African Bollworm Management In Ethiopia

Status and Needs

Edited by

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Proceedings of the National Workshop held at the Plant Protection Research Center Ambo, Ethiopia during 17 - 19 April 2002

Correct Citation: Mohammed Dawd, S. Sithanantham and Tadesse Gebremedhin (ed.). 2004. African Bollworm Management in Ethiopia: Status and Needs. Proceedings of the National Workshop held at the Plant Protection Research Center, Ambo, Ethiopia, during 17-19, April 2002.

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Acknowledgements

The workshop organizers wish to place on record their sincere appreciations for the excellent support and assistance received from Ethiopian Agricultural Research Organization (EARO), both through the Plant Protection Research Center (PPRC), Ambo, and the National Pulse Research Program (NPRP), Debrezeit, which made it possible to successfully convene the workshop.

The contribution of the Regional African Bollworm Biocontrol Project being implemented by the International Center of Insect Physiology and Ecology (ICIPE) and funded by the German Federal Ministry of Technical cooperation (BMZ) through scientist participation and in cooperating with EARO to support the publication of the workshop proceedings as a document is also gratefully acknowledged.

The technical assistance provided by colleagues of the Plant Protection Research Center team and the ICIPE project in preparing this document is sincerely appreciated. We also thank Abebe kirub for editing the language in the final copy.

We would like to thank all who contributed for the success of this workshop. In particular, we would like to mention the valuable cooperation extended by Shimeles Getinet, Birhanu Bekele, Takele Negewo and the supporting staff of PPRC, Ambo.

Foreword

The Ethiopian Agricultural Research Organization (EARO) national priority is to enhance the contribution of Agricultural Development Lead Industrialization (ALDI) and reduce poverty. Sustainable protection of crops from pests is a key component for ensuing optimum yields and acceptable quality of the produce both to local and export market. Plant protection research in Ethiopia is focused on environment-friendly approach, to minimize the current pesticide-dependant scenario and to enable the farmers to implement Integrated Pest Management (IPM) approach.

The African bollworm, *Helicoverpa armigera* is key pest of a wide range of crops like, vegetables, legumes, fiber crops, oil seeds and cereals. It is commendable that scientists of the Plant Protection Research Center of the Ethiopian Agricultural Research Organization jointly with the regional African Bollworm biocontrol project led by International Center of Insect Physiology and Ecology (ICIPE) convened a national workshop to identify the needs and opportunities for sustainable management of the pest in Ethiopia. It is also pleasing to note the wide participation, especially by the regions and their valuable recommendations. This document presents the IPM scenario according to target crops and different regions and provides component wise scope for IPM research and management of African bollworm. There is no doubt that the over all workshop recommendation to recognize African Bollworm as a national priority pest will receive positive consideration with policy makers.

I congratulate the organizers, participants and editors for their contribution to provide this useful document for planning further research and implementation of IPM for this important pest in Ethiopia.

Abera Deresa
Deputy Director General
Ethiopian Agricultural research Organization

The African Bollworm, *Helicoverpa armigera* is a highly polyphagous and migrant pest, which occurs as a key pest very widely on a range of smallholder crops in Africa and Asia, besides in Australia and Europe. The ICIPE-led African Bollworm Biocontrol Initiative for Vegetable-based Cropping Systems in Eastern Africa, funded by BMZ (the German Ministry for Technical Cooperation), seeks to combine scientific expertise from within and outside the region, to assist the partner National Agricultural Research Systems (NARs) in sustainable management of this pest. Besides the multidisplinary team of scientists at ICIPE, experts from two German institutions (University of Hohenheim, Stuttgart and Biological Control Research Center (BBA), Darmstadt) are providing a major scientific backup input as lead collaborators. The four national partners are the biocontrol teams of Ethiopia, Kenya, Tanzania and Uganda.

The present phase of this regional network is focused on surveys for collection, characterization and cataloguing of one group of native biocontrol agents (egg parasitoids), besides related baseline studies on adaptation and methodology refinement for field release assessment. This initiative also seeks to establish a gene bank for native egg parasitoids of African bollworm for East Africa.

These proceedings regard the achievements made so far in their initiative presented and discussed the national workshop on African Bollworm Management in Ethiopia, jointly convened by the Ethiopian Agricultural Research Organization (EARO) and the ICIPE-led African Bollworm Biocontrol Project. It is an important reference document for researchers, extensionists and policy makers. Of course, it will also assist in seeking funding for future research on this key pest in Ethiopia, as well as in the region. ICIPE has continued to enjoy very fruitful and close partnership with EARO in all the major mandate themes of ICIPE – Human health, Plant health, Animal health and Environmental health. I congratulate the concerned scientists of EARO and ICIPE for this fruitful joint initiative to promote research, capacity building and information sharing as a means of contribution to efforts to sustainably manage this key pest.

Hans R. Herren
Director General
ICIPE

Initiative for Utilisation of Native Egg Parasitoids in Controling African Bollworm in Eastern Africa

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Abstract

The African bollworm, ***Helicoverpa armigera****, is a major pest of several vegetable crops, especially tomato, besides associated crops like legumes and cotton in Eastern Africa. The present initiative seeks to improve the utilization of native egg parasitoids, especially Trichogrammatids, in augmentative biocontrol of this pest in the region in partnership with the national biocontrol teams of Ethiopia, Kenya, Tanzania and Uganda. Onfarm surveys backed up by onstation multi-crop plots have been undertaken for assembling and characterizing the inter- and intra-species diversity of the native Trichogrammatids among major target crops especially tomatoes, across representative production ecologies. The survey collections are being kept as representative live cultures in regional genebank and are being tested for adaptation to temperature regimes and humidity ranges. Monitoring of* ***H. armigera*** *adults by pheromone traps and assessing the egg numbers on tomato are in progress at benchmark locations. Refinements in field methodology for assessment Trichogramma release impact are being pursued. The potential demand for Trichogramma as biocontrol product has been assessed as positive and potential delivery systems / agents identified in Kenya. It is visualized that the well adapted native Trichogrammatid species/strains would be chosen for the major production ecologies in the partner countries and that pilot scale mass production undertaken so to promote wide-scale awareness and adoption of this promising biocontrol technology in the region.*

Introduction

The African bollworm (ABW), *Helicoverpa armigera* (Hb.), is a key pest on vegetable crops in Africa (Lkin *et al.*, 1993). It is known to cause damage to a wide range of vegetable crops like tomato and capsicum in Eastern Africa. Since chemical pesticide-based, control of this pest is found to be not sustainable and suitable, safer alternatives like biological control options need to be identified and disseminated for use by the multitude of smallholders who depend on growing these target corps of ABW for their likelihoods. The potential for research leading to improved utilization of native egg parasitoids (mainly Trichogrammatids) for biocontrol of ABW in Africa has been well documented (Sithanantham *et al.*, 2001a). Recently, the International Center of Insect Physiology and Ecology (ICIPE) has launched a regional initiative, in partnership with four national programs in the regional, namely Ethiopia, Kenya, Tanzania and Uganda to fill in critical knowledge gaps, towards improved utilization of the native egg parasitoids in augmentative biocontrol of ABW in vegetable-based cropping system in the region (Sithanantham *et al.*, 2001b). This paper presents an overview of this regional initiative.

Objectives and Visualized Outputs

Summary of objectives and outputs	Objectively verifiable indicators
Overall objective: Sustainable horticultural production enhanced.	
Project purpose (long term): Biocontrol of key pests on vegetables in Eastern Africa promoted. Proposed Phase 1 objective: Scientific base for a successful biological control programme using egg parasitoids in the region generated.	Producers use less synthetic pesticides in major urban/export vegetable production in the region. Demand for biocontrol as alternative to pesticide application on target vegetable crops in pilot areas enhanced by 25-33%.
Results/Outputs visualised: The diversity of native egg parasitoid species in vegetable-based cropping systems determined and catalogued.	Surveys of native egg parasitoids occurring in focal sites to represent major ecologies in the partner countries completed by mid of 2002. Species determination by conventional taxonomy techniques completed by end 2002; molecular characterization by mid 2003 and species distribution mapping completed by mid 2003
Egg parasitoid species and strains with desirable biological attributes identified in lead partner country.	Egg parasitoid species, which show favorable biological attributes identified by end 2002. The extent of pesticide tolerance among strains of the most promising species assessed by end 2003.
Egg parasitoid release rates optimized and exploratory field release and impact assessment in one target crop undertaken in lead partner country.	Parasitoid release rate in one target crop optimized by end 2002 Field cage testing to verify the potential of the promising species on the target crop completed by mid 2003 Experimental assessment of parasitoid release impact on priority vegetable crop completed in pilot country by end 2003
4. Local demand quantified, delivery systems identified and pilot production unit for demonstration established in lead partner country.	Local demand and potential delivery systems identified in one lead country by mid 2002. Small-scale pilot production unit for local egg parasitoid supply established by late 2002
5. Assessment of risk to non-target lepidoptera undertaken	Laboratory testing of risk to important non-target lepidoptera completed by end 2002 Field assessment completed by end 2003
6. Regional collaborative network for egg parasitoid utilization established and biocontrol awareness promotion undertaken	NARS partners participate actively and benefit from network activities identified at the initial partner's workshop in early 2001.

Collaboration and Partnerships

NARS Partners

- National Biocontrol Program, KARI, Kenya: Dr. Francis Nang'ayo (till Aug. 2001); Dr. Charles Kariuki and Mr. Samuel Njihia (Sept. 2001 onwards)
- National Biocontrol Program, NARO, Uganda: Dr. James Ogwang
- National Biocontrol Program, MoA, Tanzania: Mr. Victor Mgoo (till September 2002; Mr. Elibariki Ensami (October, 2002 onwards)
- National Biocontrol Program, EARO, Ethiopia: Mr. Mulugeta Negeri (till Nov. 2001); Dr. Dawd Mohammed (Dec. 2001 onwards)

German Partners

- University of Hohenheim, Institute of Phytomedicine, Stuttgart:Prof. Dr. C. P. W. Zebitz and Dr. C.J. Monje
- Institute of Biological Plant Protection, BBA, Darmstadt: Dr. S. A. Hassan

Others

- Dudutech (Biocontrol) Enterprises, Naivasha/Nanyuki, Kenya
- GTZ-IPM Project, Arusha, Tanzania

ICIPE-BMZ EGG PARASITOID COLLABORATIVE PROJECT- collaborating Institutions/ Projects

Kenya: Biocontrol Research unit, KARI, Muguga.
Uganda: Biocontrol Research Unit, NARO, Namulonge
Tanzania: Biocontrol Research Unit, Kibaha
Ethiopia: Plant Protection Research Centre, EARO, Ambo

Understanding the Native Diversity of Egg Parasitoids

Onfarm surveys have been undertaken to assemble and characterize the diversity at family, genus, species and below species levels among mainly Trichogrammatid and to some extent scelionid egg parasitoids, which are naturally parasitising the ABW eggs on tomato crops. The surveys are focused on ecological representation instead of geographical coverage and backed up by GIS characterization of the collection sites. A regional gene bank of egg parasitoids of ABW has been established at ICIPE to keep representative live collections for further research and utilization. It is expected to catalogue all the collections made and establish a repository of reference specimens for future taxonomic support and identification assistance.

Assessing the Adaptation to Climatic Stresses

Representative collections of egg parasitoids from the major ecologies (among low, mid and high altitude sites) are being tested for their relative adaptation to climatic stresses, mainly temperature and relative humidity regimes. Particular attention is paid to identify those adapted to warmer temperature regimes (30-35^{0}c), at which there is some limitation often encountered in the survival and/or activity of the Trichogrammatid egg parasitoids.

Refining the Field Methodologies for Impact Assessment

Onstation benchmark locations have been established for monitoring the ABW adult population of *H. armigera* with pheromone traps. In addition, pesticide-free plots of tomato, capsicum, okra, cotton, pigeonpea and sunflower have been grown for assessing the ABW egg numbers on plant basis (egg load) during the reproductive period of the crops. In addition, field methodology refinements for assessing the impact of field release of the promising native Trichogrammatid are also being undertaken.

Potential Demand and Delivery Scenario Visualized

Through stakeholder participatory workshop held in Kenya the potential demand for mass-produced native *Trichogramma* among the growers of vegetable crops, besides other high value crops, has been assessed to be substantial. The possible delivery systems for such commercially produced *Trichogramma* have also been identified. Research on enhancing the efficiency of the local commercial mass production system for *Trichogramma* is being pursued.

Risk Assessment Methodology Studies

While the use of Trichogrammatid egg parasitoids is known to be ecologically safe, it is recognized important to cater to environmentalist, concerns and so to address ethical considerations for safety to non – target species by refining both laboratory and field methodologies for risk assessment applicable to the developing country scenario (Sithanantham, 2003) are in progress.

Linkages to Farmers' Groups and Private Sector

Since the adopting of ABW biocontrol technology is often linked to farmers' tendency for use of chemical pesticides for ecotnrolling other pests on the target crops, build linkages have been established with 1 – 2 farmers' groups near to major bench mark sites, for empowering them with the awareness on and capacity for utilising *Trichogramma* for ABW biocontrol in their target vegetable crops. To motivate/stimulate interest among the private sector to invest in commercial mass production of *Trichogramma*, promotional linkages are being established. In Kenya, for example, a private company (Dudutech) is linking with the project for technical/training support for *Trichogramma* commercial production.

Capacity Building of National Partners

The project caters to orientation training of the national collaborating scientists from the national biocontrol teams. Research training to through M.Sc. (3) and Ph. D (2) projects is also being funded to build up a cadre of specialized researchers among national chosen from within the subregion. Short training has also been given at technician level for each national team in handling and rearing of the parasitoids.

Vision

It is visualized that in the following phase, the national partners will be able to undertake validation and dissemination activities towards popularizing this biocontrol technology as an IPM component in the vegetable based cropping systems in the partner countries.

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African Bollworm on Vegetable Crops in Ethiopia:
Research Status and Needs

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Abstract

This paper summarizes the African bollworm (ABW) research on vegetable crops with emphasis on tomato and hot pepper. Series of experiments towards developing integrated management of the pest including natural enemies survey, population dynamics and control methods such as varietal, cultural, and insecticidal have been carried out over the years. Some parasitoids are known to occur naturally, but biocontrol efforts are yet to be made. Studies on critical periods for protection from fruit borers, which include ABW and Potato tuber moth - PTM) have shown that early fruiting period was more important for reducing the losses. ABW tends to be potentially more important (than PTM) only under rainfed tomato production. Field-testing of tomato genotypes has shown that 'Serio' was significantly less damaged by fruit borers (includes ABW) and yielded significantly more marketable fruits than the commonly grown varieties – Marglobe and Moneymaker. In hot pepper, decamethrin was found to satisfactorily control ABW, while trap crop of lupin was found to harbor four times the number of ABW eggs and larvae than on the target crop. Future research needs for improved management of H. armgiera on vegetable crops in Ethiopia are discussed.

Introduction

Different types of leafy, root, bulb and fruit vegetables are grown in different agro-climatic regions of the country under rain fed and irrigated conditions. The country has immense potential to develop vegetables in small scale and commercial agriculture. The production may vary from the cultivation of few plants in the backyard for home consumption to large-scale production for the domestic and export markets. The bulk of the vegetables are produced in the central lowland (Awash valley and the lake region) and eastern Ethiopia where the climate, soil conditions, irrigation, infrastructure and market outlets are favorable.

The crops are cheap sources of vitamin, minerals, and protein, good sources of income to small farmers and sources of employment. They are important to Ethiopia, where the people experience malnutrition due to heavy dependence on cereals. They also give higher yield per unit area of land compared to cereals. Products like tomato paste, tomato juice, oleoresin etc. are produced for domestic and export markets. There are several production and technical constraints that limit the expansion of the vegetable sector in the country, which include the pest problems and their management. Key insect pests that damage vegetables in the country include onion thrips (*Thrips tabaci*) on onion, Diamondback moth (*Plutella xylostella*) on cabbage and fruit worms - Potato tuber moth (PTM) and African bollworm (ABW) on tomato.

African bollworm, *Helicoverpa armigera* Hübner, is a polyphagous insect pest ana attacks a large number of vegetable crops cultivated in Ethiopia (Abate, 1986; 1988). Of these, tomato and pepper are the more important targets on which a higher level of damage is often inflicted. Most of the research information on the management of this insect pest on vegetables is limited mainly to tomato and pepper (Abate and Gashawbeza, 1994). Studies, so far done towards developing Integrated Pest Management (IPM) include biological control (natural enemies identification and bio-pesticide use), cultural practices, varietal tolerance and insceticidal control these crops is reviewed. Future research needs are also discussed in this paper.

ABW Management Research on Tomato

The African bollworm (ABW), *Helicoverpa armigera* (Hübner) is among over 23 species of insect pests known to attack tomato in Ethiopia (Abate 1988). It is probably next in importance to the potato tuber moth (PTM), *Phthorimaea operculella* (Zeller), among insect pest species. These two species can cause total loss in susceptible tomato varieties (Gashawbeza and Abate, 1993). Until the early 1980's, ABW was regarded as the only major fruit worm attacking tomato. Experiments carried out on tomato at the Melkassa research center from mid 1980's revealed that PTM was more important than ABW in terms of damage inflicted on the crop. The studies carried out at Melkassa center on tomato fruit worms and reported here have targeted both the pest species.

Yield Loss Estimation

The reported yield loss due to African bollworm on tomato and hot pepper, along with some other target crops is presented in Table 1. It can be seen that loss due to ABW appears to be higher on cotton than vegetables and other crops. Yield loss reported on tomato by Ferede (1988) from experiments conducted to identify effective insecticide for two seasons, 1985/86 – 1986/87, is due to both ABW and PTM; level of fruit damage was 12.81 and 4.52 % (1985/86) and 3.28 and 12.01% (1986/87) for PTM and ABW respectively.

Management Interventions

Survey of natural enemies

Abate (1991) catalogued the natural enemies associated with ABW in Ethiopia (Table 2). Five dipterous and three hymenopterous parasitoids were reported from leguminous crops alone. The lack of adequate information on natural enemies associated with ABW on vegetables and other non-leguminous crops is, because no experiment was done aimed at identifying the associated natural enemies on these crops.

Critical periods of attack

An experiment was carried out for two seasons between 1992/93 and 1994/95 with the objective of identifying the susceptible crop stage of tomato to fruitworm attack. In 1992/93, a factorial RCBD with split plot design was used; applications of cypermethrin and the biopesticide, *Bacillus thuringiensis*, were the main plot treatments and the different growth stages of tomato as subplot treatments. In 1994/95, a randomized complete block design was used with only cypermethrin application. Results of the two experiments are presented in Tables 3 and 4, respectively.

A result of the 1992/93 experiment (Table 3), showed that cypermethrin, with 19.0 ± 2.2% fruit damage and 2.6±0.5 fruit worms per 100 fruits, and was more effective than *B. thuringiensis* (28.6 ± 1.3% damage and 5.8 ± 0.3 fruitworms per 100 fruits). The interaction between main plot and sub plot treatments were non-ignificant. All applications of cypermethrin gave significantly superior control than the untreated check, where as they were not significantly different for *B. thuringiensis* application. Cypermethrin applied once at maturity caused significantly lower ABW infestation than application at early flowering stage. The effect of the pesticide application at crop maturity stage was also seen (by the lower level of damage by number and weight) and insect population in the intensively treated plot compared to the rest of the treatments. The proportion of PTM and ABW damage was 74.5% and 25.5% by number and 78.4 and 22.6% by weight, respectively.

Results of the 1994/95 (Table 4) showed that damage both by fruit number and weight was significantly lower in plots treated with the insecticides than the untreated check. Among plots that received the treatment only once in the growing period, those treated at EFT resulted in lower insect population and fruit damage than those treated at EFL or MAT. The difference in damaged fruits was not significant between EFT and MAT; however, damage in plots treated at EFL was significantly higher than those at EFT or MAT. As in fruit damage, significantly higher insect infestation was recorded in the untreated plot than in the rest of the treatments. However, differences in % damaged fruit among the rest of the treatments were not significant, although it was lower in the intensively treated plot. The relative importance of the two species, PTM and ABW, in the different growth stages of tomato is indicated in Table 5. It can be seen that, overall, PTM with 8.8 and 8.4% damage by number and weight was more important than ABW with 4.2 and 3.9% damaged fruit by number and weight, respectively. However, their importance at the two stages, EFT and MAT, where low population with insecticide application was observed (Table 5), appeared to be different. As can be seen, incidence of PTM in plots treated at MAT was lower than at EFT. On the other hand, ABW incidence was lower in plots treated at EFT than at MAT; with a significant difference in damaged fruit weight. However, lower level of damage by each species was observed in all treated plots than the untreated plots.

It can be concluded that early fruiting stage is the most important crop stage of tomato at which control measure be taken against fruit worms to effectively reduce losses in quality and quantity of the product. The crop maturity stage was found to be the next important stage since lower level of fruit worms incidence with insecticide application was observed than the early flowering stage. This suggests that depending on the importance of these insect species, two applications of this insecticide, once at early flowering and once at fruit maturity is apparently more useful. Although the two species of fruit worms are known to appear almost at the same time in the growth stages of the crop, lower incidence of ABW in plots treated at EFT and PTM at MAT indicates the relative early appearance of ABW compared to PTM in tomato field.

