impaired the effectiveness of the native *C. sonorensis* (Cameron) because the two species inbred and produced infertile hybrids (King *et al* [illegible]).

Attempts to establish a specific larval parasitoid, *Eucelatoria bryani* (Coq.) of *Heliothis*, imported from the USA have failed at ICRISAT Center (ICRISAT 1984) although the National Centre for Biological Control, Bangalore, has reported that it is slowly becoming established around Bangalore (Nagarkatti 1982). The constraint in the establishment of this parasitoid in central India is that it cannot survive temperatures greater than 35°C which are common in the summer (Bhatnagar *et al* 1983). The Indian Council of Agricultural Research (ICAR), New Delhi is now considering introducing the larval parasitoids *Hyposoter didymator* (Thunb.) and *Apanteles kazak* Telenga from Europe where they are reported to check *H. armigera* even under pesticide treated conditions (S P Singh, Perl. Communication). We have to see whether these parasitoids could be established in the country.

The adoption of NPV for the control of *H. armigera* is possible. However, its use at farmers' level has not yet been permitted by the Govt. of India for several reasons including the possibilities of its harmful effects on man and animals. NPV is not effective on all crops; it has been reported to be effective on chickpea (Narayanan 1979; Santharam and Balsubramanian 1982) but not on pigeonpea (Santharam *et al* 1981).

The potential of using predators in biological control of *Heliothis* has been amply demonstrated elsewhere. Ridgway *et al* (1977) obtained good control of *Heliothis* spp. on cotton by periodic releases of eggs and larvae of *Chrysopa carnea* Stephens. The Institute of Agricultural and Forestry Sciences in Shang-Chiu (1976) reported 70–80% reduction in *H. armigera* larval population in cotton fields within 5–7 days of the introduction of colonies of *Polistes* wasps. This type of augmentation of natural enemies could also be attempted here, provided that work on native predators to find their limitations in the manner done for *Delta* wasps at ICRISAT Center is carried out at least for the major predators.

An important consideration for the success of biological control in an IPM Program is the use of insecticides that are relatively less toxic to parasitoids and predators than to the pests (Croft and Brown 1975). This, however, calls for the testing of available insecticides against, at least, the major parasitoids and predators as is being done in the developed countries.

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References

Bhatnagar V S and Davies J C 1978 Factors affecting populations of gram pod borer, *Heliothis armigera* (Hubner) (Lepidoptera, Noctuidae) in the period 1974–77 at Patancheru, Andhra Pradesh; *Bull. Entomol.* 19 52–64

Bhatnagar V S and Davies J C 1979 Pest management in intercrop subsistence farming; *Proc. Int. Workshop on Intercropping*. ICRISAT, Patancheru, AP, pp 249–257

Bhatnagar V S, Lateef S S, Sithanantham S, Pawar C S and Reed W 1982 Research on *Heliothis* at ICRISAT; *Proc. Int. Workshop on Heliothis Management*, ICRISAT, Patancheru, AP, pp 385–396

Bhatnagar V S, Pawar C S, Jadhav D R and Davies J C 1985 Mermithid nematodes as parasites of *Heliothis* spp. and other crop pests in Andhra Pradesh, India; *Proc. Indian Acad. Sci. (Anim. Sci.)* 94 509–515

Bhatnagar V S, Sithanantham S, Pawar C S, Jadhav D R, Rao V R and Reed W 1983 Conservation and augmentation of natural enemies with reference to integrated pest management in Chickpea (*Cicer arietinum* L.) and Pigeonpea (*Cajanus cajan* (L.) millsp.); *Proc. Int. Workshop in Integrated Pest Control for Grain Legumes*, EMBRAPA Centro Nacional de Pesquisa-arroz, Goiania, Brazil, pp 157–180

Croft B A and Brown A W A 1975 Responses of arthropod natural enemies to insecticides; *Annu. Rev. Entomol.* 20 285–335

ICRISAT 1982 *Proc. Int. Workshop on Heliothis Management* ICRISAT, Patancheru, AP, p 410

ICRISAT 1983 *Annu. Rep.* 1982 p 285

ICRISAT 1984 *Annu. Rep.* 1983 p 165

ICRISAT 1985 *Annu. Rep.* 1984 pp 282–283

Institute of Agricultural and Forestry Sciences of Shang-Chiu 1976 A preliminary study on the bionomics of hunting wasps and their utilization in cotton insect control; *Acta Entomol. Sinica* 19 303–308

Jadhav D R, Bhatnagar V S and Pawar C S 1985 The species status of *Heliothis armigera* (Hub.) (Lepidoptera: Noctuidae) in Andhra Pradesh, India on the basis of aedeagal cornutal spines; *Curr. Sci.* 54 239–240

Jayaraj S 1981 Biological and ecological studies of *Heliothis*; *Proc. Int. Workshop on Heliothis Management*, ICRISAT, Patancheru, AP, pp 17–28

King E G, Powell J E and Smith J W 1981 Prospects for Utilization of parasites and predators for management of *Heliothis* spp.; *Proc. Int. Workshop on Heliothis Management*, ICRISAT, Patancheru, AP, pp 103–122

Nagarkatti S 1982 The Utilization of Biological control in *Heliothis* management in India; *Proc. Int. Workshop on Heliothis Management*, ICRISAT, Patancheru, AP, pp 159–167

Narayanan K 1979 Studies on the nuclear polyhedrosis virus of gram pod borer, *Heliothis armigera* (Hubner) (Noctuidae Lepidoptera). Ph D thesis, Tamil Nadu Agricultural University, Coimbatore

Pawar C S Srivastava C P and Reed W 1984 Some aspects of population dynamics of *Heliothis armigera* at ICRISAT Center, *III Oriental Symposium*, 21–24 Feb 1984, University of Kerala, Kariavattom, Kerala

Ridgway R L, King E G and Carrillo J L 1977 Augmentation of natural enemies for control of plant pests in the western hemisphere, in *Biological control by augmentation of natural enemies* (eds) R L Ridgway and S B Vinson (New York: Plenum Press) pp 379–416

Sankaran T 1983 Prospects for natural enemy utilisation in pest management on pulses, *Proc. Group Discussion. Pulse Pest Management*, ICRISAT, Patancheru, AP, pp 17–23

Santharam G and Balasubramaniam M 1982 Effect of Nuclear Polyhedrosis Virus (NPV) used alone and in combination with insecticides in controlling *Heliothis armigera* (Hubner) on bengal gram; *J. Entomol Res* 6 179–181

Santharam G, Balasubramaniam M and Chelliah S 1981 Control of *Heliothis armigera* (Hubner) on red gram (*Cajanus cajan* L) with a Nuclear Polyhedrosis Virus and insecticides: *Madras Agric. J.* 68 417–420

Solayappan A R 1980 Mass production of *Trichogramma* for release in factory areas in *Biological Control of Sugarcane Pests in India* (eds) S Sithananthan and A R Solayappan, Madras TNFCSF Ltd pp 29–35