Seasonal pattern of ABW occurrence

Monthly plantings of a local fresh market variety "Marglobe" were made between January 1992 and December 1994 in a 6 m X 6 m plot replicated 2 times at the Melkassa center. Seasonal changes of fruitworms infestation and their damage were measured by counting the proportion of attacked fruits by number and weight. The pooled data over the 3 years period and the weather data are presented in Figs 1-3. Fruit worm infestation remained high in tomato planted between August and November and low in the rest of the months. It was noted that fruitworms incidence was higher in tomato planted in these months, with peak in September planting as observed by highest insect infestation and proportion of damaged fruit weight, although the proportion of damaged fruit by number was slightly higher in the November planted crop. On the other hand, fruitworm population remained low in those planted between January and April than the rest of the months, with the lowest population and damage in March planting. Proportion of PTM and ABW based on their damage both by number and weight in the different planting months is illustrated in Fig 2. Due to likely differences in the biology of two species, insect numbers were not used to assess their relative abundance. PTM larvae were counted by dissecting the damaged fruits, since the larvae feed from inside after boring into, where development continues up until the adult emerges unlike ABW larvae that feed by inserting its front body and leaves the fruit before pupation. As can be seen in Fig 2., the proportion of PTM damaged fruits (both by number and weight) was higher than that for ABW in all the seasons. However, the proportion of ABW damaged fruits was relatively higher in those planted between February and April than the rest of the months. There was relatively low insect infestation in the tomato crops planted in these planting seasons compared to others, other than the peak months, August through November, inspite of slight differences in damaged fruits. This substantiated the view that the relative insect numbers does not help as a measure of the relative importance of the two species. A sharp decline in the insect populations, despite lower difference in damaged fruits indicates a relative increment in the incidence of ABW. Monthly mean weather data for the three years is presented in Fig. 3. It can be generalized from Fig 1 and 3 that fruitworm populations and their damage increased in tomato, when the fruiting time coincided with warmer period of the year (December - April), and about 4 to 5 months are usually required for the plant to fruit from time of planting. On the other hand, from Fig 2 and Fig 3, it is seen that ABW activity or damage appeared to be greater than that of PTM decrease in fruits harvested during the rainy season (June, July and August). It can be generalized from the results that fruitworms appear as principal insect pests when tomato is produced in the drier period using irrigation, with PTM representing the major proportion of damage. ABW can be considered as potential pest in rain-fed tomato production.

Potential for utilizing host plant resistance / tolerance

Tomato germplasm introduced by Horticulture Division of Melkassa centrer for various purposes was evaluated for resistance to fruit worms between 1992 and 1995. 87 genotypes were evaluated in the first season. Fifteen of them were rated as resistant and 2 of them as highly resistant. Further evaluation of the 'highly resistant' genotypes, in the ensuing years both with and without insecticide protection, led to the identification of some resistance sources. Data from Abate and Gashawbeza (1997) (Table 6) shows the genotypes reported as resistance sources to fruit worms. These include 'Pusa Early Dwarf ', 'Pusa Ruby', 'Seedathing' and 'Serio'. The commercial variety 'Marglobe' was found to be susceptible. Serio (now called Melka salsa) was also a high yielder, with marketable yield advantage of nearly 132 % over the commercial variety, 'Marglobe'.

ABW Research on Hot Pepper

Abate (1988) reported 20 insect species attacking hot pepper (*Capsicum annum*) in Ethiopia. Of these, ABW is reported as the most important insect pest (Abate, 1995). Experiments on insecticidal control and use of lupin as a trap crop against ABW were carried our in the early 1980's.

Insecticide Evaluations

An experiment was carried out at Bako research center during 1979/80 and 1980/81. Effective control of the pest was obtained from Decamethrin (Table 7) (Abate and Adhanom, 1982). Yield loss due to ABW as high as 27% was reported from this experiment.

Trap Cropping Evaluations

An investigation was carried out in 1981/82 and 82/83 seasons at Bako research center. Hot pepper was interplanted with lupin in a hectare of land. Five rows (1981/82) and three rows (1982/83) of lupin were planted at 25 meter intervals. Counts on ABW population were made on the row of lupin adjacent hot pepper row (HP 1) and then at 5 (HP 2) and 10 m (HP 3) away from lupin row. Details of results of this experiment can be found in Abate (1985) and Abate (1988). Table 8 extracted from Abate (1985) shows that the trap crop (Lupin) caught more ABW than did hot pepper at each of the distances, HP 1, HP 2, or HP 3. An average of four-fold higher ABW population was observed on the trap crop (lupin) compared to the main crop (Hot pepper).

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African Bollworm: A Key Pest in Pulses Production in Ethiopia

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Abstract

Research efforts made so far in Ethiopia to develop control or management options for African Bollworm in different pulse crops are reviewed. The extent of damage caused by this pest to pulse crops has been variably estimated on chickpea, faba bean, haricot bean, field pea and cowpea. Adult monitoring has shown the seasonal fluctuations and peaks at Debre zeit site. Screening for pest tolerant and good yielding genotypes has been initiated in chickpea. Insecticide evaluations have been done at several centers and there is need to focus on rational pesticide use and resistance management. Some studies have been made on cultural practices, especially planting dates, plant density and trap cropping and this aspect needs to be followed up more holistically. Limited survey of natural enemies has been undertaken. But this should be followed up by efforts to conserve/augment the key biocontrol agents. The future research priorities and needs for strengthening ABW management impact on pulse crops in Ethiopia are discussed.

Introduction

The productivity of pulse crops is often constrained by both biotic and abiotic stresses. Among the biotic stresses, several insect pests including ABW are known to reduce the yields of pulse crops in the field, besides bruchids, which cause losses in quantity and quality of seeds during storage (Table 1). The African Bollworm (ABW), *H. armigera* (Lepidoptera: Noctuidae) is a major field insect pest affecting pulses in several agro-ecological zones. It is also listed among pests, which are medium priority in research on chickpea, field pea and faba bean at national level (Table 2). Besides pulse crops, ABW also affects fibre crops, vegetables, cereals and oil crops in Ethiopia (Tadesse, 1989). This paper attempts to summarize the scattered research results and identify gaps in the management of ABW attacking pulses in Ethiopia.

Yield Losses

Research on the quantification of yield losses due to ABW on chickpea, faba bean, field pea, cowpea, and haricot bean has been conducted at Debre Zeit, Holetta and Melkassa research centers. The data assembled are from designed onstation experiments in the respective research centers and from onfarm surveys. From field surveys, the estimated losses on faba bean have ranged from 3.5 to 57.5% pod damage (average 21%), while on field pea a range in yield loss of 32 to 42% has been recorded (Kemal and Tibebu, 1994).

In Ethiopia, more than 80% pod damage has been recorded in surveys on early sown chickpeas, while another survey in chickpea growing area of the central highlands of Ethiopia showed green pod damage ranging from 21 to 36% (ICRISAT, 1991; Geletu and Million, 1996). In haricot bean, ABW is estimated to cause about 12-16% yield loss compared to bean stem maggot that causes 11 to 100% yield reduction (Tsedeke, 1995a). On cowpea, 10% pod damage was recorded. Yield loss estimates due to ABW on grass pea, pigeon pea and lentil are not yet available in the country.

Monitoring Seasonal Distribution and Abundance

The seasonal activity, abundance and the related damage caused by ABW pulse crops in Ethiopia differ greatly from place to place and year to year (Tibebu, 1983; Tebkew and Mekasha, unpublished). Pheromone and light traps have been used to monitor and forecast peaks of *H. armigera* (ICRISAT, 1982).

Monitoring the seasonal distribution and abundance of ABW in relation to chickpea crop has been carried out at Debre Zeit Agricultural Research Center using light and pheromone traps (Tibebu, 1983). Using light traps, Tibebu (1983) found that the catches of ABW adults was low from January to April and increased apparently with emergence of moths starting from the first week of May reaching the peak in June and July. He also found that higher catches were observed when wind speeds were 1.94m/s and during periods with higher temperature. Monitoring the ABW activities in chickpea fields using pheromone traps was undertaken in 1987/88, 1988/89 and 1991/92 cropping seasons at Debre Zeit (Fig. 1). It was found that in 1987/88 cropping season, peak moth catch was during the first weeks of November, December, January and February, with the catch in December being the highest for the season. Low catches were observed between the second week of February and first week of June. The second peak occurred between mid June and July and then declined up to October. In the 1988/89 cropping season, the catches were very low in November and first week of January but the catch increased dramatically and attained peaks during the third week of December, second week of January and first week of February. Other peaks were observed between the last week of May and mid of June. In the 1991/92 cropping season, the catches increased sharply from the first week of November to the first week of December and declined until mid July. Then the catches increased from the third week of July to mid September. Correlation with weather variables showed that moth catches and rainfall were highly correlated and the first peak was observed after the small rain (belg rain), while the second peak was seen after main rain. In general, the light and pheromone trap studies at Debre Zeit showed that there was high year-to-year fluctuation in seasonality of the pest, while the presence of moths occurred through out the year. Currently, attempts are being made at the Ambo Research Center to monitor the seasonal abundance of *Helicoverpa* in that area. Preliminary studies on the overseasoning of ABW at Debre Zeit have shown that soil types can affect moth emergence (Tibebu and Tessema, 1985). It has been found that light soil delayed ABW adult moth emergence (>100 days), while black soil, which is a major soil where chickpea is predominately grown, permitted the moths to emerge earlier (57 days).

Host Plant Resistance/Tolerance

Entomologists and breeders have screened world germplasm stocks and identified sources of resistance to several of the most important insect pests of grain legumes in regional and international research institutes. For example, chickpea germplasm, which are resistant /tolerant to ABW are recorded and are providing clues for optimism that locally adapted ABW resistant varieties, could be developed for large-scale production. Based on this optimism, screening for resistant/tolerant genotypes from world and local collections has been initiated for chickpea, haricot bean and cowpea in Ethiopia. So far, all the screening is in pesticide-free fields, under natural infestations. Screening of chickpea from local collections and introductions for resistance/tolerance to ABW was done from early eighties until 1991/1992 cropping seasons at Debre Zeit Center, but conclusive results could not obtained, mostly due to low pest infestation levels achieved in the trials. However, Tibebu (1983) reported that some differences were observed among the 18 genotypes screened in the field, based on % pod damage that ranged from 3.3-51%. The one positive information gathered from this screening work was that in general the Kabuli type chickpeas were more susceptible to ABW than the Desi type chickpea (DZARC 1988; 1989; 1990; 1991; 1992). Similar results were obtained at by ICRISAT, when it started multilocation testing of promising ABW resistant chickpea genotypes since 1980. The chickpea varieties (Desi and Kabuli types) so far released from Debre Zeit Research Center do not have substantial levels of resistance to ABW.

In haricot bean and cowpea, resistance screening was done during 1982-84 at Melkassa Research Center and some differences were observed among the test entries (Tsedeke *et al.* 1986). In haricot bean, the entry B-364 was found to be the least infested line.

Use of Insecticides

Synthetic insecticides are used in the control of ABW in different pulses crops in many countries. In Ethiopia, a limited number of insecticides are registered to control ABW on different crops (Table 3). The scope for wide-scale use of insecticides in managing ABW in pluse crops is generally limited because the subsistence pulse farmers do not mostly afford to buy and apply the insecticides. Experiments have been conducted to select effective insecticides to control ABW on chickpea, cowpea, and haricot bean and field pea at Debre Zeit, Holetta and Melkassa research centers. Single application of cypermethrin followed by endosulfan at peak flowering and mid podding of chickpea gave effective control of ABW (Tibebu, 1983). In field pea, single application of cypermethrin was found effective in controlling ABW (Kemal and Tibebu, 1994). Although cypermethrin is found effective in controlling ABW, endosulfan is popular and is being used by a number of farmers as they can afford to buy the insecticide. In haricot bean, based on two season results at Awassa and Melkassa Research Centers, cypermethrin application at flowering or reaching an infestation level of 2-4 eggs/25 plants is recommended for good control of ABW (Tsedeke and Adhanom, 1981).

The use of conventional insecticides for the management of ABW is not being recommended even in major pulse growing countries like India, due to the potential for development of resistance by the pest to several insecticides (Table 4). However, considering that the amount of insecticides currently applied on pulses by small-scale farmers is so meager in Ethiopia, the development of insecticide resistance in the pest population is not of present concern. Nonetheless, with the high insecticide use in cotton, Tessema *et al.* (1980) speculated that there could be already some levels of build up of insecticide resistance in ABW population in cotton growing region, because most insecticide use is currently targeted in controlling cotton pests in state farms, and these populations can disperse to pulse growing areas.

Potential for Cultural Practices

Cultural practices have been shown to reduce the level of damage by several pests in different crops and perceived to be more practicable at small-scale farmers' level. Attempts have been made to develop cultural practices mainly by altering planting dates, plant populations, introducing trap crops, inter cropping and strip cropping, for possible control of ABW damage on few pulse crops in some agro-ecological zones (AEZs). At Debre Zeit research center, the effects of plant populations (17, 25, 33, 50 and 65 plants/m^2) and sowing dates (early August, mid August and early September) were studied during 1988-1992 for the management of ABW on chickpea, but due to low levels of natural pest pressure in the station trials, conclusive results could not be drawn (DZARC 1989; 1990; 1991; 1992). However, the general trend showed that early sown chickpea (mid August) with high plant population sustained relatively higher percentage pod damage than the later sown ones. Even though early sowing resulted in substantial yield advantage, it is recommended with insecticide applications to reduce ABW damage (Geletu *et al.* 1996).

In cowpea and haricot bean, the effects of inter row spacing and plant population was studied for two seasons and non significant differences were observed in reducing pod damage in cowpea, but in haricot bean, wider spacing and low plant population reduced the pod damage caused by ABW. Similarly, in haricot bean, sowing date and plant density studies for two seasons at Melkassa and Awassa research centers showed that ABW damage was high in early sown haricot bean with high plant density (Tsedeke, 1992). It was also noted that the abundance of natural enemies affecting ABW was affected by the sowing date and plant density treatments, but the populations of some species of the natural enemies were found to increase whereas others decreased in the promising treatments. Attempts were made to also evaluate the use of trap crops to reduce the damage of ABW in haricot bean, using maize for two seasons, and it was recommended that growing maize as a strip crop at 10m intervals reduced pod damage by ABW in haricot bean (Tsedeke, 1995a).

Opportunities for Biological Control

Biological control is the utilization of the role of parasites, predators or pathogens that could help to temporarily control or continually regulate pest population at densities below what they would be in the absence of these natural enemies. The potential role of natural enemies in regulating the pest densities has been increasingly focussed since the early 1980s by international research centers working on pulses. In Ethiopia, research efforts towards biological control of ABW and other pests are so far minimal, even though the work has been stared in 1947 (Adane *et al.* 1995). So far, in the country, about 131 predators belonging to 29 families in nine orders and 245 parasitoids belonging to 18 families in three orders have been recorded affecting different crop pests on pulses. Tsedeke (1995a) reported eleven natural enemies attacking ABW in bean and cotton fields in the rift valley of which Trichogrammatid egg parasites and Ichneumonids.

Larval parasites were found to be more important. Tsedeke (1995b) identified other natural enemies like the Tachinids (*Voria ruralis, V. capensis* and *Periscepsia carbonaria)* and the wasp, *Tiphia sjostedti* as affecting ABW in haricot bean fields. Recently, survey work done at Ambo Research Center has shown that Assasin bugs, Tachinids, Ichneumonid wasps (*Charops* sp), spiders and egg parasitoids (*Trichogramma* sp) are found attacking *Helicoverpa* in different crops. The Ichneumonid wasps in Welo area were found to cause 5-10% mortality of ABW in chickpea (Mulugeta Negere personal communication). Additonally, another Ichneumonid species attacking ABW has been found to occur recently in northeast Ethiopia in chickpea fields (Tebkew Damte, personal observation). Some attempt is being made to survey and document natural enemies associated with *Helicoverpa* in eastern Ethiopia.

Limited survey results on entomopathogens attacking insect pests were conducted and pathogenic fungi and viruses were found to be naturally infecting ABW (Adane, *et al.* 1995). Among the pathogenic viruses, nuclrear polyhedrosis virus (NPV) was recovered and isolated from diseased ABW larvae in Ethiopia. Entomopathogens such as Nuclear Polyhedrosis Virus (NPV) have been found to provide good control of larvae of ABW in India and concerted efforts are underway to develop NVP sprays to manage ABW in chickpea fields.

Table 1. Ecozone-wise listing of pulse pests regarded as production constraints in Ethiopia

AEZs*	Target crops	Pests as production constraints
SA2	low land pulses	bruchids
SM1	low land pulses	bruchids
SM1	chickpea, lentil	pod borer*, aphids
SM2	low land pulses	bean stem maggot, flower beetles
SM2	faba bean, fieldpea, chickpea, grasspea and lentil	aphids and pod borer*, bruchids
SM3	faba bean, field pea	aphids
SH1	lowland pulses	bean stem maggot
SH2	low land pulses	bruchids
SH2	faba bean, field pea, chickpea, lentil	aphids, pod borer, bruchids
SH3	faba bean, field pea, chickpea, lentil	bruchids
M1	chickpea	pod borer, bruchids
M2	low land pulses	bruchids
M2	faba bean, field pea	aphids, pod borer and bruchids
M3	faba bean	aphids, pod borer
H2	low land pulses	bruchids
H2	faba bean, field pea, chickpea, lentil	aphids, pod borer
H3	faba bean, field pea	aphids, pod borer

(*: Agroecones grouping by EARO)

Table 2. Priority of some pulse pests as constraints at national level in Ethiopia

Crop	High priority	Medium priority	Low priority
faba bean	-	pod borer*, bruchids	aphids
field pea	aphids, bruchids	pod borer*	-
chickpea	bruchids	pod borer*	cutworm
lentil	aphids, bruchids	-	-
haricot bean	bruchids	-	-
cow pea	bruchids	-	ABW
grasspea	aphids		aphids

(*: Pod borer (mainly ABW))

Table 3. List of insecticides registered for ABW control in Ethiopia

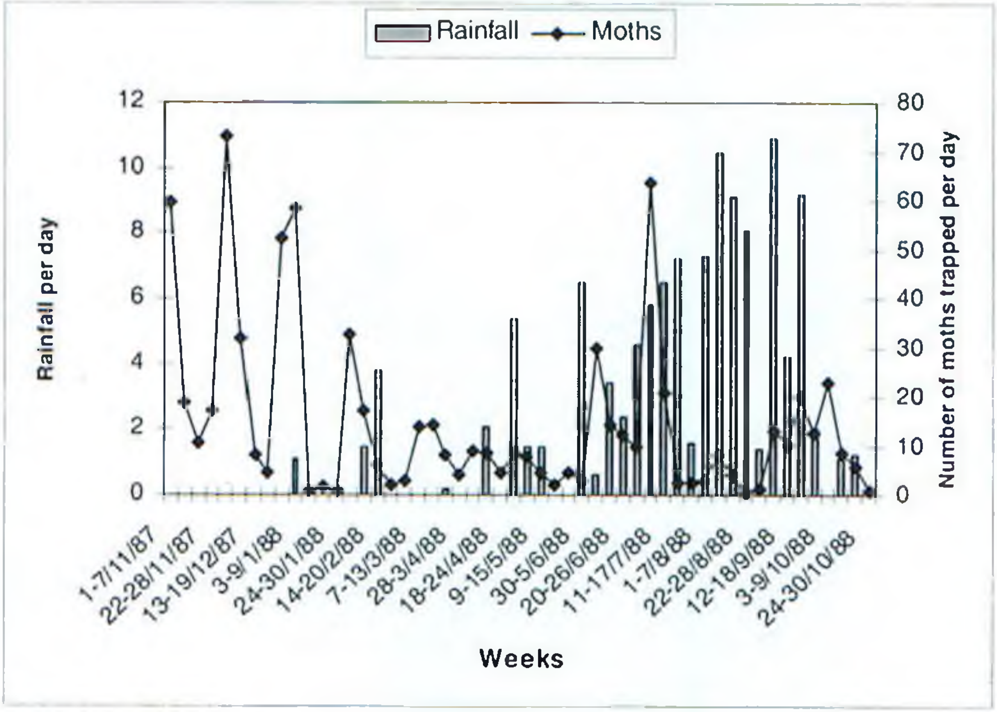
Trade name	Common name
cypermethrin	Cymbush 25%, Ripcord
deltamethrin	Decis 2.5 EC, Decis 0.5 EC/ULV, Decis 0.6ULV
alphacypermet-hrin	Fastac 7.5 g/l ULV, Bestox 7.5 ULV
endosulfan	Thionex 25% EC/ULV, Thionex 35% EC, Thiodan 35% ULV, Thiodan 35% EC

(Source: Abdurahaman, 1997)

Table 4. Known records of insecticide resistance among *H. armigera* populations

Insecticide group	Insecticide	Country
Chlorinated hydrocarbons	DDT	China, Australia, Thailand
BHC/ cyclodienes	endosulfan	India, Australia, Portugal
	endrin	Australia, Thailand
	toxaphene	Australia
Organophosphate	malathion	Portugal
	methyl parathion	China, Australia
Carbamates	carbaryl	China, Australia, Tajik (USSR), Thailand
Synthetic pyrethroids	cyfluthrin	Thailand
	cypermethrin	Thailand, Australia, Indonesia, India
	deltamethrin	Thailand, Australia
	fenvalerate	Thailand, Australia, India
	permethrin	Australia

(Source: FAO, 1992)



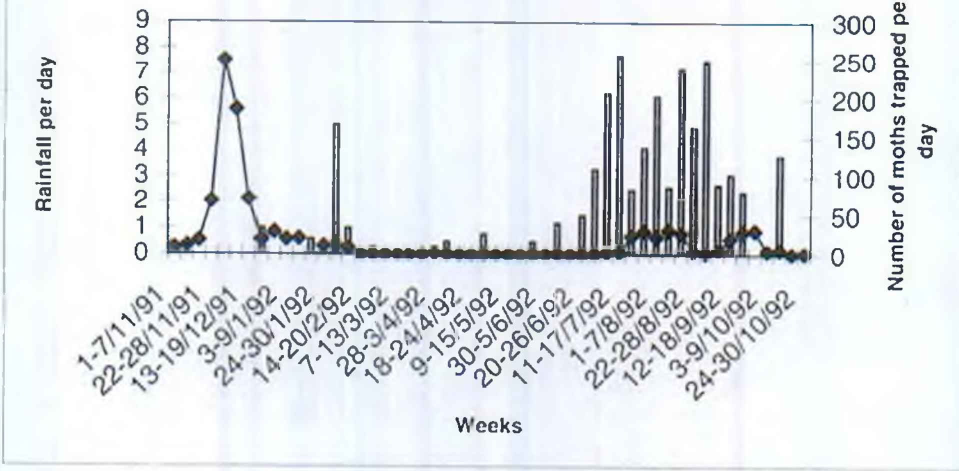
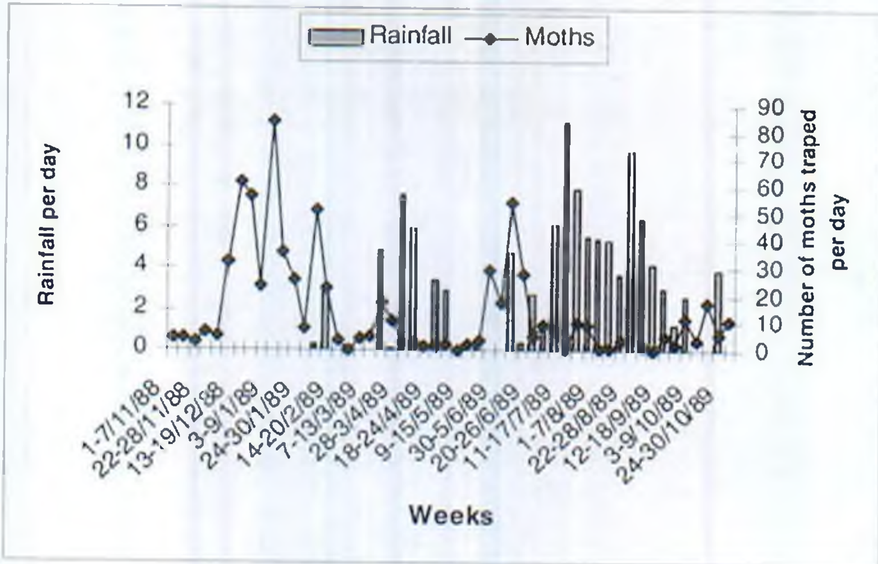
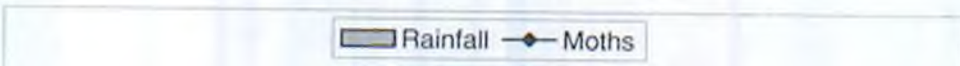


Fig. 1. Seasonal catches of adult *H. armigera* and weekly rainfall pattern at Debrezeit, Ethiopia


Rainfall
Moths
Rainfall per day
Number of moths traped per day
Weeks
1-7/11/88
22-28/11/88
13-19/12/88
3-9/1/89
24-30/1/89
14-20/2/89
7-13/3/89
28-3/4/89
18-24/4/89
9-15/5/89
30-5/6/89
20-26/6/89
11-17/7/89
1-7/8/89
22-28/8/89
12-18/9/89
3-9/10/89
24-30/10/89


Rainfall
Moths

Conclusions

Research efforts made so far in Ethiopia for improved management of ABW in pulses are mostly fragmentary and not yet culminated in a package of control options to be passed on to small-scale farmers. Considering the importance of pulses to the national economy of the country and their role in fulfilling the protein deficiency of the people, the most important research gaps in the management of ABW are highlighted below:

1. While pulses are grown in different AEZs, the economic importance of ABW in different zones and target crops has to be quantified as yield losses using on-station experiments and field surveys. Since production package development is based on AEZs, the information is pertinent to prioritize research efforts.
2. Since ABW is a very difficult pest to control and its distribution, abundance and the damage it inflicts on pulses is largely crop and weather dependent, concerted efforts are needed for monitoring its activity using pheromone traps networks, which requires regional and international collaboration. Tracking ABW population is not only important for developing models for long term pest forecasting but also to monitor and manage resistance in populations from within and from neighboring countries.
3. Development of tolerant cultivars to ABW should be intensified through developing efficient screening techniques, since; open field screenings are not dependable. New techniques of insect resistance screening and mechanism studies, besides resistance breeding also require strong regional and international linkages that will facilitate the training, information and germplasm exchanges.
4. The use of insecticides in the control of ABW may continue as one of the options for some years until alternative options are availed to pulses growers in Ethiopia. In order to promote need-based use, there is need to evolve action thresholds for ABW.
5. Beneficial cultural and cropping practices that could suppress ABW populations and/or augment the natural enemies activity should be identified. There is also need and opportunity for to finding out native natural enemies (insects and pathogens), which could be used for ABW biocontrol in Ethiopia. The outcome of such endeavors will benefit the region and the effort needs regional and international cooperation.
6. Integrated Pest Management (IPM) principles are desirable but are not yet packaged for use in the management of ABW in Ethiopia. Therefore, research efforts towards evolving IPM strategies for this pest should be encouraged.

Appropriate international and in-country collaboration in research, combined with capacity building initiatives should be planned and implemented.

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Survey of African Bollworm, *Helicoverpa armigera* on Chickpea in North Western Amhara Region

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Abstract

*The African Bollworm (**Helicoverpa armigera**) is reported as the major constraint for chickpea productivity. On farm surveys were carried out during 1992-98 and 2000-02 in different districts of ANRS to fill in the knowledge gaps relating to this pest. The survey covered eighteen districts, in five zones of the northwestern part of the ANRS. In each district, farmers' chickpea fields were so chosen to represent the villages. The African bollworm (ABW) was found to occur in all chickpea growing areas within 1600-2700 masl. A maximum of 114 larvae per metersquare was recorded in a chickpea field, but overall was about 37 larvae. While a maximum of 75% pod damage was recorded in a field, the common range was 8-10%. Most farmers were found to be aware of ABW, and the control practices, but they lacked knowledge about its biology. Different bird species and ants (predators), as well as a larval parasitoid, Charops sp (Hymenoptera, Braconidae) was found commonly as the natural enemies of ABW.*

Introduction

In the Amhara National Regional State (ANRS), farmers grow chickpeas as an important protein source food used as Wot, Kollo and Nifero. Moreover, it is preferred as a rotation crop to enrich the nitrogen content of the soil. It covers 121,140 hectares and provides 835,550-quintal production (CSA 2001), i.e., 57% and 47% of the national acreage and production respectively. However, productivity of chickpeas in the region is very low and the most serious and widely reported production constraint is infestation by the African Bollworm (ABW). According to Geletu *et al* (1994), ABW is a major factor contributing to low production of chickpea in the country. Despite the importance of ABW in the region, little research attention has been given to study the distribution, density and the magnitude of crop loss caused by ABW. The Bahir Dar Plant Health Clinic (BDPHC) carried out this survey with the objectives of

- assessing the distribution and larval density of ABW on chickpea
- estimating the pod damage caused by ABW on chickpea
- identifying the local natural enemies of ABW
- understanding the farmers' practices and awareness about ABW

Materials and Methods

Target Area

The surveys were carried out in Northwestern part of the ANRS including North Gondar, Awi, East Gojam, West Gojam and South Gondar administrative zones. In these zones, eighteen districts (worewdas) were surveyed. Among these districts, estimation of both larval density and pod damage assessment was undertaken in twelve districts, while larval density alone was assessed in two districts and pod damage alone estimated in four districts, due to variation in crop stage and average area need.

Duration

The surveys were carried in different areas, according to seasonal resources/needs, from 1992/93 to 1998/99, and during 2000/2001–2001/2002. For each district, a minimum of one year and a maximum of 5 years of survey were done.

Survey Design

Districts and villages (Kebeles) were selected on the basis of chickpea production, variability in the range of altitudes and accessibility. Farmers' chickpea fields were also similarly selected and the size of each plot was determined. In each chickpea field, sampling was done in both diagonal lines, by taking 1 m^2 quadrant sample points at 10 meters (pace) interval.

Sampling Method

In each sample quadrant, the number of ABW larvae, were counted and recorded. Any natural enemies observed were also noted for their occurrence. After these counts and observations, one chickpea plant was randomly taken from each quadrant sample and the damaged and undamaged pods were counted. % pod damage for each field was computed as:

$$\frac{\text{damaged pods} \quad \text{X } 100}{\text{damaged + undamaged pods}}$$

The average number of larvae per m^2 was also computed for each field by dividing total number of larvae by total number of quadrants.
Farmers were also informally interviewed to assess their awareness of the biology of the pest, besides opinions about the control practices.

Materials

Altimeter and quadrant (1m x 1m) were used for measuring altitudes and for larva counting respectively. Meter tape was used to measure and determine intervals between sample quadrants.

Results and Discussion

Occurrence and Larval Infestation Levels

The pest was found in all chickpea growing areas surveyedbetween1600 and 2700 meters above sea level (masl) in Northwestern Amhara National Regional State (ANRS) (Tables 1-3). Based on data from individual farmers' fields and years, the population of ABW larva was found to range from 0 to 114 per Meter Square. The overall over years in each district (woreda), was found to range between 0.63 and 37.3 larvae per m^2 (Tables 1-3).

Pod Damage

Four years of survey in Denbia (1993/94–1998/99), in Alefatakusa (1995/96–1998/99) and in Gondar (1992/93–1998/99) districts (Woredas) of North Gondar zone indicated overall pod damage of 7.8, 6.7 and 7.8% respectively (Table 4). Three years of survey (1993/94–1997/98) in Belessa district (Woreda) in the same zone indicated 11.1% pod damage (Table 4), while one year (1996/97) data of Dabat district (Woreda) in the same zone, and was 1.2% damage. The overall damage in North Gondar zone was therefore estimated as 7.5% (Table 4).

Three years (1993/94 – 1995/96) survey in East Gojam zone indicate 8.4 and 7.4% pod damage in Enemay and Enarji enawga districts (Woredas) respectively (Table 5). One-year (1994/95) survey in Shebelberenta district (E.Gojam) showed 3.5% pod damage (Table 5). Accordingly, in East Gojam, the overall pod damage was estimated about 7.5% (Table 5).

Three years (1992/93 – 1994/95) survey in Yilmana densa district (West Gojam zone) indicated 4.8% pod damage, where as in Jabitehinan district (West Gojam), two years' survey 1993/94 and 1997/98) showed 26.2% pod damage. Further, a one-year survey (1994/95) in Wonberma district of the same zone indicated 8.9% pod damage (Table 6). Therefore the, an over all pod damage of 17.4% was estimated for west Gojam zone (Table 6).

In south Gondar, a one year (2000/2001) survey each in Libokemkem, Ebinat, Fogera and Dera districts indicated 14.7, 3.9, 5.5, and 9.4% pod damage respectively, while the overall damage for this zone was 8.6% (Table 7).

The maximum larval density of $114/m^2$ (Table 3) and maximum pod damage 75.67% (Table 6) were recorded in Jabitehinan district (West Gojam zone) around

Laybir state farm within 1600–1700 masl, while in Dabat district (North Gondar) within 2600–2700 masl there was 1.15% pod damage (Table 4). This indicated that pest density and pod damage tended to increase as the altitude decreased. Weigand and Tahhan (1989) stated that pheromone trap catches were high, probably due to high temperature and low rainfall; i.e. low temperatures and high rainfall resulted in low population densities of pod borer in Syria.

Natural Enemies

Pupae of a larval parasitoid, *Charops* sp, (Hymenoptera, Braconidae) were observed in various fields of chickpea during the survey. Different species of ants and birds were also observed predating larvae of ABW.

Farmers' Awareness and Practices

On crops damage by ABW

Most farmers were aware of the damage caused by ABW and listed the following crops:

- chickpea	- tomato
- field pea	- sun flower
- faba bean	- safflower
- grass pea (vetch)	- black cumin
- haricot bean	- pepper
- linseed	- maize
- niger	- tef
- cotton	- millet
- wheat	- lupins
- sorghum	- barley

On seasonal differences in pest prevalence

Most of the farmers perceived that ABW infestation were usually more severe when small (shower) rains occurred in November. Heavy (strong) rainfall did not seem to favor ABW. Farmers around Lay bir state farm felt that early planting (August) was prone to greater infestation and higher pod damage. This confirms the results from the present survey where the highest incidence (114 larvae per m^2) (Table 3) and maximum (75.6%) pod damage (Table 6) were encountered in the filed which was under early planting. Geletu and Abebe (1982) stated that early planting appeared to enhance the incidence of ABW, while the late-planted chickpea were mostly less affected. Under normal seasonal conditions, the right planting time for most areas is September. Unusual rainfall in September-November may prompt farmers to undertake double cropping, i.e. to sow chickpea after the harvest of tef, barley or maize in October–November. Such late-planted chickpea was usually not attacked by ABW. Some of the farmers also believed that the ABW larvae come down from the atmosphere (through wind and rain) by the order of God!

On economic importance the pest

Farmers ranked ABW as the second most important problem next only to wilt/root rot on chickpea. ABW is regarded as key pest as it occurs in most years on chickpea.

On natural enemies

Farmers considered birds as their 'friends' because several birds were found to help in ABW control by preying on ABW larvae.

On control practices

Some farmers used to collect ABW larvae by hand and dip them in water or cow urine or gasoline inside small containers. In 1990/91 in North Gondar zone, 9% of chickpea fields were controlled by cultural means, whereas in South Gondar, 8.8% were controlled in 1991/92. In 1990/91 EC among the infested chickpea fields in Awi zone, 78% was controlled by cultural practices.

When ABW infestation was severe, the Government supplied insecticides free of charge. The insecticides sprayed in 1986/87 EC in North Gondar included: sevin (carbaryl) 85% wp, trichlorophon 80%wp, cypermethrin 2.5% EC, cypermethrin 5% EC, diazinon 100% ULV and malathion 50% EC.In 1990/91 EC in North Gondar ABW in 47% fields was controlled were chemical means. In 1991 /92 EC among the infested chickpea fields in South Gondar, about 7.6% were treated in the insecticides for ABW control.

Table 1. African bollworm larval density in various districts of North Gondar and South Gondar zones

Districts (Woredas)	Production year	Altitude (ml)	Villages (kebeles) surveyed	Farmers chickpea fields surveyed	Mean area of sampled fields (ha)	ABW larvae per m²		
						Min.	Max	Avg.
Denbia (North Gondar)	1992/93 (1985 EC)	1820-1900	4	5	2.00	3.00	6.00	4.50
	1993/94 (1986 EC)	1820-1965	10	10	3.70	4.00	150	8.30
	1994/95 (1987 EC)	1845-1950	8	10	3.75	3.30	8.30	4.70
	1995/96 (1988 EC)	1820-1940	8	10	3.45	0.00	1.80	0.72
	1998/99 (1991 EC)	-	3	4	1.75	9.30	15.70	12.48
							Mean	6.14
Alefatakusa (North Gondar)	1995/96 (1988 EC)	1800-2030	6	10	2.67	0.00	6.00	2.32
	1997/98 (1990 EC)	1820-1900	2	22	10.95	2.00	150	8.40
	1998/99 (1991 EC)	-	2	8	2.19	10.20	15.80	13.30
							Mean	8.00
Gondar (North Gondar)	1992/93 (1985 EC)	1730-2480	7	8	4.75	1.30	21.00	14.00
	1993/94 (1986 EC)	1875-2000	10	10	2.75	1.00	20.00	6.70
	1994/95 (1987 EC)	1945-2469	9	10	4.55	1.30	9.70	4.96
							Mean	6.55
Belesa (North Gondar)	1993/94 (1986 EC)	1707-1860	4	5	2.1	0.30	16.70	6.50
	1994/95 (1987 EC)	-	4	10	5.25	10.00	32.00	21.60
	1997/98 (1990 EC)	1840-2150	5	22	7.03	9.00	40.00	19.00
							Mean	15.7
Libokemkem (S. Gondar)	1994/95(1987 EC)	1900	5	10	1.87	0.70	7.30	3.79

Table 2. African bollworm larval density in various districts of East Gojam zone

Districts (Woredas)	Production year	Altitude (ml)	Villages (kebeles) surveyed	Farmers' chickpea fields surveyed	Mean area of sampled fields (ha)	ABW larvae per m²		
						Min.	Max.	Average
	1993/94 (1986 EC)	2430-2560	5	5	3.00	2.00	8.00	4.50
	1994/95 (1987 EC)	2320-2440	7	10	2.50	1.00	2.60	1.80
Enemay	1995/96 (1988 EC)	2440-2640	8	10	4.50	0.00	4.3O	0.55
							Mean	2.28
	1993/94 (1986 EC)	2330-2500	5	5	1.35	0.00	4.00	1.60
	1994/95 (1987 EC)	2270-2470	8	10	3.79	0.30	1.00	0.65
Enarjienawga	1995/96 (1988 EC)	2460-2580	6	10	2.60	0.00	1.70	0.49
							Mean	0.71
	1994/95 (1987 EC)	2260-2360	4	10	2.90	0.30	1.60	0.94
Dejen	1995/96 (1988 EC)	2460-2510	5	10	2.08	0.00	3.30	0.52
							Mean	0.63
Shebelberanta	1994/95 (1987 EC)	2317-2360	7	10	2.40	0.30	4.70	1.60

Table 3. African bollworm larval density in various districts of West Gojam and Awi zones

Districts (Woredas)	Production year	Altitude (m)	Villages (kebeles) surveyed	Farmers chickpea fields surveyed	Mean area of surveyed fields (ha)	ABW larvae per m²		
						Min.	Max.	Average
Yilmanadensa (W. Gojam)	1993/94 (1986 EC)	1860-2408	10	12	2.08	2.70	11.50	6.30
	1994/95 (1987 EC)	2225-2256	4	10	2.15	0.30	6.00	2.50
Jabitehinan (W. Gojam)	1993/94 (1986 EC)	1760-1910	4	9	2.50	0.00	4.60	2.10
	1997/98 (1990 EC)	1600-1700	2	7	5.00	81.00	114.00	97.50
	2001/2002 (1994 EC)	1600-1700	1	3	-	8.00	17.60	12.27
Womberma (W. Gojam)	1994/95 (1987 EC)	1890-2010	4	10	5.70	1.00	9.30	3.49
Bahir Dar (W. Gojam)	1998/99 (1991 EC)		1	2	0.20	12.00	31.66	21.83
Guangua (Awi)	2001/2002 (1994 EC)	-	3	3	-	5.60	9.60	8.30

Table 4. Chick pea pod damage in various districts of North Gondar zone

Districts (Woredas)	Production year	Altitude (m)	Villages (kebeles) surveyed	Farmers chickpea fields surveyed	Mean area of surveyed fields (ha)	Pod damage (%)		
						Min.	Max	Average
	1993/94 (1986 EC)	1820-1965	10	10	2.70	0.90	15.40	5.30
	1994/95 (1987 EC)	1845-1950	8	10	3.75	5.20	17.00	10.90
	1995/96 (1988 EC)	1820-1940	8	10	3.45	2.50	10.70	6.30
Denbia	1998/99 (1991 EC)	-	3	4	1.75	8.20	9.30	8.60
	1995/96 (1988 EC)	1800-2030	6	10	2.67	1.80	18.40	8.10
	1996/97 (1989 EC)	1800-1820	4	10	1.75	0.72	20.40	4.10
	1997/98 (1990 EC)	1820-1900	2	22	10.95	1.80	12.60	7.00
Alefatakusa	1998/99 (1991 EC)	-	2	8	2.19	4.30	8.90	6.50
	1992/93 (1985 EC)	1730-2480	7	8	4.75	8.50	38.00	15.70
	1993/94 (1986 EC)	1875-2000	10	10	2.75	1.00	17.80	6.60
	1994/95 (1987 EC)	1945-2469	9	10	4.55	1.50	10.00	5.70
Gondar	1998/99 (1991 EC)	-	3	4	1.25	8.10	20.80	12.40
	1993/94 (1986 EC)	1707-1860	4	5	2.10	4.80	10.00	6.40
	1994/95 (1987 EC)	-	4	10	5.25	7.30	16.50	12.30
Belesa	1997/98 (1990 EC)	1840-2150	5	22	7.03	7.00	43.00	15.00
Dabat	1996/97 (1989 EC)	2600-2700	2	10	1.60	0.00	5.40	1.15
						Mean of N.Gondar		7.51

Table 5. Chick pea pod damage in various districts of East Gojam zone

Districts (Woredas)	Production year	Altitude (m)	Villages (kebeles) surveyed	Farmers chickpea fields surveyed	Mean area of surveyed fields (ha)	Pod damage (%)		
						Min.	Max.	Average
	1993/94 (1986 EC)	2430-2560	5	5	3.00	1.30	6.70	3.60
	1994/95 (1987 EC)	2320-2440	7	10	2.50	1.800	13.70	5.20
Enemay	1995/96 (1988 EC)	2440-2640	8	10	4.50	6.8	24.60	11.00
	1993/94 (1986 EC)	2330-2500	5	5	1.35	1.40	5.90	3.70
	1994/95 (1987 EC)	2270-2470	8	10	3.79	2.80	18.60	7.50
Enarjienawga	1995/96 (1988 EC)	2460-2580	6	10	2.60	3.20	30.00	8.40
	1994/95 (1987 EC)	2260-2360	4	10	2.90	0.20	5.20	2.40
Dejen	1995/96 (1988 EC)	2460-2510	5	10	2.08	3.50	22.40	11.88
Shebelberenta	1994/95 (1987 EC)	2317-2360	7	10	2.40	0.30	6.50	3.50
						Mean of E.Gojam		7.51

Table 6. Chickpea pod damage in various districts of West Gojam zone

Districts (Woredas)	Production year	Altitude (m)	Villages (kebeles) surveyed	Farmers chickpea fields surveyed	Mean area of surveyed fields (ha)	Pod damage (%)		
						Min.	Max.	Average
	1992/93 (1985 EC)	2090-2100	3	3	1.50	6.00	11.00	8.90
	1993/94 (1986 EC)	1860-2408	10	12	2.08	0.60	7.00	4.90
Yilmnadensa	1994/95 (1987 EC)	2225-2256	4	10	2.15	0.30	8.30	4.20
							Mean	4.80
Jabitehunan	1993/94 (1986 EC)	1760-1910	4	9	2.50	0.60	3.80	1.80
	1997/98 (1990 EC)	1600-1700	2	7	5.00	15.70	75.60	27.70
							Mean	26.16
Wonberma	1994/95 (1987 EC)	1890-2010	4	10	5.70	4.00	12.90	8.90
							Mean	8.90
						Mean of W.Gojam		17.43

Table 7. Chickpea pod damage in various districts of South Gondar zone

Districts (woredas)	Production year	Villages (kebeles) surveyed	Farmers chickpea fields surveyed	Mean area Surveyed of fields (ha)	Pod damage (%)		
					Min.	Max	Average
Libokemkem		3	10	2.35	1.99	23.8	14.72
Ebinat		5	10	2.75	1.72	6.94	3.93
Fogera	2000/2001	2	10	3.35	0.38	10.8	5.52
Dera	(1993 EC)	2	10	2.75	1.36	14.3	9.41
						Mean	8.64

Conclusions and Recommendation

The surveys showed that the African bollworm is an economically important pest on chickpea causing an overall pod damage of 8-10% on chickpea. It is distributed throughout the chickpea growing areas (1600-2700 masl) in Northwest Amhara National Regional State (ANRS). It is known to damage various crops grown in the area. Onfarm surveys showed that most farmers were aware of importance of ABW, but also lacked knowledge of its biology. It is perceived that there is also good potential for natural enemies, like predators (ants, birds) and parasitoids (*Charops* sp.) to keep a check on the population of ABW. Since ABW is a polyphagous pest, infestation and damage assessment survey should be carried out on the various economically import crops pm a systematic and continuing basis. Future research should pay attention to conserving the natural enemies like predators and parasitoids that exist in the field as well as to mass rear in some of them for augmentation. To enhance farmers' awareness of improved ABW management options, training programs shall be designed, and the use of biorational. Control methods (Botanicals, *B.t.*, NPV etc) should be included in the research agenda.

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Research on African Bollworm in Chickpea in Western Amhara Region

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Abstract

*Since early 1990s, studies on African Bollworm (ABW) **(Helicoverpa armigera)** management have been carried out for western Amhara region at Adet Research Center. This paper covers ABW management research on chickpea in western Amhara. The aspects include surveys on the distribution and intensity of ABW, insecticidal control and cultural practices such as sowing dates besides plant density and host plant resistance. Insecticides have been shown to control ABW satisfactorily on chickpea. Endosulfan has been more promising, since yields are relatively higher than with the other tested insecticide, cypermethrin. ABW damage has been found to bey reduced by delay in planting time. Chickpea planting in Ethiopia is following the main rainy season on residual moisture and the dates may slightly vary according to location. Planting about the end of September may be recommended for Woreta area. Increasing plant density led to higher % pod damage but the grain yield was also enhanced. In low ABW and adequate soil moisture conditions, a higher seed rate could apparently help enhance chickpea yields. Four chickpea genotypes with low (less than 1%) pod damage were identified namely ICCL-981/83-DZ/2-1, IC-7958/83-DZ/1-1, ICC-788/82-DZ/4 and ICC-84204. The improved variety Marye also recorded low (1.4%) pod damage. The importance of strengthening ABW research in the region is indicated.*

Introduction

The Amhara Region produces, 46% of pulses in Ethiopia (CSA, 1995). The region is first in pulse production and second to Oromya in total crop production. Crop productivity is however, low in the region and insect pests, among other factors, which contribute to such low productivity. Agricultural research in western Amhara is only about 15 years old. Research on insect pests is even more recent and some studies have been done on African bollworm. This paper highlights research activities carried out on this pest at Adet Research Center. The topics covered include insect pest survey, sowing dates, plant density, insecticides and host plant resistance.

Pest surveys

In the 1990s, surveys were carried out to determine the types and status of insect pests on chickpea. African bollworm was found to cause as high as 100% pod damage in some localities of Yilmana Densa and Achefer areas (Melaku *et al.*, 1998). Higher infestations coincided with lower altitudes. ABW was also recorded on barley during the off-season. The relative occurrence of ABW on different crops, based on surveys is given in Table 1.

ABW Management Research

Chickpea is one of the most important food legumes grown in northwestern Ethiopia. This region produces 43% of the country's chickpea production (Geletu and Million, 1996). Apart from its food value, it is grown for crop rotation purposes.

Relatively few field insect pests attack chickpea and ABW is the most damaging pest. It feeds on different parts of the plant including the leaves and flowers though damage that is more apparent is made to the pods. Complete pod damages due to ABW were reported on chichpea in earlier surveys in the area. It is a persistent problem of chickpea in East Gojam bordering Abay gorge. Research attempts to control ABW in Ethiopia are limited. Some research carried out earlier had indicated that early sowing of chickpea favored ABW damage.

Sowing Dates and Insecticides

The presently experiment was designed to determine the efficacy of few insecticides and sowing dates at the northwestern Ethiopia condition. It was carried out at Woreta for two years (1992 to 1993). It was laid out in a split-plot design, replicated 3 times. The variety used was a local one. Sowing dates were assigned to the main plot and the insecticides to the subplots. Sowing dates were September 15, 30, October 15 and 30. Plots consisted of 6 rows spaced 30 cm apart, 10 cm between plants and 4 m long.

Insecticides used were endosulfan at 427 g ai/ha, cypermethrin at 62.5 g/ha. Insecticides were applied when 4 eggs, 2 larvae, or 2 damaged pods were observed in a row. Four rows were inspected to determine infestation level. % ABW damaged pods at harvest and grain yield were recorded.

The insecticides were found to reduce % pod damage due to ABW (Table 2). There was nearly 10-fold more damage on untreated plots than on treated ones. Previous studies had shown that cypermethrin effectively controls ABW on haricot bean (Tsedeke *et al.*, 1986). The effect of sowing dates on pod damage was not consistent. Nevertheless, there was decreasing trend in pod damage as planting was delayed (from September 15 to October 30). Similar results were reported earlier by Geletu and Abebe (1982).

Yield did not differ significantly between planting dates and treatments. In conclusion, early planting has generally been proved to cause higher ABW infestation. However, infestations do not necessarily mean low grain yield. Conclusions should be drawn based on yield data. At Woreta, September 30 planting is advised.

Response in grain yield can only be observed by applying insecticide on highly infested crop. Infestation in the present case was low. Maximum pod damage was 16%. In Debre Zeit, more grain was observed on early-planted crop (Tsedeke *et al.*, 1986). Early planting has been reported appeared to enhance the damage by ABW (*Helicoverpa armigera*); while late-planted chickpeas were less affected by ABW (Geletu and Abebe, 1982). This may be due to favorable climatic factors for the occurrence of the pest. The variety Dubie when sown in August was found to be the most susceptible with 29.3% pod damage (Geletu and Abebe, 1982). The damage was more serious in 1981 crop season than in 1978 or 1980. This could be due to small rainfall received during (December) flowering and pod filling stage, which was probably conducive to the development of the insect.

Occasionally, ABW causes more than 80% pod damage on early sown chickpea. In 1992 season, it caused heavy damage to late-sown chickpea in Alem-Tena; the damage was more severe on Kabuli than on desi chickpea. However, no systematic screening for tolerance for *Helicoverpa* has been undertaken so far (Geletu and Million, 1996).

Effect of plant density

Infestation by ABW has been reported to increase with increasing plant population (Ahmed *et al*, 1990; Kemal and Tibebu, 1994). Some researchers have also recommended high seed rates for newly released chickpea varieties (up to 140 kg/ha). Such high seed rates may aggravate ABW damage; previous researchers thought it would do so (Ahmed *et al.*, 1990; Kemal and Tibebu, 1994. This experiment reported presently was done to determine the interaction between plant population and ABW incidence. This experiment was carried out at Debre Work from 1999/2000 to 20001/2002. It was laid out in a split- plot design replicated 3 times. Spacing between replicates, plots, and rows was 2m, 1.5 m and 0.3 m, respectively. Plot size was 3 m long by 0.3 m row spacing by 5 rows (ie 4.5 m2). Spacing between plants varied according to seed rates or plant population. The main plots were assigned to varieties (namely *Worku* and Local), and subplots to plant densities (seed rates or plant populations): 2.5 cm between plants (or 600 seeds/plot), 7.5 cm between plants (or 200 seeds/plot), 12.5 cm between plants (or 120 seeds/plot), 17.5 cm between plants (or 86 seeds/plot). Number of larvae on a random sample of 5 plants per plot and % pod damage and finally yield data were recorded.

In 1999/2000 season, there was no significant difference among plant densities and varieties in % plant damage, larval count and % pod damage (Table 3). However, on the variety Worku as opposed to the local, there was indication of increasing plant damage and ABW larval count with increasing plant density. The plant densities of 200 seeds/plot and 120 seeds/plot had the lowest % pod damage on Worku; the trend was the opposite in the local variety. Extreme densities of 600 seeds/plot and 86 seeds/plot had the highest infestation in the latter.

In 2000/2001 cropping season, % damaged pods showed a near significant difference among plant densities (p=0.057), not between varieties. Reduction in plant density tended to causereduction in pod damage; i.e. more plant population caused more pod damage. The same case was reported on haricot bean but not on chickpea (Tsedeke *et al.*, 1986). Worku variety seemed to suffer more damage than the local (Table 4). There was no significant yield difference between varieties as well as among plant densities although increasing plant population increased yields ((p>0.05). *Worku* variety seemed to yield higher than the local.

In 2001/2002, infestation was rather low and the pod damage was almost negligible (Table 5). Most of the plots did not show any damage symptom at all. However, one plot showed 7.4% pod damage. The local variety seemed to be more susceptible. Plant densities 200 seeds/plot and 86 seeds/plot seemed to suffer more on both varieties.

Increasing plant density caused increase in pod damage as well as grain yield. This shows that ABW was not adequate in these trials infestation to affect yielding potential. So, in such low ABW conditions, as much seed rate as affordable may help maximize chickpea production.

Screening for Varietal Resistance to ABW

The trial was carried out at Woreta for two years (1993 and 1994). A total of 150 lines in the first year and 78 in the second year obtained from PGRC/E and other sources were planted in non-replicated double rows of 2 m long and 40 cm spacing. Data were recorded on a random sample of 10 plants from each line. This was done at peak flowering and pod filling stages. Data recorded were number of larvae/plant, number of pods/plant (sorted into damaged and healthy).

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Table 1. Status of ABW on different crops in western Amhara State, Ethiopia

Crop	Season
Chickpea*	Off-season
Faba bean**	Main
Field pea**	Main
Grass pea**	Main
Barley**	Off-season
Maize**	Main
Noug**	Main
Linseed**	Main

* major; ** minor

Table 2. Effect of sowing dates and insecticides on ABW infestation and grain yield of chickpea at Woreta, Ethiopia, 1992 to 1993

Sowing dates	Control	Endosulfan	Cypermethrin	Mean
% pod damage				
Sept 15	16.57 (4.01)	1.80 (1.42)	1.0 (1.21)	6.46 (2.21)
Sept 30	8.20 (2.79)	3.00 (1.50)	2.60 (1.30)	4.60 (1.86)
Oct 15	11.73 (3.39)	1.84 (1.30)	3.03 (1.68)	5.53 (2.12)
Oct 30	6.43 (2.58)	0.00 (0.71)	0.0 (0.71)	2.14 (1.33)
Mean	10.73 (3.19)	1.66 (1.23)	1.66 (1.23)	
LSD	-	0.55	NS	
Yield (t/ha)				
Sept 15	2.31	1.58	1.71	1.87
Sept 30	2.60	3.22	2.62	2.80
Oct 15	1.15	2.57	1.73	1.82
Oct 30	3.36	3.03	2.92	3.10
Mean	2.34	2.60	2.25	2.36
LSD	NS	NS	NS	NS

Values in parentheses are square root transformations of original data

Table 3. Effect of plant density and variety on African bollworm (ABW) on chickpea at Agulach and Dijendumit, Debre Work, Ethiopia, in 1999/2000

Character observed	Plant density (no. of seeds/plot)	Agulach		Dijendumit		
		Worku	Local	Worku	Local	
% plants damaged by ABW	600	3.8	2.8			
	200	3.6	2.7	-	-	ns
	120	2.6	3.8			
	86	2.6	3.1			
ABW larval count/10 plants	600	2.8	2.2	1.4	1.5	
	200	2.4	2.1	1.3	1.3	ns
	120	2.9	2.6	1.1	1.7	
	86	1.8	1.8	1.0	1.3	
% pod damage	600	8.0	6.7	3.3	2.3	
	200	5.2	8.2	1.9	1.4	ns
	120	6.8	9.9	1.4	3.2	
	86	9.1	5.3	2.1	2.8	
Yield (kg/ha)	600	2727.0	2493.8	261.7	919.8	
	200	3009.8	2145.6	327.1	341.9	*
	120	1655.5	1751.8	228.3	550.6	
	86	1396.2	929.6	118.5	558.0	

NS: Not statistically significant; * significant

Table 4. Effect of plant density on ABW on chickpea at Debre Work, 2000/2001 (data transformed according to the formula $\sqrt{x+0.5}$)

Plant density (number of seeds/plot)	Number of pods/5 plants				Number of damaged pods/5 plants				% damaged pods/5 plants		Grain yield (kg/ha)	
	Maturity stage		Vegetative stage		Maturity stage		Vegetative stage					
	Worku	Local	Worku	Local	Worku	Local	Worku	Local	Worku	Local	Worku	Local
600	6.10	4.95	1.42	1.42	2.02	1.05	1.27	0.88	3.30	1.69	348.5	327
200	6.63	6.97	1.43	1.43	2.03	1.43	1.39	1.17	3.00	1.84	360.74	239
120	6.84	9.09	1.42	1.42	1.05	0.88	1.10	0.71	1.27	1.16	245.3	241
86	7.79	7.88	1.43	1.42	1.05	1.1	1.05	1.17	1.19	1.42	234.69	170
	NS	NS	NS	NS	NS	NS	NS	NS	*	*	NS	NS

Table 5. Percentage pod damage of chickpea due to African bollworm at Debrework, 2001/2002

Plant density	Worku	Local
600	0.00	0.00
200	0.27	2.45
120	0.00	0.00
86	0.80	0.34

Conclusion

ABW is regarded as a common pest on many target crops in the region. The real hot spot, so far identified, is the whole range of the plain bordering the entire length of Abay gorge. However, this place has been inaccessible and so we could not do our experiments there. The present experiments have indicated that insecticides can effectively reduce ABW damage. Also early planting and increasing plant population tend to increase ABW damage. Some genotypes are relatively less attacked than others by ABW. Further studies on other and related management aspects of ABW on chickpea should be undertaken in hot spots.

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Survey of Beneficial Arthropods on Cotton in the Lower Awash Valley

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Abstract

A pilot survey of beneficial arthropods in cotton ecosystems was carried out in 1987 at the Tendaho State Farm in the Lower Awash region. Farms, which had been subject to continuous application of insecticides for the control of key pests, like whitefly and bollworms were selected for the survey. About 14,508 beneficial arthropods were collected, comprised of species in the orders - Coleoptera, Araneida, Neuroptera, Diptera, Heteroptera and Hymenoptera. Varying population levels of beneficial arthropods were observed in fields treated with different insecticide regimes, indicating differences in selectivity for predators/parasitoids among the chemicals used. The survey provides a preliminary baseline for planning further investigations and possible selection of relatively compatible pesticides for future development of Integrated Pest Management (IPM) system.

Introduction

In Ethiopia, agricultural production is dominated by subsistence farmers who use the traditional practices of growing a mixture of crops, often in patches of plots arranged in mosaic pattern. This farming scenario favors the occurrence of favorable genetic diversity among the natural enemies that can impose a physical restriction on the development of insect pests (Samways, 1981). On the other hand, there are state and private farms, which grow cash-and food-crops at large commercial levels. Such large-scale farms mostly practice monoculture system often repeating similar crops, which tends to favor the development and dominance of a few species of insect pests. This situation often leads to repeated application or complete reliance on the use of pesticides (Tessema *et al.*, 1980). The excessive use of pesticides mostly leads to development of resistance by the target pests, often associated also with fast 'resurgence' or 'flare up' of high population of such resistant generation of the pest due to decimation of the native natural enemies (Tsedeke, 1996).

This scenario has often been observed on cotton producing state farms of the Awash and Rift Valley regions. The pest status of insects in cotton of the state farms has been observed to be changing through seasons. Observations made in the Lower Awash Valley showed that the white fly (*Bemisia tabaci*) and the African bollworm are endemic, but increased to such high infestation levels that could affect the profitability of cotton production in the area towards the end of 1980s. The frequency of insecticides application increased from 3 to 12 in the above-mentioned period (Kumssa and Berhane, 1988). Attempts made to suppress the continuously rising population of these pests to below economic threshold levels have not been so successful. As such, the Lower Awash state farms have come to be known as examples of resurgence of target pests, besides upsurge of secondary pests.

Realizing the negative side effects of the continuous application of broad-spectrum insecticides in the Lower Awash Valley, the entomology section of MSFD started looking for the means of adopting integrated pest management (IPM) system, by promoting judicious application of selective insecticides. Since the major source of the beneficial arthropods is reckoned as the crop farm ecosystem in which the crop is produced, a preliminary survey of beneficial arthropods was undertaken during 1987 in the Lower Awash region.

Materials and Methods

Thorough assessment of the available range of locally occurring beneficial arthropods was made. Attempt was made to compare the number of beneficial arthropods on fields treated with insecticides by taking pre- and post application samples. The samples were from the fields that were treated with Endosulfan 25% ULV, Amitraz 20% ULV, Phosphamidon 250 ULV Primiphos methyl 50% ULV and Dimethoate 40% ULV were compared (Klein, 1987; Berhane and Klein, 1990).

The sampling was mostly through the passing the D-VAC suction device a few centimeters above the top of the crop at four randomly fixed spots per selected field and counting the insects trapped .In addition, leaf samples infested with the pupae of *Bemisia tabaci* were also randomly collected for the observation of parasitoids emerging from the puparia. Sampling was done before and after application of pesticides at fixed interval of time. Identification of most of the collected beneficial arthropods was carried out in Ethiopia, while duplicate samples were sent abroad for export confirmation / authentication as per needs.

Results

The total number of beneficial arthropods collected during the survey was 14058.
The family-wise composition of the beneficial arthropod collected is as follows:-

Coleoptera:	Coccinellidae, Carabidae, Staphlinidae
Diptera:	Syrphidae
Neuroptera:	Chrysopidae.
Hymenoptera:	Aphelinidae (*Encarsia, Eritmocerus*), Trichogrammatidae, Mymaridae, Scelionidae, Braconidae.

The others collected included species from Pteromalidae, Torymidae, Chalcididae, Encrytidae, Eurytomidae, Eulophidae, Elasmidae, Diapridae, Ceraphronidae, Eucoilidae, Agaonidae, Signiphoridae, Ichneumonidae and Bethylidae.

A summary of the numbers of the beneficial arthropods (parasitoids and predators) counted in the pre and post assessment samples are presented in Tables 1 –5.

Table 1: Number of parasitoids and predators per sample of comparing dimecron, rogor and thiodan at Dubti section-1*

Parasitoid or Predator	DBA	Dimecron		Rogor		Thiodan	
		1.5 DAA	5 DAA	1.5 DAA	5 DAA	1.5 DAA	5 DAA
Chrysopa	9	1	11	1	9	3	27
Pred.bugs	17	1	19	1	9	1	12
Spiders	37	14	21	14	9	11	18
Encarsia	298	8	478	3	197	116	1482
Eretmocerus	-	-	-	-	-	-	11
Mymaridae	12	2	19	2	4	1	31
Scelionidae	31	5	14	2	6	4	33
Eulophidae	5	3	2	-	1	-	8
Diapriidae	2	-	-	-	3	-	1
Trichograma	3	1	2	1	2	-	4
Total	411	35	556	24	240	136	1632

*: DBA = Days before application; DAA = Days after application; Dimecron 250 ULV, applied on 12Sept. 1987; Roger 40% ULV, applied on 12Sept. 1987; Thiodan 25% ULV, applied on 21Aug. 1987

Table 2: Number of parasitoids and predators after actellic-ULV sprays-Dubti section-3

Parasitoid or predator	DBA 3	DAA 3
Spiders	8	1
Bugs	29	7
Encarsia	146	16
Scelionidae	4	1
Eretmocerus	10	1
Total	200	29

*DBA= Days Before application; DAA= Days After Application Acetellic 50 ULV applied 30 Sept. 1987

Table 3: Number of parasitoids and predators in fields sprayed with thiodan plus mitac- Dubti – section 5

Predator or Parasitoid	DBA 2	DAA 1	DAA 7	DAA 2
Chrysopa	2	-	1	7
Spiders	24	-	5	17
Predator Bugs	19	-	6	71
Encarsia	441	33	406	29
Mymaridae	12	1	5	9
Trichogramma	2	3	1	-
Diapriidae	5	1	-	7
Scelionidae	9	1	7	1
Total	437	39	431	8

*DBA = Days before application; DAA = Days after application; Treated with Thiodan 25+ Mitac 20 on 19Sept. 1987 and 3Oct. 1987 against ABW + whitefly

Table 4: Number of beneficial arthropods collected on fields treated with thiodan 25% ULV, Dubti farm section-1

Beneficial arthropods	Dates of Sampling							
	10-9-87	14-9-87	17-9-87	20-9-87	26-9-87	28-9-87	3-10-87	Total
Chrysopa	14	3	27	-	12	19	-	75
Pred. Bugs	17	1	12	-	5	10	7	75
Spiders	48	11	18	-	8	13	12	110
Aphelinidae	273	116	1497	159	811	960	902	4718
Mymaridae	9	1	31	8	16	19	11	95
Scelionidae	24	4	33	5	2	2	9	79
Chalcidoidea	13	1	14	2	5	15	8	58
Total	398	137	1632	174	859	1038	949	5187

Table 5. Number of beneficial arthropods collected from fields treated with Phosphamidon 250 ULV, Dubti section – 1

Beneficial arthropods	Dates of sampling							
	10-9-87	14-9-87	17-9-87	20-9-87	26-9-87	28-9-87	3-10-87	Total
Chrysopa	8	1	11	-	1	18	-	39
Predator bugs	23	1	19	-	3	3	6	55
Spiders	49	14	21	-	3	10	10	107
Aphelinidae	467	8	478	48	52	755	597	2405
Mymaridae	19	2	19	1	5	24	10	80
Scelionidae	37	5	14	4	1	1	5	67
Chalcidoidea	16	4	4	5	1	-	1	31
Total	619	35	566	58	66	811	629	2784

Discussion

The survey revealed that appreciable range and varying number of beneficial arthropods exist in the sample areas, which are fields subjected to application of different insecticides. Relatively higher number of beneficial arthropods was found to occur in the sample fields that had received treatment with Endosulfan 25% ULV, compared to the other insecticide treatments.

Spiders are commonly considered as a dominant component of the predators in cotton ecosystems. These arthropods mainly prey on mites, lepidopteran eggs and larvae. On the other hand, ladybird beetles are reckoned as the main predators of aphids. Surveys made by some entomologists have indicated that the most dominant pest of cotton in Ethiopia is the African bollworm (*Helicoverpa armigera*) and this is not adequately suppressed by the beneficial arthropods identified during this survey, possibly due to insecticide interference. According to Tesseme *et al.* (1980), the only significant parasitoid that appears to impact on the population of *H. armigera,* according to the report is the egg parasitoid, *Trichogramma* spp. Predators such as larvae and adults of ladybird beetles and lacewing larvae are also known to effectively suppress ABW larvae (Tsedeke, 1982).

Conclusion

Beneficial arthropods are in general the most important natural control agents that can fit in integrated pest management (IPM) practices. Studies should be made to determine selective compounds, appropriate dosage rates and careful timing of application wherever it is necessary to use chemical control. The survey results suggest further investigations to identify the more selective insecticides for the development of IPM system for the management of cotton pests.

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African Bollworm Management in the Southern Region of Ethiopia

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Abstract

In the Southern Region of Ethiopia, the African bollworm causes significant yield loss to sorghum, besides substantial damage to cotton, chickpea, beans and tomato. Among the potential control methods to be explored are maturity periods and varieties and improving pesticide application methods (for sorghum), besides optimum timing and appropriate/selective pesticide use (for pulses, cotton). The need for further research and training is indicated.

Introduction

The African bollworm (*Helicoverpa armigera*) has been recorded throughout the Southern Nations Nationalities and Peoples' Region (SNNPR) and attacks several crops under wide and diversified agro-ecological zones ranging from 400 masl at Omorate (South Omo zone) to 3600 masl at different localities of the region. In the Southern region, the pest is a serious threat to sorghum, beans, chickpea, cotton and tomato, while only limited damage has been recorded on crops like maize, wheat, flax, sunflower and peanut. Crop damage is caused by the larvae feeding on the buds, fruits, pods and milky or dough stage of seeds. In most cases, the infestation is associated with budding and flowering of the crops.

Infestation and Yield Loss on Sorghum

Yield and production of sorghum is often under pressure due to various factors, which include attack by insect. Despite the use of pesticides, there is still great yield loss due to African bollworm (ABW) attack at milk and dough stages, when the grains fill in the Southern and Western parts of the region (South Omo, Bench Maji and Shaka zones). Wide area coverage of ABW out break occurs every two or three years in these areas.

The ABW infestation and yield loss estimate survey was carried out in Nov- Dec 1998 in Yeki woreda (Shaka zone) Bench and Sheko woredas (Bench Maji zone) on sorghum crop in western parts of the region. In these areas, the African bollworm infested 1101 ha of sorghum crop field. The share of infested area when compared to total sorghum crop in the area is about 17 %. To estimate the intensity of infestation and damage level, 900 plots (an area of 1 m^2 each) were randomly selected from ABW infested fields. On an average, 6 larvae per sorghum plant were counted. The visual crop damage estimation showed an average of 27% yield loss. In general, if pesticide has not been used, the crop loss would have been much higher than this value. In some fields, the pest wiped out the entire crop yield.

Response of Sorghum Cultivars to ABW

The Gambela "Mash" variety and five local cultivars ("Anchiro" compact head) "Bobe" loose head, "Shure" compact head, "Donka" loose head and "Suban" compact head, are being used by the farmers. Among these cultivars different levels of ABW infestation intensity was recorded during 1989 crop season. Heavy infestation was observed on Gamebela Mash, Anchiro, Bobe, Suban and Shuri cultivars, where as only Donka, (loose head red cultivar), which is inferior in food quality, had shown light infestation level. Sorghum fields, which were already mature, had escaped from ABW attack.

Management of ABW on Sorghum

In cases where the pest damage is minor, shaking the plants to induce the larvae to drop from the sorghum head and hand picking was deployed to control the pest. However, during out break seasons, sumathion 50% EC at the rate of 0.5- 1 lt/ha cypermethrin 10 % EC at 2 lt/ha and malathion 50 % EC at 1-2 lt/ha were used to control the pest. Chemical application is often used in Bakogazer woreda (S. Omo zone) Sheko and Bench woredas in Bench maji zone and Yeki woreda from Shaka zone on sorghum crop. Pesticide type preference is ultimately based on the availability of the chemicals in that area. So far, the pesticides used for control in the region against ABW on sorghum in two zones in 1998 are illustrated in Table 1.

Challenges to Control the ABW on Sorghum

- During pest out break seasons, a number of challenges have been experienced in carrying out effective control measures:
- Poor and inadequate field assessment practices to detect pest incidence.
- Unavailability of suitable pesticides.
- Re-infestation usually occurs and re-spraying is required due to lack of effective pesticide and timely operation.
- Inaccessibility and poor spray coverage on tall (about 2-3 m) sorghum plants for effective control.
- Lack of knowledge of effective spray techniques
- Farmer's consider such out breaks as Gods curse against them and no control measures are taken up.
- Expectation of farmers for exemption of loans and tax payment
- Pesticide application performed mostly after heavy damage already had occurred.

ABW Infestation on Pulses

Pulses are grown both in low and high altitude areas of the region. It is important as a nutritive food and cash crop. Beans, peas, chickpea, lentil, cowpea, and pigeon pea are the widely grown pulse crops. While all of them are usually attacked by ABW, chickpea dominantly suffers than the other pulse crops in the region. In Gurage Zone; northern part of the region, out break of African bollworm occurs more often, for which pesticide application is needed to bring the pest under control. The ABW population, however, undergoes considerable fluctuation and so does the intensity of damage to the crop from year to year.

Yield Losses and ABW Management on Pulses

At present, it is becoming quite common to see as much as complete chickpea yield loss on some fields in Goro woreda in Gurage zone. In this woreda, 20-30% of chickpea yield loss is estimated every year due to ABW attack. Nevertheless, on other pulses the yield loss by ABW does not exceed 5 % in many parts of the region.

Cultural practices like ploughing the soil during dry season could help expose to sunlight and natural enemies do have remarkable impact in reducing population build up. Further, if it is low population level and at a very initial infestation period, hand picking the larvae can have some effect. It is usual practice to intercrop beans with many other crops in the region for many reasons. This practice might have contributed very much to reduce the ABW infestation on beans. On chickpea, especially in Goro woreda, pesticide application is deployed every year to control ABW damage. Within the last four years period though, ABW infestation level on chickpea has fluctuated up and down and the damage remain high enough to induce yield loss.

Importance of ABW on Cotton and Vegetables

Tomato and pepper are important vegetable crops attacked by ABW at various levels and grown in different parts of the region at a homestead level in very small scale for home consumption. This homestead production does get little attention, though it suffers from many production constraints including African bollworms. However, quite a large area of pepper (Over 12000 ha) is produced in Gurage, Kaffa, Silte Sidama zones and Alaba special Woreda every year. In these areas, pepper contributes the share of market. The damage level of ABW on tomato and pepper has not yet been estimated and due attention has not been given to its management.

Cotton is another important cash crop only restricted in the belt of the rift valley and at a very limited area in Gibe Omo river basins. State farms and private estates in Gamo Gofa and S. Omo zones produce the greatest share. The contribution of small-scale farmers is important in Gamo Ggofa and Wolaita zones and in the Derashe and Konso special Woredas. African bollworm is a major pest of cotton on state farms and private estates. In those farms, frequent pesticide application has been carried out to control ABW.

Table 1. Farmers' pesticides control against ABW on sorghum in Shaka and Bench Maji zones in 1998

Woreda	Infested area (ha)	Sprayed area (ha)	Pesticide quantity
Yeki	242	564	847 lt
Bench	156	92	184 lt

Table 2. Farmers' pesticide based control of ABW on chickpea in Goro (Gurage Zone)

Year	Infested area (ha)	malathion 50%EC/ sumathion 50% EC (lt)
1998	1020	400
1999	240	90
2000	670	375
2001	280	80

Discussion and Conclusion

African bollworm is becoming potential danger for many crops in the region. The existing indigenous knowledge and cultural practices are not well organized to achieve effective control. The contribution and importance of intercropping beans with other crops and rotation practices are not evaluated adequately in regard to crop protection in general and ABW in particular. Early sown sorghum tends to escape from the infestation of ABW, which shows further studies are is required to assess the role for planting date as a factor to reduce ABW damage.

Natural enemies of ABW have not yet been assessed and recorded. Their role in reducing population build up has not yet been recognized. Poor selection of pesticides and adjustment of application time ultimately bring about ineffective control results. The current pesticide control practices are not economically justified. Above all, inadequate knowledge to identify the pest and lack of field monitoring practices are crucial limitations for carrying out effective control measures. In general, to alleviate any production gap, effective and timely training of development agents and farmers is of paramount important to achieve efficient and sustainable ABW control.

A Review on African Bollworm, *Helicoverpa Armigera*, Resistance to Insecticides

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Abstract

The extensive use of pesticides starting from inorganic insecticides to organochlorides, cyclodienes, organophosphates, carbamates, and synthetic pyrethroids has resulted in the development of resistance to wide spectrum of molecules. By 1962, about 150 species of pest insects were documented as resistance and by 1976; the number went up to 539 insects and 121 other arthropods. In Ethiopia, studies conducted in 1979 at PPRC, Ambo showed that African bollworm populations collected from Ambash and Arbaminch had resistance to DDT, but were susceptible to endosulafan whereas samples taken from Nura Era and Melka Werer were resistant to both DDT and endosulfan. In recent years (2000-2002), reports fromcotton growers in Melka Werer area have indicated that endosulfan (25%ULV, 35% EC) @2.5 and 3 lt/ha and deltamethrin (50% ULV, 25% EC) @ 0.7 and 2.5 lt/ha at frequency of 3 to 4 times failed to control African bollworm, suggesting the need for further research to verify and possibly try to preventively manage resistance in Ethiopia, as it is a pest of major importance in the country. The global scenario of resistance development to pesticides in H. armigera and strategies being evolved to manage resistance is reviewed.

Definition and types of Resistance

The term resistance was defined by the World Health Organization (WHO), as the development of ability in a strain of insects to tolerate doses of toxicants, which would prove lethal to majority of the individuals in a normal population of the same species.

Resistance is of two types: Simple resistance is limited to only one insecticide and not to the related ones (e.g., Malathion resistant house flies are not resistant to the other organo- phosphates) versus cross resistance, where an insect resistant to one insecticide is also resistant to the related ones (e.g. DDT resistant house flies are also to other chlorinated hydrocarbons).

Mechanism of Resistance

The mechanisms of resistance can be broadly classified as physiological and behavioral and genetical (Srivastava, 1996).

Physiological mechanisms/ Detoxification

It is fairly well accepted (though not conclusively proved) that resistance to insecticides is due to the ability of the insects to detoxify (degrade) them by enzymes, the detoxifying enzymes being present in large quantities in R(resistant) strains and absent or present only in minute quantities in S (susceptible)strains of insects. The detoxifying enzymes are synthesized by the microsomes (membranous particles) in the cytoplasm. Endoplasmic reticulum has also been suggested to trap toxins and render them non-toxic, there by inducing resistance. The best-known detoxifying enzymes are dehydrochlorinase, which detoxifies DDT to non-toxic DDE in DDT-resistant houseflies, carboxylesterases, which specifically degrade Malathion in Culex, and oliesterases, which are capable of breaking down many other organophosphates in insects. These non-toxic breakdown products can be excreted or stored in the body without doing any harm to the insect.

Behavioral Mechanisms /Avoidance of Treated Areas

It is observed that R strains (as in houseflies) tend to become sedentary and do not prefer insecticide treated surface for resting. This means that they have an increased discrimination between treated and untreated surfaces. Other examples of avoidance are in the scale in California, which closes its spiracles when the HCN concentration is raised above a certain level and in the arsenic resistant codling moth, which habitually rejects the first bite of the treated leaf, thus rejecting the insecticide.

Genetics of Resistance

It is generally agreed that resistance to insecticides is controlled by heredity (genes) and the transmission of the character for resistance conforms to the Mendelian pattern. Genes governing resistance may be single (monogenic resistance, as DDT resistance in houseflies) or multiple (polygenic resistance, as BHC resistance in houseflies). On exposure to insecticides, these genes are activated to regulate the cytoplasmic organelles to gear up the production.

The Development and Detection of Resistance

Laboratory and glass house selection of resistance with various insecticides is usually defined in terms of statically significant increase in the resistance ratio of selected to the sensitive population. Resistance is a pre adaptive phenomenon. Whenever we continuously apply pesticide, the field population contains both susceptible and resistance population, subsequently, susceptible population will be eliminated and resistance population will remain. Finally, it will lead to a failure of pesticides to control resistant population. Resistance is detected or verified by estimating the ratio between LD_{50} values of the susceptible (reference) strain and the test strain.

$$\text{Resistance ratio} = \frac{LD_{50} \text{ of the test strain}}{LD_{50} \text{ of susceptible strain}}$$

Pesticide Resistance Studies

Studies from other Parts of the World

H. armigera was found resistant to *Bacillus thuringiensis,* carbaryl, endosulfan, endrine, DDT+toxaphene, organophosphate, and synthetic pyrethroids (Mehrotra and Phokela, 2000), Bhatia (1988) on pulses and cotton in many developing countries. Studies by Armes *et al.* (1996) in India, Pakistan and Nepal showed significant levels of resistance of ABW to cypermthrin and fenvalerate. The respective range in resistance levels was 5 to 6500 fold and 16 to 3200 fold. In India, the population of H. armigera on cotton has developed resistance to synthetic pyrethroids and several other insecticides in Andhra Pradesh, Haryana, Tamil Nadu, Karnataka, and Punjab. The resistance to cypermethrin was 164 to 300 fold, to DDT 70 fold, to fenvalerate 79 fold, to carbaryl, monocrotophos, endosulfan, quinalphos and triazophos from 1.67 to 12.5 folds (Anonymous, 1997).

In Egypt, Abdallah *et al.* (1985) reported differences in susceptibility of *H. armigera* populations from four locations to profenfos, chlorpyrifos, endosulfan and mephosfolan. Jaarsveld *et al.* (1998) reported from South Africa that resistance was evident for synthetic pyrethroids tested; while no indication was available against bifenthrin. Studies by Martin *et al.* (2002) among 22 insecticides, both pyrethroids and organophosaphates in Ivory Coast has shown that some of the organophosphates such as isoxathion showed positive cross resistance, while others such as acephate and triazophos showed negative cross resistance to synthetic pyrethroids.

Pesticides Research in Ethiopia

Efforts on pesticide studies in Ethiopia started in the early 1970s. Recommendation on pesticide use has been made by Crowe and Shitaye (1977). Pesticide research in Ethiopia concentrated on conventional synthetic pesticides and it is appalling that even those banned in other countries are still in use or unrestricted and a total amount of 1,349,735 kg/lt have been used by state farms in 1988-92 (Table 1) and cases of resistance have been reported (SPL, 1979,1980).

African bollworm resistance to insecticides

Insecticide resistance of *H. armigera* was studied for three years (1977-79) at Ambo Plant Protection Research Laboratory. In the 1977 study, LC_{50} laid 0.00126-0.00501% and 0.00282-0.00473% for DDT and endosulfan (thiodan), respectively (Table 2). Based on LC_{95}, a diagnostic dose was determined, the application of which had caused 100% larval mortality in all the treatments. The population tested had a little contact with the insecticides and the probability of finding resistant individuals was low. However, in 1978 there were some larvae, which survived after treatment with diagnostic dose from samples of Melka Werer, Ambash, Nura Era and Arbaminch (Table 3).

The reaction of these strains on diagnostic dose of DDT and endosulfan was found to differ. Samples from Ambash and Arbaminch had individuals apparently resistant to DDT but susceptible to endosulfan and samples from Nura Era and one sample from Melka Werer were found to be resistant to both DDT and endosulfan (Table 3).

As shown in Tables 2 and 4, the ratio of LC_{50} of susceptible Ambo strain and LC_{50} of tested strain from cotton was low and did not exceed 3.1 (Ambash). This indicates that in spite of the presence of resistant individuals, the level of resistance is low and so far is not dangerous since the pest can still be controlled with intensive application of chemicals. However, high concentration of chemical application will kill susceptible individuals and select resistant ones, and this tends to bring in a gradual increase of the resistance level. Insecticides registered for use for the management of African bollworm are listed in Table 5.

In recent years (2000-2002), though there have been no detailed studies, reports from Melka Werer area, have revealed that endosulfan (25%ULV, 35% EC) @2.5 and 3 lt/ha and deltamethrin (50% ULV, 25% EC @ 0.7 and 2.5 lt/ha at frequency of 3 to 4 times failed to control African bollworm on cotton. These insecticides have shown a decreasing efficacy through time. Testing of these insecticides for resistance may give some clue about the resistance ratio. Chlorpyriphos, alphamethrin, and lambdacyhalothrin are still effectively managing the pest. But to avoid the evolution of resistance among *H. armigera* in Ethiopia, preventive strategies should be identified, besides promoting IPM, which should be supported with the development of botanical insecticides, biological control, cultural practices and other IPM techniques.

Table 1. Pesticide usage (Kg or Lt) by the state farms in Ethiopia, (average for 1988-1992)

Crop	Pesticide group				
	I	H	F	R	Total
Cotton	842,942	5,478	7,902	272	856,594
Cereals	47,395	28,5772	45,128	9,772	388,067
Citrus	28,245	6,848	12,402	0	47,493
Vegetables	16,500	0	28,445	12	44,957
Mustard	3,800	3,648	0	0	7,448
Tobacco	2,950	0	0	0	2,956
Pulses	0	1,860	0	0	1,860
Grapes	0	0	360	0	360
Total	941,838	303,604	94,237	10,056	1,349,735
%	69.8	22.5	7.0	0.7	100.0

I=Insecticide, H=Herbicide F=Fungicide, R=Rodenticide

***Source:** Gordon et al. (1995)*

Table 2. Results of determination of LC_{50} and LC_{95} DDT and Thiodan for the larvae of *H.armigera*. Ambo, 1977

Collection area /crop/ date	Insecticide	LC_{50} ±S $LC_{50\%}$ a.i	LC_{95} % a.i
Ambo/pea/12-8-77	Thiodan	0.00376±0.00082	0.01060
Ambo /pea/29-9-77	Thiodan DDT	0.00316±0.00074 0.00501±0.00182	0.0150 0.03980
Ambo /light trap/27-07-77	Thiodan DDT	0.00282± 0.00065 0.00126±0.00019	0.01190 0.003160
Bako/pigeon pea/3-8-77	Thiodan DDT	0.00282 ± 0.00065 0.00376 ± 0.00064	0.01190 0.01410
Bako/pigeon pea/15-7-77	Thiodan DDT	0.00473±0.00139 0.00376±0.00118	0.0224 0.0237
Awassa/maize/23-8-77	Thiodan DDT	0.00421±0.00098 0.00335±0.00094	0.0178 0.0126

Table 3. Mortality of ABW larvae treated with a "diagnostic dose" of DDT and Thiodan.

Collection place/date	Compound	Number of larvae under treatment	Number of dead larvae	Mortality %
Amibara 23-08-78	DDT Thiodan	120 120	120 120	100 100
Abadir 24-08-77	DDT Thiodan	300 250	300 250	100 100
Melka Werer 19-09-78	DDT Thiodan	420 210	409 210	97.4 100
Ambash 19-07-78	DDT Thiodan	220 200	202 200	91.8 100
Arba-Minch 28-09-78	DDT Thiodan	250 150	245 150	98 100
Melka Werer 24-10-78	DDT Thiodan	170 180	163 178	95.8 98.8
Nura Era 25-10-78	DDT Thiodan	210 190	201 187	95.7 98.4
Ambo 5-10-78	DDT Thiodan	100 100	100 100	100 100

Table 4. L_{50} values of DDT for ABW Larvae.

Collection place	Date	Lc_{50} +/- SLc_{50} (%a.i)
Ambo	19-10-78	0.00376 +/- 0.00087
Melka Werer	19-9-78	0.00933 +/- 0.0037
Ambash	19-09-78	0.0119 +/- 0.00358
Nura Era	24-10-78	0.0078 +/- 0.00200

Table 5. List of registered insecticides for the management of *H. armigera* in Ethiopia

Trade name	Common name	Approved uses
Bestox7.5ULV	alphacypermethrin	for the control of African bollworm on cotton
Cymbush 25%EC	cypermethrin	for the control of cotton pests on large scale farms
Decis 0.5 EC/ULV	deltamethrin	for the control of African bollworm and leaf hoppers on cotton
Decis 0.6 EC/ULV	deltamethrin	for the control of African bollworm and leaf hoppers on cotton
Decis 2.5 EC	deltamethrin	for the control of African bollworm and leaf hoppers on cotton
Fastac 7.5g/l ULV	alphacypermethrin	for the control of African bollworm 0n cotton
Karate 0.8ULV	lambdacyhalothrin	for the control of cotton pests on large scale farms
Karate 5 EC	lambdacyhalothrin	for the control of cotton pests on large scale farms
Ripcord 5% ULV	cypermethrin	for the control of African bollworm, leaf worm and thrips on cotton
Thiodan 25%ULV	endosulfsan	for the control of African bollworm on cotton, maize and sorghum
Thiodan 35%	endosulfsan	for the control of African bollworm on cotton, maize and sorghum
Thionex 25 %EC/ULV	endosulfsan	for the control of African bollworm on cotton, maize, sorghum and tobacco
Thionex 25 %ULV	endosulfsan	for the control of African bollworm on cotton, maize and sorghum
Thionex 35 %EC	endosulfsan	for the control of African bollworm on cotton, maize, sorghum and tobacco
Ethiosulfan	endosulfsan	for the control of African bollworm on cotton,

***Source:** MOA, Crop Protection and Regulatory Department, 2000*

Minimizing the Problem of Insecticide Resistance

Insecticide Resistance Management (IRM) Strategies

The strategies for preventive and responsive management of resistance to pesticides may include the following:

- Avoiding the repetitive use of the same molecule (pesticide) and alternating with others, which can give comparable extent of control
- Evolving within- season strategies, so to initially use softer (greener) pesticides and to limit the hard (resistance provoking) candidates to mid/late part of the season.

Integrated Pest management (IPM)

Cultural practices, biological control practices, pheromones, selective insecticides can help in minimizing the effect of insect resistance to insecticides.

Cultural practices

- Clean cultivation: Destruction of crop residues, weeds and trashes can help to avoid the multiplication of *H. armigera*
- Crop rotation and ploughing: Continuous cultivation of cotton over large areas has contributed to the outbreak of *H. armigera*. Most state farms are the victims of this problem. Ploughing helps to expose the diapausing pupae, a major source of resistance, to sun heat and natural enemies will help to reduce the coming generation
- Trap/companion cropping: Beneficial crops, which are known to be more attractive for *Helicoverpa* oviposition (eg. African marigold, pigeonpea) could be tried for being planted as beneficial companion crop to divert the egg laying form the target crop (eg. cotton, tomato).

Biological control

Parasitoids, bacteria and virus have contributed to minimize the population of *H. armigera*.

- Parasitoids: The release of *Trichogramma* at the rate of 100,000-150,000/ha 6 times at weekly interval minimizes the population of the insect pest
- Bacteria: *Bacillus thuringiensis* Berliner products sprayed at weekly intervals will help to reduce the population of *H. armigera*.
- Virus: NPV (Nuclear Polyhedrosis Virus) @250 larval equivalent /ha also helps to reduce the population of the insect pest

Pheromone trap monitoring

Pheromone traps can be used to detect both the presence as well as the relative numbers of adult stage of the pest species. The trap catches may be used to forward alert regarding the impending peaks in oviposition of *H. armigera*.

Policy Support

National policies to promote IPM require close regulation at all stages related to importating, manufactuing, distributing, using and disposing pesticides. In the case of pesticides, which do not meet prescribed standards for safety, persistence, etc., import and manufacturing bans should be imposed. At a minimum, the conditions laid by FAO Code of conduct on the regulation, distributionand use of pesticides should be adopted. Pesticide subsidies need to be eliminated in order to make IPM an attractive alternative. The funds so saved may be utilized for the implementation of IPM.

Farmers' participation

Farmers' participation is a major component of IPM implementation. A number of terms have been proposed for the new approach, which involves farmers to analyze their own situation. These include "Farmer –first and- last", "Farmer participatory research", "Farmer first", "Participatory technology development (PTD)" (Chamber *et al.*, 1991). All these seek to bring the farmer closer to the extensionist than the usual approach. Farmers' participatory approach is not well utilized in Ethiopia and needs to be practised properly to promote IPM in the country and so help avoid insecticide resistance, resurgence and residue problems.

Collaboration

Improved institutional relationship plays a major role to improve crop protection technologies in Ethiopia. Coordination of efforts within and between countries, between national research institutes, training and implementation institutes/programmes, and amongst international development agencies is crucial to promote IPM and minimize the use of insecticides.

Human Reseouces Development

Field pest observers, extension workers and farmers should be trained to promote insect pest management.

The training approach should be "experimental discovery learning" process, whereby the trainees are being exposed to the existing field situation. They are expected to practise how to manage pests, how to observe and distinguish between pests, and natural enemies, how they interact. Action threshold levels are basis for the application of judicious use of pesticides as well as for understanding the action of pesticides and its environmental consequences. Ethiopian Agricultural Research Organization (EARO), leading national universities, Ministry of Agriculture and international organizations, should prepare suitable training modules.

Farmer training can be done through IPM farmer field schools. This may be done by forming a group consisting of neighbour farmers, who could meet periodically for both learning as well as discussing the IPM related topics.

Legislative Control

Legislative action is imperative to stop the accidental entry, from outside the country, of certain pests, which may not be present in that country. Discipline must be enforced among citizens not to bring in certain prohibited material, which they might attempt because of ignorance of the danger involved or because of sheer temptation. Thus legislation is of four kinds:

1. Legislation for foreign quarantine to prevent the introduction of new pests from abroad.
2. Legislation for domestic quarantine to prevent the spread of established pests with in the country or with in the particular state.
3. Legislation for notified campaigns of control against pests.
4. Legislation to prevent the adulteration and mishandling of insecticides or other devices used for control of pests.

Legislations listed in number 2 and 3 are not operating in Ethiopia and needs a concern of the international and national organizations to push it forward for the attention of the government.

Research, Training and Policy Needs

With a view to minimize the destruction of natural enemies, studies should be undertaken for rational use of pesticides. This helps to control resurgence, while ensuring that the same pesticide is not repeatedly used within the season to minimise resistance development. National capacity for pesticide resistance monitoring and preventive management must be enhanced. Insecticide Resistance Management (IRM) should become a concurrent activity to promption of IPM for *H. armigera.*

Such needs can be fulfilled with the extended assistance of the government and other funding agencies. The assistance could strengthen the efforts of creating laboratories that will facilitate the promotion, monitoring, supervising and controlling of pesticide resistance. Then it will be possible to implement integrated pest management strategy and reduce resistance, resurgence, residue and environmental pollution that end to be often caused by indiscriminate use of synthetic pesticides.

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Biological Control of African Bollworm, *Helicoverpa armigera:*
Potential in Ethiopia in Context of Global Scenario

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Abstract
The African bollworm, **Helicoverpa armigera,** *is a key pest of several crops of income focus in Ethiopia. Presently the farmers find it difficult to satisfactorily control this pest with the conventional approach of using synthetic pesticides. In the last few decades, considerable progress has been made elsewhere in biocontrol of Helicoverpa/Heliothis, which can provide the background for evolving suitable plans for biocontrol promotion in Ethiopia. Till recently, the efforts made in the country are largely limited to recording the natural enemies. In Ethiopia, some predators of H. armigera, common are assissin bugs, and some spiders. The common parasitoid groups recorded on ABW on cotton in cotton growing areas include Trichogramma spp., Charapos spp. and Telenomus spp. Only recently, there have been efforts to systematically collect and identify native egg parasitoids of African bollworm, as part of a four-country initiative led by ICIPE. The bacterial pathogen B.t. has shown scope for effective control of first and second instar larvae. In Ethiopia, there is a great potential on the use of biological agents for the control of Lepidopteran insect pests including the ABW. The future should focus on building local capacity for assembling and conserving the native species/strains in a national gene bank. North–south cooperation in biosystematics and systems of enhancing the field performance of the native biocontrol agents should be considered. South-south collaboration in mass production to suit the local situation and local delivery systems should also be pursued. Capacity building of national researchers and middle level trainers as well establishment of pilot production units for demonstration and training activities need to be considered. Participation in collaborative network for African bollworm biocontrol in should be further strengthened. Linkages with IARCs like ICIPE, ICRISAT, and ICARDA which have expertise and experience in H. armigera biocontrol should be kept up so as to sustain the scientific underpinning and training back-up, in the short and medium term. Collaboration should also be built with advanced research institutions both within and outside Africa.*

Background

The old world bollworm, *Helicoverpa armigera* (Hübner), has been reported to occur almost globally except in the Nearctic and Neotropical regions (Knutson and Nagarkatti, 1989). The need for international collaborative research on biological control of *Heliothis /Helicoverpa* was well documented by Jackson *et al.* (1989), in an overview paper of the proceedings of an international "Workshop on Biological Control of *Heliothis*: Increasing the Effectiveness of Natural Enemies" (King and Jackson, 1989). This workshop covered the available information on both the old world and new world species of *Helicoverpa*.

Biological Control Strategies

Biological control offers an array of strategies by which the natural enemies of the target pests could be utilized for suppression of the pest populations. These may be categorized into three groups as below:

- Classical biological control which involves introduction of exotic natural enemies to control pests introduced into new regions
- Augmentation biocontrol which is based on enhancing the numbers of the natural enemies, largely by mass production and release/deployment and
- Conservation biocontrol, which deals with systems that minimize the disruption, as well as promote the *in situ* survival and abundance of native natural enemies.

Classical Biocontrol

This is focused on introduction of exotic natural enemies with the aim of promoting their self-establishment as an area-based strategy. Depending upon the origins of the pest and the natural enemies, suitable terminologies may be employed. The successful Africa-wide Program for Biological Control of the Cassava Mealy Bug, led by IITA (International Institute of Tropical Agriculture) during the 1980s and 1990s was based on introducing exotic parasitoids to suppress this pest introduced from South America. Recently, ICIPE has successfully implemented the introduction of the braconid larval parasitoid, *Cotesia flavipes* from Pakistan (Asia), for biological control of cereal stem borers on maize in Eastern and Southern Africa (Omwega *et al.*, 1995; Overholt, 1998). Where justified, there are also possibilities to consider introduction of exotic parasitoids against indigenous pests, as means of filling in gaps in the spectrum of locally available natural enemies.

Augmentation Biocontrol

This system involves the mass production of natural enemies and releasing/deploying them for enhancing the biocontrol impact on the target pest. This approach includes both 'inoculation' and 'inundation' strategies. The agents that are utilized for this approach include parasitoids, predators and pathogens (bacteria, protozoa, fungi and viruses). The biological control agents so deployed could be either indigenous or exotic. The potential for augmentative biocontrol of caterpillar pests and termites in Africa appears promising (Sithanantham and Maniania, 2001; Sithanantham *et al.*, 2001a, b; Maniania *et al.*, 2001). *Trichogramma* spp. and Chrysopids are among the candidates for augmentative-release programmes. Successful examples include the inundative releases of *T. chilonis* on cotton in India, combined with the release of the predator *B. scelestes*, which suppressed *H. armigera* as successfully as insecticides, with a similar cost-benefit ratio (Dhandapani *et al.*, 1992; Romeis & Shanower, 1996; Kaushik & Arora, 1998).

Conservation Biocontrol

This approach has received relatively little attention so far in developing countries, apparently due to limited appreciation of the role of native parasitoids and predators in suppressing the pest build up *in situ* at farm level. Nevertheless, conservation biocontrol methods offer a great potential for sustainable pest control (Gurr *et al.*, 1998; Landis *et al.*, 2000). Hedge plants in farm boundaries could serve as refugia and so assist in supporting parasitoids and predators in off-season. Planting of flowering plants in and around fields to provide nectar/pollen for enhancing the survival/performance of some of the beneficial taxa should also receive attention. These are largely low cost options and can contribute as inexpensive components of agro-ecosystem biodiversity conservation as well as natural biocontrol. By adopting this method, the indigenous natural enemies could also be conserved (Ballal, 1998). Studies on role of refugia as a component of *in situ* conservation have been undertaken recently in India (Yadav, 2001). Some promising results have been reported when artificial food sprays were applied to enhance natural enemy abundance/efficacy (Mensah, 1997). Indirect contribution to conservation could be achieved by adjusting the crop production and protection practices so especially by rational and selective use of pesticides to minimise the interference to the survival and activity of natural enemies that abound the farming ecosystem.

Records of Natural Enemies Recorded

Extensive lists of beneficial insects attacking the different life-stages of *H. armigera* have been published for India (Manjunath *et al.*, 1989; Romeis & Shanower, 1996; Sharma, 2001; Lingappa *et al.*, 2001), Pakistan (Mohyuddin, 1989), South East Asia (Napompeth, 1989), China (ShiJun and Yanquin, 1989), Australia (Zalucki *et al.*, 1986; Twine, 1989), Egypt (Ibrahim and Fayad, 1989), Eastern and Southern Africa (Greathead and Girling, 1989; Nyambo, 1990; Van den Berg *et al.*, 1988, 1993a) and Western Europe (Meierrose *et al.*, 1989). An indicative list of families among predators and parasitoids reported in India is provided in Table 1.

Recent studies in India on the population dynamics of *H. armigera* have evaluated the role of natural enemies under sprayed and unsprayed situations in two cropping systems, sunflower and pigeon pea (Ballal, 1998). Several potential natural enemies are found present in the sunflower system, which should be considered for utilisation (Singh and Ballal, 1999). *Trichogramma chilonis* along with ants, spiders and anthocorids (*Orius maxidentex)* have been found to be among the most important indigenous natural enemies of *H. armigera* in this system (Ballal and Singh, 2000). The ant, *Componotus sericus* and *H. armigera* NPV are also reckoned as important natural bio-agent of *H. armigera* in the pigeonpea crop (Ballal, 1998).

In Egypt, *Microplitis rufiventris* was found to be the most frequent among the different indigenous parasitoids in cotton fields. However, low levels of parasitism were recorded, indicating that the parasitoid complex played a limited role in controlling *Helicoverpa* spp. (Ibrahim and Fayad, 1989), which could be due to the widespread application of pesticides, particularly during the cotton growing season and consequent low population of *Helicoverpa* spp. *Cotesia* (*Apanteles*) sp., C. *ruficrus, M. ruficventris, Chelonus inanitus, Copidosoma sp., Bracon brevicornis, Barylypa amabilis, B. rufa, Peribaeba orbata* and *Exorista larvarum* were also frequently recovered from *H. armigera* (Ibrahim and Fayad, 1989).

The Tachnid, *Pluxorista laxa*, is an important parasitoid of *H. armigera* in Sudan on cotton and beans (Pearson, 1958; Lazarevie, 1971). The common parasitoids reared from *H. armigera* were *Euplectrus laphygmae, P. laxa, Exorista sp., E. xanthaspis, Pseudoginia rufifrons* (=*Isomera cinerascens*), *Palexorista* (=Sturmia) *inconspicua, Invreia* (=*Hyperchalcidia*) *soudanensis, Chelonus pilosulus, C. versatilis, Disophrys* sp., *Meteorus laphygmarum, Elasmus johnstoni, Goniophthalmus halli, Pediobius furvus, Cadiochiles* sp., and *Bracon kirkpatricki* (Wilkinson, 1932; Nixon, 1943; Pearson, 1958; Lazarevic, 1971). Parasitoids of ABW recorded in Sudan by Balla (1970) and Pearson and Darling (1958) are given below:

Family Tachinidae: *Hypeuchalcidia soudanensis* Skeff; *Drino imberbis* Weid. *Exorista fallax* Meig; *Goniophinalmus halli* Mesnil; *Isomera cinerascens* Rodani; *Sturmia inconspicua* Meig
Family Braconidae: *Cardiochiles sp.; Microbracon kirkpatricki* Wilk
Family Eulophidae: *Euplectrus laphygmae* Ferr

In South Africa, egg parasitism by *Telenomus ullyetti* and *Trichogrammatoidea lutea* varied between 5.9% and 34% while larval parasitism on cotton varied from 0.5% and 27% (Greathead and Girling, 1989). The low parasitism rate was considered to be possibly due to intensive pesticide application (Reed, 1965b). Rate of insect parasitism was found to be higher on corn and weeds than on cotton (Reed, 1965b; Nyambo, 1984). High egg parasitism had little effect on larval population (Parsons, 1940a).

In southern and eastern Africa, the number of species recorded as regularly attacking *H.* armigera is perhaps only a small proportion of the total (Greathead and Girling, 1982). The important parasitoids of *H. armigera* on cotton were *Bracon brevicornis, Trichogrammatoidea lutea, Platytelenomus busseolae, Telenomus ullyetti, Linnaemyia longirostris, Palexorista laxa* and *Palexorista* sp. nr. *inconspicua* (Parsons, 1940a; Pearson, 1958; Cuthbertson and Munro, 1941). *Apanteles maculitarsis* and *Cardiochiles nigricollis* are abundant on various crops and *Chelonus curvimaculatus* is common on corn (Parsons, 1940a). Out of 39 parasitoids recorded, 13 were of infrequent occurrence and caused 5% of the total parasitism (Taylor, 1932; Curran, 1934; Parsons and Ullyett, 1934; Parsons, 1940a, b; Cuthbertson and Munro, 1941; Pearsons, 1958; Prinsloo, 1984; Greathead and Girling 1982, 1989).

In Botswana, two species of *Trichogramma, Telenomus* sp., *Chelonus versatilis, P. laxa, Nemoraea capensis* and *Goniophthalmus halli* were recorded on *H. armigera* (Room, 1979). *Dejeania bombylans, Gonia* sp. and *Strmia* sp. are very important parasitoids of *H. armigera* in Zimbabwe on cotton and citrus (Cuthbertson, 1934; Hall and Ford, 1933). In Zambia, *Trichogrammatoidea lutea* is an important parasitoid of *H. armigera* on maize (Bebbington and Allen, 1935). The important parasitoid of *H. armigera* in Uganda on cotton is the braconid *Cardiochiles trimaculata* (Coaker, 1959). *Charops* sp., *Chelonus* *bifoveolatus, Enicospilus* sp. nr. *communis, Dolichogenidea* sp. (ultor group), *Linnaemya agilis, Cardiochiles triculatus, Rogas* sp., *Euplectrus* sp., and a number of predators suppressed the population of *H. armi*gera (Coaker, 1959). In Tanzania, *Charops* sp. is an important ichneumonid parasitoid of *H. armigera* on legumes. The low parasitism rates in Northern Tanzania built up too late to prevent serious damage on cotton (Nyambo, 1990). *Palexorista imberbis* was the common parasitoid of fifth and sixth instar larvae of *H. armigera* at Ukiriguru, Western Tanzania (Reed, 1965b). It attacked 25 % of caterpillars in June-July. Apart from these, *Trichogrammatoidea* sp. and *G. halli* were also recorded. In Kenya, *Palexorista laxa, Apanteles diparopsidis* and *C. curvimaculatus* were strongly associated with sorghum; *Cardiochiles* spp. with cotton and *Charops* sp., with the weed Cleome sp. For *P. laxa, Cardiochiles* spp. and *Charops* sp., the crop effect explained about 50% of the variance in parasitism among crop, month and year (Van den Berg *et al.*, 1990). In Ethiopia, tachnid parasitoids were found to be abundant in strip cropped plots of *Phaseolus vulgaris* with corn and in weedy plots than in monocultures (Abate, 1991). The relative importance and role of different groups of natural enemies of *H. armigera* in Eastern Africa has been demonstrated (Van den Berg *et al.*, 1990; Van den Berg and Cock 1995).

Parasitoids

Egg parasitoids

Parasitoids that attack the egg stage of pests confer the added benefit of minimizing cosmetic damage, besides suppressing the pest populations. *Trichogramma chilonis* Ishii has been found to occur in significant numbers on eggs of *H. armigera* in India. The relative potential of egg parasitoids for *H. armigera* biocontrol in India has been found to differ with target crop systems (Romeis and Shanower, 1996). One to three days old, eggs of *Heliothis* were the most preferred for oviposition by females of *T. perkinsi* and *T. chilonis* (Somachoudhury and Dutt, 1988). The major focus of current and recent research has been on trichogrammatid egg parasitoids, mainly for inundative releases. Romeis and Shanower (1996) have reported that the levels of egg parasitism by endemic *Trichogramma* spp. vary widely on different host plants. Smith (1996) described trichogrammatids to be more specific to host habitat (host plants) than to host insect species. The research status, gaps and opportunities for utilizing egg parasitoids for managing lepidopteran pests including *H. armigera* in Africa have been documented (Sithanantham *et al.*, 2001a). Recent research at ICIPE has recorded species of *Trichogramma* and *Trichogrammatoidea* that occur naturally on eggs of pests (*H. armigera*) in Kenya (ICIPE, 2001). Presently, ICIPE is leading a regional initiative involving Kenya, Ethiopia, Tanzania and Uganda for characterizing the native biodiversity and so to provide a basis for their selective utilization (Sithanantham *et al.*, 2001d). Within Africa, initiatives to utilize egg parasitoids for biocontrol of *H. armigera* have commenced on tomato in Egypt (Abbas, 1998). The status of the parasitoids under Ethiopian conditions is discussed by Tibebu (1983).

In Ethiopia, the egg parasitoids recorded on African bollworm in cotton growing areas were *Trichogramma spp.* (IAR, 1985) and *Telenomus spp.* A survey for *Trichogramma* and other egg parasitoids was conducted by Ambo Plant Protection Research Center and about 12% eggs were found parasitized. The emerged adult parasitoids were identified as belonging to Trichogrammatidae (*Trichogramma spp.)* and Scelionidae (*Telenomus spp.)*.

Larval/pupal parasitoids

Some of the larval parasitoids of *H. armgiera* are also amenable for mass production and release in plantations as well as in short term crops. In India, the parasitoids being commercially multiplied for control of *H. armigera* are *Cotesia kazak*, *Campoletis chlorideae* and *Eriborus argenteopilosus*, (Swamiappan, 2000). Kushwaha (1989) indicated that species belonging to the genera *Bracon, Banchopsis, Campoletis, Enicospillus, Eriborus, Palexorista, Carcelia* and *Goniophthalmus* are apparently more important among the larval/pupal parasitoids of *H. armigera* observed in India. The larval parasitoid, *Campoletis chlorideae, Carcelia* spp. and *Goniophthalmus halli* have been found to exert varying levels of field parasitism on *H. armigera*, in relation to the host plants (Romeis and Shanower, 1996). The dominance of hymenopteran versus dipteran parasitoids on *H. armigera* larvae has been found to differ among host plants as illustrated pigeonpea and chickpea (Bhatnagar *et al.*, 1982, Sithananatham, 1985); while this may be true for some tachinids and *C. chlorideae*, it should not be extrapolated to apply to all parasitoids in both the groups (Romeis and Shanower, 1996). Laboratory reared *C. chlorideae* and those collected from the pulse ecosystem could not parasitise *H. armigera* larvae on cotton in comparison to parasitoids collected in the cotton system itself. Laboratory reared *C. chlorideae* performed differently when exposed to larvae collected from cotton plots situated in different regions of the country (Ballal *et al.*, 2001). *C. chlorideae* strains evaluated from different agro-ecosystems showed that the Sehore strain was most efficient (Ballal and Ramani, 1994). *C. chlorideae* released on *H. armigera* infested microplots of chickpea resulted in 30% parasitism (Anonymous, 1992). Parasitoid host ratio of 1:5 seemed to be ideal for releasing *C. chlorideae* on *H. armigera* larvae on chickpea plants. Sithanantham et al. (1982; 1983) observed that field parasitism of *H. armigera* larvae tended to be lower on resistant than susceptible cultivars of chickpea and pigeonpea. Presence of kairomones released through host larval feeding on the plants has been found to be important for the performance of the parasitoids.

Similarly, *E riborus argenteopilosus* has been found to be more efficient in parasitising *H. armigera* on chickpea and pigeonpea in comparison to Dolichos and sunflower (Anonymous, 1999). A recent study on cotton in Burkina Faso revealed that *H. armigera* larval parasitism rates could be as high as 33% (Streito and Nibouche, 1997). In Africa, efforts to mass-produce such parasitoids, especially those amenable for rearing on factitious hosts like *Ephestia/Plodia* could be initiated. An important factor would be to integrate their release with appropriate adjustments in pesticide use on the target crops, to maximise to their impact on the target pests.

Some attempts were made at Ambo to study the parasitoid composition and effectiveness. To find specific composition, parasites were collected from 1000 *Helicoverpa armigera* larvae and among these 139 parasites were reared which roughly represented 15 species. In some cases, the larvae were parasitized up to 44%. The parasites *Apanteles spp.* (Family Braconidae) appeared to be the most numerous ones, making 61.1% of the total number of the parasites. The rest of the Hymenoptera belonged to the family Ichneumonidae. A little more than 10% of the larvae were infested with Diptera parasites (Family Tachnidae) parasitoids (SPL, 1979).

Predators

More than sixty species of arthropods have been recorded as predators of *H. armigera* in India. However, this association has not been confirmed under field conditions for about one third of the species (Romeis and Shanower, 1996). Exclusion experiments have indicated that naturally occurring predators played a major role in keeping *H. armigera* populations at low levels in the sunflower system in India (Ballal, 1998). Van den Berg and Cock (1993a, b) have found that ants and anthocorids occur as the important natural enemies on *H. armigera* in maize, sorghum and sunflower in East Africa. Exclusion experiments in cotton in Eastern Africa have shown the potential for ants and anthrocorid bugs to contribute to reduction in *H. armigera* larvae (from 24.5 – 5.4 per plant) and in damage to reproductive parts (by about 25%) (Van den Berg, 1993). In South Africa, Pearson (1958) observed that on cotton, the anthocorid, *Orius insidiosus* (Say) destroyed up to 40 % of the *H. armigera* eggs. *Chrysoperla* sp. is useful in destroying young larvae and ants, especially *Pheidole* sp. in destroying pupating larvae and pupae. Ants can cause 89% mortality and *Dorylus* sp. accounted for 94% of the total (Greathead and Girling, 1989).

Predators of *Helicoverpa* that may qualify for the designation of "key" predator, include the pirate bugs, *Orius spp.*, big-eyed bugs, *Geocoris sp.*, fire ants, *Solenopsis spp.*, geen lacewings, *Chrysopa spp.*, cotton fleahopper, *Pseudatomoscelis seriatus*, black and white jumping spiders, *Phidippus audax*, crob spiders, *Misumenops spp.*, winter spiders, *Chiracanthium inclusum*, and striped lynx spider, *Oxyopes salticus* (Johnson *et al.*, 1986). Other key predators in certain areas include damsel bugs, *Nabis spp.*, *Collops spp.*, assassin bugs, *Zelus* and *Sinea spp.* lady beetles, *Hippodamia* and *Coleomegilla spp.*, star-belled orb weavers, *Acanthepeira stellata*, long jawed orb weavers, *Tetragnatha laboriosa*, and ridge faced crab spiders, *Misumenoides formosipes* (Sterling, 1983). Adult leafhopper assassin bugs, fire ants, large winter spiders, celer crabs spiders, grey spiders, and some earwing species can successfully attack and kill fully-grown larvae (Ehler 1990). Fay (1979) suggested that 35,000-50,000 predators per acre were sufficient to remove *Helicoverpa* daily. As new evidence becomes available concerning the identification of the "key predators," predators-prey age-structure relationship, and many other factors, the prediction of natural enemy efficiency should become sufficiently precise for use in pest management programs (Ehler, 1990). Yadav (2001) has reviewed recent studies conducted in India on the role of crop plants on the performance of the Chrysopid predator, *Chrysoperla carnea*. On pigeonpea, chrysopid larvae have not been apparently effective predators of *H. armigera* eggs (Ballal, 1998). Romeis *et al.* (1995) have documented that *H. armigera* eggs placed on leaves of pigeonpea plants were readily removed, while eggs placed on reproductive plant parts (flower buds, flower petals, pods) were rarely collected.

In Ethiopia, some natural enemies of *Helicoverpa armigera* larvae collected and identified so far are assissin bugs, ladybird beetles, and some spiders (EARO, 2000). Some polyphagous predators are also identified below:

Anthocoridae: *Orius* sp.
Reduviidae: *Pirates aurigens; Rhinocoris rapax* (*Rh. Pucturates*); *R. segmentarius*
Caradidae: *Calasoma rugosum; Chaenius* spp.; *Carabus* sp.
Chrysopidae: *Chrysopa spp.; C. carnea* (SPL, 1985)

In Ethiopia, the population of wasp predator, *Tiphia* sp. has been found to increase with increasing habitat diversity as in weed plots (Abate, 1991).

Among predators, the ants killed up to 90% pupae in the soil (Taylor, 1932; Curran, 1934; Cuthbertson, 1934; Parsons and Ullyett, 1934; Parsons, 1940a; Cuthbertson and Munro, 1941; Pearson, 1958; Prinsloo, 1984; Greathead and Girling 1982, 1989). In East Africa, predators, especially ants and anthocorids, are the most important natural enemies of *H. armigera* on corn, sorghum and sunflower (Van den Berg and Cock, 1993 a, b). In Egypt, *Scholothrips sexmaculatus, Orius* spp., *Chrysoperla carnea, Scymnus* sp., and *Coccinella* sp. preyed on eggs and 1st instar larvae (Ismail and Swailem, 1975; Ibrahim and Fayad, 1989). The predators recorded in Sudan were *Eumenes maxillosa* and *C. carnea*, along with the parasitoids, *C. versatilis* and *Disophrys* and predators were more effective (Wilkinson, 1932; Nixon, 1943; Pearson, 1958; Lazarevic, 1971). In Tanzania, a number of predators – *Chrysoperla* sp., *Glypsus conspicuous, Macrorhaphis acuta, Pheidole* sp., *Myrmicaria* sp., *Ammonphila*, birds, lizards and frogs-were frequenting the cotton field (Reed, 1965b).

Pathogens

Various pathogens are available for *H. armigera* control (Table 2). Although some degree of success has been achieved with the use of pathogens in the management of ABW, microbial control agents are at present used very little compared with chemical pesticides. This is due not so much to the lack of the potential of the pathogens but to the user's lack of understanding of the nature of the pathogens (Bell, 1982). Of the microbial agents (bacteria, fungi, nematodes, protozoans and viruses) crystal-bearer bacteria, *Bacillus thuringiensis* and the *nuclear polyhedrosis viruses* (NPV) are currently given the best chances of success in most *Heliothis, Helicoverpa* management programs (Bell and Romine, 1985). In general, the level of control of these species in cotton obtained with *B.t.* (isolate HD-1) has been more consistent than that obtained with NPV (Bell, 1982). Certain insect pathogens, especially viruses and bacteria, have been combined satisfactorily with various adjuvants (wetting and sticking agents) such as blood albumin, milk powder, wheat flour, soybean flour, corn flour, cotton seed flour, soybean oil, glycogen, ground chick-peas, sucrose and several of the recent proprietary surface-active agents (Hafez, *et al.*, 1987; Smith and Hostettler, 1982; Tanada, 1959). Commercial spray adjuvants like Coax and Gustol are available (Luttrell *et al.*, 1982). Molasses is used both as an adjuvant and especially as an adhesive (Potter *et al.*, 1982; Svestka and Vankova, 1976). These adjuvants usually increase the effectiveness of insect pathogens (Bell, 1982; Tanada, 1959). According to Bell and Romine (1985), the yield of seed cotton in Phoenix, Arizona, USA was 32% more in cotton treated with the *B.t.* + adjuvant compared to the yield in cotton treated with the bacterium alone.

Bacterial Pathogens

Bacillus thuringiensis (*B.t.*) is the most extensively studied pathogen among *H. armigera* and other caterpillar pests (Singh, 1999). The toxicity of the bacterial pathogen is mainly due to the parasporal protein crystal, which varies among different varieties of *B.t.* The bacterium *B.t.* has been used successfully against *H. armigera* (Roome, 1975) and many other insect pests. Contrary to the promising reports, *B.t.* has also been found ineffective against *Helicoverpa armigera* (Hb.) (Collingwood and Bourduxhe, 1980; Krishnaiah *et al.*, 1978; Roome, 1975).

B.t. is one of the earliest microbial insecticides to be commercially produced worldwide. The commercial products include Dipel, Thuricide, XenTari, Bactosperms e.t.c. In Kenya, three commercial *B.t.* products are currently available - Dipel®, Thuricide® (both *B.t.* var. *kurstaki*) and XenTari® (*B.t.* var. *aizawai*). The efficacy of *B.t.* could be enhanced by adjuvants like neem seed kernel extract (2%). *B.t.* products have been recommended for *H. armigera* control on tomato, cotton, tobacco and sunflower (Singh, 2000). It is important to note that insects can develop resistance to the *B.t* toxin and bacterial toxins should be used judiciously (Gelernter, 1997).

In Ethiopia, laboratory and field evaluation of *Bacillus thuringiensis* Berliner variety *kurstaki* for the control of *Helicoverpa armigera* on haricot bean was carried out at the Melka Werer Research Center, between June 1990 and September 1991. Two laboratory tests were conducted using four levels of *B. thuringiensis* suspension (0.00 kg/ha, 1.50 kg/ha, 1.75 kg/ha and 2.00 kg/ha) on first, second, third and fourth instar larvae to determine the most effective dosage of *B. thuringiensis*. The most promising treatments (3) were used in field experiments comparing with a conventional insecticide, endosulfan (Thiodan®) 35 % E.C.). *B. thuringiensis* at the rate of 1.50 kg/ha controlled first and second instar larvae of *H. armigera* up to an average of 99.58% and 90.42%, respectively (Alemayehu, 1992; Alemayehu *et al.* 1993).

Fungal Pathogens

There is a worldwide resurgence of interest in the use of entomopathogenic fungi as biological control agents. Genera that have been most intensively investigated for mycoinsecticides include *Beauveria, Metarhizium, Verticillum, Hirsutella, Erynia, Nomuraea, Aspergillus, Aschersonia, Paecilomyces, Tolypocladium, Leptolegnia, Coelomomyces* and *Legenidium*. The fungal pathogens that have shown some potential on *H. amigera* include the genera of *Beauveria* and *Nomuraea*. Singh (2000) indicated *B. bassiana* and *N. rileyi* as occurring in nature on *H. armigera* in India. In Australia, a fungus *Beauveria bassiana* was librated against *H. armigera* without any effect (Waterhouse and Sanda, 2001). The fungus *Beauveria rileyi* (Farlow) was isolated from dead larvae in Bonake, in Cote De' ivore (Ignoffo, 1965).

Numerous strains of *M. anisopliae* exist and they have been based on the production of the esterases apart from the morphology (de Conti *et al.*, 1980). *Nomuraea rileyi* of cosmopolitan occurrence, infecting mainly, *Helicoverpa* (*Heliothis*) *armigera, Trichoplusia ni* and *Plusia* sp. and is a potential candidate for development into a mycoinsecticide. The fungus is reportedly safe to several parasitoids and predators viz., *Chrysoperla carnea, Apanteles* sp., *Campoletis* sp., *Telenomus proditor, Coccinella* sp. and *Microplitis* *croceipes*. Initial studies with this entomofungal pathogen have been limited to reports of epizootics and laboratory testing for efficacy against *H. armigera* and *S. litura* (Gopalakrishnana and Narayanan 1988, 1986). *N. rileyi* has been reported to cause late-season epizootics of caterpillar pests of soybeans which generally produced a relatively heavy load of soil-borne conidia that act as a natural reservoir for the seasonal initiation of *N. rileyi* epizootics in soybean caterpillars (Ignoffo *et al.*, 1977).

Viral pathogens

Nuclear Polyhedrosis Viruses (NPVs) have been shown to be efficient and cost-effective biocontrol agent for *H. armigera*. *Helicoverpa* NPVs have been isolated and used substantially in India (King, 1994; Rabindra, 2000), China and Australia (Grzywacz, 2001) but very little efforts have been made to utilize them in Africa. The scope for utilizing NPV in augmentation biocontrol of *H.armigera* in Africa has been recently emphasized (Sithanantham *et al.*, 2001b,e). In Eastern Africa, studies by Coaker (1958) showed potential of NPV. Preliminary trials have been carried out using *B.t.* and HaNPV as biological pesticides in Uganda (Coaker, 1959), Tanzania (McKinley, 1971) and Botswana (Roome, 1975), but the work was not continued. In South Africa, satisfactory control of *H. armigera* on citrus with HaNPV was reported. The potential for utilization of native biocontrol agents including NPV in Africa (Sithanatham *et al.*, 2001a) and the importance of this component in an ecosystem approach to management of *H. armigera* in the region (Sithanantham *et al.*, 2001b) has been emphasized. Initiatives at ICIPE for a countrywide survey to on natural occurrence of HaNPV from various vegetable crops within Kenya, laboratory isolation, bioassays and mini-field plots tests under natural conditions showed potential for NPV (Baya *et al.*, 2001). Field tests on *Helicoverpa* NPV for control of *H. armigera* in pigeonpea in Kenya have shown promise (Minja *et al.*, 2003). Other viruses known to occur on *H. armigera* include cytoplasmic polyhedrosis virus (CPV) Ascovirus and poxvirus (Singh, 2000).

The polyhedral virus disease seems to be endemic in certain parts of Sudan (Ripper and George 1965). The virus caused disease in *H. armigera* on cotton in Uganda in 1955 and was used in small-scale tests (Coaker 1958). Cotton plants were sprayed by low volume hand sprayer at 20 ml/plant and 1, 2, 5, 10, 20, and 40, all x 10^5 polyhedra/plant when larvae were in instars III and IV and the ED_{50} was approximately 10^6 polyhedra/plant and the ED_{80} about 10^7.

Other pathogens

Vairimorpha sp. which is a protozoan and *Steinernema* spp. which are entomopathogenic nematodes have also been known to be potential biocontrol agents for *H. armigera* (Singh, 2000). Pathogenic protozoa species are found in all the major protozoan species, including flagellates, amoebas, and ciliates. However, most of the entomopathogenic protozoa are in the order Microsporida. Nematode parasites of insects may display either facultative or obligate parasitism. Facultative parasitic nematodes are able to parasitize healthy insects yet retain the ability to reproduce and develop external to the host. Obligate nematode parasites have no free-living stages that receive nourishment and thus cannot complete their life cycle outside the host.

The research on the use of algae and rickettsiae as a means of biological control agent is at a very infant stage though there is some potential in the future.

Interventions on Biocontrol

Introducing Natural Enemies

Exotic parasitoid species have been introduced in different geographical regions as an attempt to enhance *H. armigera* biological control in countries like Australia (Michael, 1989), New Zealand (Cameroon and Valentine, 1989) and India (Nagarkatti and Singh, 1989). Romeis and Shanower (1996) have provided an updated review of the introduction attempts made in India, the first introduction being the egg parasitoid *Trichogramma pretiosum* Riley (Hymenoptera: Trichogrammatidae) in 1964 (Sankaran, 1974). Sixteen hymenopteran and two dipteran parasitoids of *H. armigera* have so far been introduced from America, Africa and Europe (Table 2). One tachnid larval parasitoid, *Eucelatora bryani* Sabrosky (introduced as *Eucelatoria* sp. near *armigera* (Coquillett) is established on *H. armigera* in India (Romeis and Shanower, 1996).

Inundative Release and Integration with Pesticide

Trichogrammatid egg parasitoids are being currently used extensively in India as inundative releases for *H. armigera* biocontrol (Table 3). Inundative releases of biocontrol agents may very often interact with other pest control interventions being practised in the target crops systems. Tests on compatibility of augmentation biocontrol agents with the other crop protection practices have proved promising (Table 4). For instance, inundative release of egg parasitoids can be harmonised with the use of pesticides by understanding their relative compatibility. Relative toxicity of pesticides to *Trichogramma* (Paul and Agarwal, 1989; Brar *et al.*, 1991) and *Chrysoperla carnea* (Singh and Balan, 1986) has been estimated and the pesticides categorised for their relative safety. Hassan (1998) has classified a wide range of insecticides (66), fungicides (53) and herbicides (42) for their relative safety using *Trichogramma cacaeciae*. He has also described the standardised methodologies approved by IOBC (International Organisation for Biological Control) for assessing the relative safety of pesticides to egg parasitoids both under laboratory and field situations.

Research Needs for *H. armigera* Biocontrol

Justifications

An FAO seminar on IPM for vegetables in Africa was held in Senegal in 1992, which recognized *H. armigera* as key pest of vegetable crops (Ikin *et al.*, 1994). A symposium of the African Association of Insect Scientists (AAIS) held in Burkina Faso in 1999, recommended that IPM research on *H. armigera* with focus on biocontrol and networking for research complementation among national research programs. Another AAIS symposium held in Addis Ababa in 2001 endorsed the promotion of *H. armigera* biocontrol research and capacity building at national and regional levels. The potential for research on egg parasitoids towards biocontrol of *H. armigera* and other caterpillar pests has been recently documented (Sithanantham *et al.*, 2001a).

Initiatives on Biocontrol

Efforts with predators and parasitoids

In South Africa, it has been demonstrated that conservation of predators could dramatically reduce the number of applications of cypermethrin for *H. armigera* control (Greathead and Girling, 1989). *Trichogrammatoidea lutea* was mass reared and released in cotton fields in South Africa in 1930s, but it was not recovered (Pearson, 1958). Later, *Trichogramma pretiosum* was imported, released, and got established (Greathead and Girling, 1989). Release of *T. pretiosum* against *H. armigera* on cotton crop in Sudan Gezira during 1988-89 gave promising results (Abdelrahman and Munir, 1989). Surveys conducted in various countries in Africa have revealed natural occurrence of trichogrammatid egg parasitoids. Research on trichogrammatid egg parasitoids has been ongoing at ICIPE (Sithanantham *et al.*, 2001b). Surveys in Kenya have led to recovery of several native egg parasitoids including from *H. armigera* (ICIPE, 2001; Abera, 2001). Abbas (1998) showed the potential for *Trichogramma* in biocontrol of *H. armigera* on tomato in Egypt. A regional African bollworm biocontrol initiative in Eastern Africa has been recently launched and led by ICIPE in partnership with the National biocontrol teams of Ethiopia (Ambo), Kenya (Muguga), Uganda (Namulonge) and Tanzania (Kibaha) (Fig. 1). The focus of this program is to evaluate the native diversity and potential of egg parasitoids for *H. armigera* biocontrol in the sub region.

Efforts with use of NPV

Preliminary trials have been carried out using *B.t.* and HaNPV as biological pesticides in Uganda (Coaker, 1959), Tanzania (McKinley, 1971) and Botswana (Roome, 1975), but the work was not continued. In Eastern Africa, studies by Coaker (1958) showed that NPV was more infective with a shorter incubation period in the younger larvae than the older larvae and 2000 million POB provided 83.3 % kill.

In South Africa, *H. armigera* occurring on citrus was satisfactorily controlled by spray application of NPV (Moore *et al.*, 1997). The potential for utilization of native biocontrol agents including NPV in Africa (Sithanatham *et al.*, 2001b) and the importance of this component in an ecosystem approach to management of *H. armigera* in the region (Sithanantham *et al.*, 2001c) has been emphasized. Recently, initiatives were made at ICIPE for a countrywide survey to collect infected *Helicoverpa* larvae from various vegetable crops within Kenya and followed it by laboratory isolation, bioassays and tests in mini-field plots under natural conditions (Baya *et al.*, 2001). Field tests on *Helicoverpa* NPV for control of *H. armigera* in pigeon pea in Kenya have shown promise (Minja *et al.*, 2003). The potential for research on egg parastitoids towards biocontrol of *H. armigera* and other caterpillar pests has been recently documented (Sithanantham *et al.*, 2001a).

Vision for Biocontrol Initiatives

Based on Ethiopian research status and needs the following initiatives in *H. armigera* biocontrol could be visualized as priority:

- National survey and mapping of native natural enemy occurrence.
- National gene bank for *H. armigera* natural enemies (parasitoids/predators/pathogens)
- Crop-focus evaluation of potential
- Improvements in mass production/quality control
- Establishment of model production units
- Demonstration of impact and ToT for dissemination

For achieving effective impact in the biocontrol initiatives some linkages are visualized follows:

- EARO could network research both internally and with external collaboration.
- Universities to link up for M.Sc./Ph.D. research training projects
- Ministry of Agriculture to provide trainers for training and demonstration
- Policy support for mass production/commercialization of biopesticides

Capacity Building

It would be useful to provide advanced training to at least two senior scientists in major groups of biocontrol agents – one on parasitoids and predators, and the other on pathogens - preferably at Ph.D. level. Young scientists could be trained (at MSc/level) in mass production and quality control, diversity characterization and conservation, adaptation to physical–chemical stresses and tritrophic interactions. In addition, short-term training at advanced research institutes should also be planed. Back up should also consider technician level training in laboratory and field techniques.

Biodiversity Characterization

The locally occurring species/strains of natural enemies of *H. armigera* should be characterized for their inter- and intra-species diversity and catalogued. Reference collections should be established on the lines of gene banks, so to support taxonomic and behavioral/adaptation studies.

Research on Enhancing Field Impact

Research should focus on dose optimization, efficient deployment methods and integrating with other crop protection practices. Crop-specific evaluations and refinements should receive more attention.

Research to improve mass production and delivery system

Appropriate techniques to enhance the efficiency and simplicity of mass production should be identified. Quality control parameters relevant to local monitoring needs should also be identified and disseminated. Non-governmental organizations (NGOs) and private enterprise should be stimulated to promote locally–based mass production and delivery units.

Securing Policy Support

Research–extension officials should keep up sensitizing policy makers in extending required support for popularizing biocontrol products and techniques. Provision should be made for stakeholder consultation workshops and field days, towards building up awareness on potential for using biocontrol.

Collaboration as a Key Component

Besides sharing themes, collaboration in research within Ethiopia, linkage with International Agricultural Research Centers (IARCs) and Advanced Research Institutions (ARIs) should be further strengthened. South–South cooperation with experienced countries such as Brazil, China and India should provide a practical orientation in biocontrol promotion.

Table 1. Predator and parasitoid groups recorded on *H. armigera* in India

Orders	Number of		
	Families	Genera	Species
Predators			
Coleoptera	5	11	11
Dermaptera	2	2	4
Orthoptera	1	1	1
Hemiptera	6	24	50
Hymenoptera	4	12	17
Neuroptera	1	6	13
Araenae*	4	10	11
Aves*	-	5	5
Diptera	2	17	37
Hymenoptera	9	46	116

***Source:** Sithanantham et al. (2001f)*

Table 2. Status of introductions of exotic parasitoids for classical biocontrol of *Helicoverpa armigera*

Natural enemy introduced	From	Target country/ (Year)	Extent of establishment*	Reference
Trichogramma pretiosum	USA	Australia (1973-75)	Used for inundative releases	Michael (1989)
Cotesia kazak	Greece	Australia (1983, 1985)	-	Michael (1989)
Campoletis chlorideae	Pakistan	Australia (1982-83)	Recovered on *H. punctigera* in lucerne	Michael (1989)
Hyposoter didymator	Grece	Australia (1983, 1985)	-	Michael (1989)
Trichogramma brasiliensis	S. America	India (1968, 1982)	No evidence of permanent establishment	Nargarkatti and Singh (1989)
T. perkinsi	S. America	India (1966)	*Only males emerged from three shipments, hence no studies were possible	Nargarkatti and Singh (1989)
T. pretiosum *T. semifumatum*	Mexico and USA	India (1968/1964)		Sankaran (1974)
Chelonus blackburni	USA	India (1976)		Nargarkatti and Singh (1989)
T. exiguum	West Indies	India (1978)		CIBC (1979)
C. insularis	Trinidad	India (1982-83)	*Establishment is not known	Nargarkatti and Singh (1989)
Microplitis croceipes	Arizona, USA	India (1970)		Nargarkatti and Singh (1989)
Cotesia marginiventrix	Arizona, USA	India (1969, 1981, 1983)		Nargarkatti and Singh (1989)
Eucelatoria bryani	Arizona, USA	India (1969, 1978)		Sankaran and Nagaraja (1979)
Lepesia archippivora	Arizona, USA	India (1969, 1970)		Sankaran (1974)
Cotesia kazak	Europe	Newzealand (1977)	Established	Cameron and Valentine (1989)
Campoletis chlorideae	India	Newzealand (1969)	Not recovered	Cameron and Valentine (1989)
Eucelatoria armigera	India	Newzealand (1969)		Cameron and Valentine (1989)
Carcelia illota	India	Newzealand (1969)		Cameron and Valentine (1989)
Palexorista laxa	India	Newzealand (1969)		Cameron and Valentine (1989)
T. australicum	India	Newzealand (1973)		Cameron and Valentine (1989)
T. euproctidis	India	Newzealand (1973)		Cameron and Valentine (1989)
T. evanescens	India	Newzealand (1973)		Cameron and Valentine (1989)
Chelonus blackburni		Newzealand (1982)		Cameron and Valentine (1989)
C. blackburni	USA	Newzealand (1982)		Nagarkatti and Singh (1989)
T. chilonis		Newzealand (1983)		Sithanantham and Navarajan (1989)
E. bryani	USA	Newzealand (1973-1974)	Considerable pest reduction	Sithanantham and Navarajan (1989)

T. brasiliensis	South America	1968 (India)		Sankaran (1974)
T. chilonis	India	1975		Sithanantham and Navarajan (1989)
Eucelatoria bryani	USA			Sithanantham and Navarajan (1989)
T. eldanae	S. Africa	India (1987)		Anonymous (1992)
Bracon kirkpatricki	E. Africa	India before (1977)		Divakar and Pawar (1987)
Glabromicroplitis (as *Microphilitis*) *croceipes*	USA	India (1970)		Sankaran (1974)
Campoletis flavicincta	West Indies			Nagarkatti and Singh (1989)

-: Information not available * **Source**: Sithanantham et al. (2001 f)

Table 3. Inundative release of natural enemies for *H. armigera* biocontrol in India: Examples

Target crop	Biocontrol agent released	Dosage (lakhs/ha)	Results	Reference
Cotton	*Trichogramma achaeae*	Inundative releases	22% parasitism	Sundaramurthy and Basu (1985)
	T. chilonis	1.0; 3 releases	As effective as insecticides	Dhandapani *et al.* (1992)
	T. chilonis	2.0	32.4 – 40.4% parasitism	Anon. (1992 and 1995b)
	T. chilonis	1.5	>60% parasitism	Singh *et al.* (1994a)
	T brasiliensis	1.5 – 2.0	Egg parasitism was 23.2 to 64.6%	Muthukrishnan (1995)
	T. brasiliensis	-	100% parasitism up 4m and 66.6% up to 5m towards wind direction	Anon. (1990)
	Trichogrammatoidea armigera	2.5 at 2m spacing	Effective	Singh *et al.* (1994a)
Tomato	*T. brasiliensis*	5.0	100% parasitism	Kakar *et al.* (1990)
		2.5	20-71% parasitism	Mani and Krishnamoorthy (1983)
		3.0	78.4% parasitism	Singh (1991)
	T. chilonis	2.5	20-96% parasitism	Yadav *et al.* (1985)
		0.6-10.9	76.3% parasitism	Divakar and Pawar (1987)
	T. exiguum	5.0	100% parasitism	Kakar *et al.* (1990)
	T.pretiosum	5.0	100% parasitism	Kakar *et al* (1990)
		0.6-10.6	92.4% parasitism	Divakar and Pawar (1987)
		2.5	31.5% parasitism	PDBC (1999)
	T. chilonis	2.5	65% reduction in fruit damage	Yadav *et al.* (1985)
	T.brasiliensis	0.5	55 %reduction in fruit damage	Singh *et al.* (1994b)
Potato	*T. chilonis*	2.5	69% reduction in *H. armigera* larvae	Yadav *et al.* (1985), Patel (1980)
Sunflower	*T. chilonis*	1.0	No record	Singh *et al.* (1994b)
Chickpea	*T. chilonis*	2.5	No record	Yadav *et al.* (1985)

***Source:** Sithanantham et al. (2001 f)*

Table 4: Examples of integrating *H. armigera* biocontrol using entomophagous insects with other IPM options for bollworms on cotton in India*

Entomophagous insect(s) used	Other IPM options used in combination	Results	Reference
Trichogramma sp. and *Chrysopa carnea*	NPV	Effective for control of *H. armigera*	Manjunath (1992)
T. chilonis and *C. carnea*	NPV, *B.t.*	Reduced *H. armigera* below EIL	Anon. (1992)
T. chilonis (1.5 lakhs/ha) and *C. carnea* (50,000/ha)	Cotton + intercrop	Higher pest suppression and yield	Jeevana Reddy (1997)
T. chilonis (1,00,000/ha and *B. hebetor* (500 adults/ha)	Phorate granules side dressing, monocrotophos, fenvalerate, quinalphos, cypermethrin, diflubenzuron + chlorpyriphos, carbaryl, deltamethrin and methyl demeton	These practices resulted in cost-benefit ratio three times greater than insecticidal control	Divakar *et al.* (1994)
T. chilonis (1.5 lakhs/ha/week)	NPV (250 le/ha) at fortnightly interval from 50 t0 100 DAS	Proved very effective	Mishra and Mandal (1995)
2-3 releases of *C. carnea* (50,000/ha), 2-5 releases of *T. chilonis* (1.5 lakhs/ha) and 2 releases of *T. chilonis* (1.5 lakhs/ha)	Bio-intensive module: Seed treatment with Imidacloprid 10g/kg seed, neem based insecticide (5ml/l) and 1-3 sprays of HaNPV (500 le/ha) and *Btk* – 11 (2kg/ha). Adoptable module: Imidacloprid, 2-3 sprays of neem based insecticides and 1-2 sprays of HaNPV (500 le/ha) and need based application of insecticides, recommended package of practices (RPP) = 7-11 insecticidal sprays	Experiments on 0.4 ha plot over 4 years revealed that the bio-intensive module resulted in significantly lesser seed cotton yield (8.59 q/ha). Adaptable module which is a blend of biorationals and chemicals proved as effective as (14.9 q/ha seed cotton yield and Rs. 21, 500/ha net profit) as RPP (15.96 q/ha seed cotton yield and Rs. 25,385/ha profit)	Lingappa and Patil (1999)

*: *Source: Sithananthum et al. (2001 f)*

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Cultural Control of African Bollworm, *Helicoverpa armigera*

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Abstract

*The African bollworm, **Helicoverpa armigera** (Hb.), is a pest of major importance in most areas where it occurs, damaging a wide variety of food, fibre, oilseed, fodder and horticultural crops. Its significant pest status is due to high mobility, polyphagy, high reproductive rate and potential for diapause, making it particularly well adapted to exploit transient habitats such as man-made agro-ecosystem. Its preference for the reproductive parts of several food and high value crops like cotton, tomato, tobacco and pulses confers a high economic cost to its depredations. The need for sustainable pest control required under these target ecosystems call for environment-friendly and integrated control methods. Cultural and habitat manipulations in the target crops or cropping systems and beneficial land management are some of the ecologically sound options to manage **H. armigera** populations. The use of intercropping, planting dates, trap crops, deep and frequent ploughing, spacing, fertilization etc are some of cultural management tactics that would merit further evaluation are reviewed, so to cater to such special needs in Ethiopia.*

Introduction

Helicoverpa armigera (Hb.) is a pest of major importance in most areas where it occurs, damaging a wide variety of food fibre, oilseed, fodder, commodity and horticultural crops. Its major pest status is rooted in its mobility, polyphagy, high reproductive rate, and diapause potential, all of which make it particularly well adapted to exploit transient habitats such as man made agro-ecosystems. Its preference for the reproductive parts of essential food and high value crops like cotton, tomato, pulses and tobacco, confers a high economic cost to its depredations. For this reason, a relatively high level of management is required, through integration of various pest management options like cultural, mechanical, physical, chemical (conventional and natural insecticides), varietal, and biological control agents.

Historically, cultural and mechanical practices have been among the farmers' most commonly used preventing crop losses due to pests. Prior to the emergence of crop protection sciences and even before the broad outlines of the biology of pests were understood, farmers had evolved many cultural practices, largely through trial and error experiences to minimize the damage caused by insect pests (Smith et al., 1976). Cultural control includes diverse set of practices, including sanitation; destruction of alternate habitats and hosts used by the pest; tillage; appropriate water management methods, utilizing favorable plant density; crop rotation and fallowing; crop planting date adjustments; trap cropping, vegetation diversity (intercropping strip cropping and weedy culture); beneficial fertilizer use; and adjusting the harvest time.

Cultural practices may affect the densities and species diversity of natural enemies. The effects of cultural practices on pests vis-a-vis natural enemies constitute the tritrophic interactions in cultural control. In some cases, these indirect effects could be discussed as a type of biological control, emphasizing the role of the natural enemies. There are also several examples in the literature demonstrating that cultural practices can enhance natural enemy abundance and possibly their efficacy. Understanding the population processes involved in the population changes is necessary to develop a general realization of how cultural practices can result in higher densities of parasitoids and predators (Jack and Nacy, 2000).

Since cultural practices are based on habitat management and require a thorough understanding of different components of the agro-ecosystem in which the pests thrive this approach has also been termed as ecological management or environmental control. The purpose of cultural practices is to make the environment less favorable for the pest and/or more favorable for its natural enemies. It is considered possible that disrupting the normal life cycle and making the environment favorable for its natural enemies through cultural practices can help the African bollworm damage in our major target crops in Ethiopia.

Cultural control methods

Cultural manipulation of the crop or cropping system and land management are known to be potential tactics to manage *H. armigera* populations. The use of intercropping, planting dates, trap crops, deep and frequent ploughing, spacing, fertilization are among cultural management tactics that are reported promising for *H. armigera* elsewhere and may merit further evaluation in Ethiopia.

Sanitation

The removal of crop residues in which the pest may be able to over winter is a commonly adopted sanitation practice. The removal and burning of crop stubble to reduce over wintering populations of ABW and post-harvest collection and destruction of volunteers would have to be considered in the management of such polyphagous insect. Moreover, efforts should be made to remove/destroy weeds at a time when peak egg laying occurs, so to substantially reduce the build up of ABW populations. Nevertheless, selective provision of a diverse vegetation within or near the fields so to add to the essential food resource for predator or parasitoid should be considered as well so to enable natural enemies to survive over longer periods.

Intercropping

Intercropping, trap cropping and presence of weeds can increase the diversity of a crop system. Whereas inter-planted crops or weeds in the crop may be more suitable host plants for a particular pest and may help reduce the feeding damage to the target crop, by diverting the pest. However, we should take precautions to avoid them serving as an attractive source of food or shelter at some point in the life cycle of the pest, enabling the pest to build up its numbers in the field and can later move in to attack the main crop more severely (Cromartrie, 1993).

Intercropping is the growing of more than one crop in the field. Generally, intercropping affects the pest populations through creating mechanical barriers and restricting the dispersal of pests, affecting the colonization when a pest descends on a non-host and thus may leave the field early, changing microclimates and increasing the population of beneficial insects by providing food source, refuges for beneficials for nesting and carrying over through unfavourable environmental periods (dry season, cold season etc.), alternate hosts/prey at a time of pest scarcity and maintaining minimal pest populations over extended periods to ensure the continued survival of the key beneficial insects. The available information on past research in this aspect is summarized in Table 1. Intercropping of cotton with chickpea, cowpea, onion, pear millet, *Crotalaria*, pigeonpea, Marigold (*Tagetes* spp.), etc. in strips is reported to divert the population of sucking pests and African bollworm (Baskaran and Narayanasamy, 1995; Stoll, 2000; Dahaliwal and Arora, 2000). Similarly, trials conducted under the All Indian Coordinated Pulses Improvement Project at several locations demonstrated that the sole crop of chickpea attracted more *H. armigera* compared to intercrops with wheat, barley, linseed, mustard and safflower. On the other hand, lentil and field pea as intercrops have led to enhanced pest infestation in chickpea (Dahaliwal and Arora, 2000).

Trap Crops

Trap crops are plant stands that grow to attract pest insects away from the target crops. Even early or late planting of a few rows of the same crop within the field in which the major crop is planted may also serve as trap; by diverting the pest further main planting. The attractiveness of trap crops may be enhanced by the use of insect pheromones or insect food substance. Using trap crop for instance, large numbers of cotton bollworm, *H. armigera* were attracted to carrot field by its flowers.

The insecticide lannate (methomyl) at 1:1000 was sprayed on the carrot flowers, resulting in adult noctuid mortality of 14 per m^2 in the sprayed field and 0.9-0.2 / m^2 in the fields 4080m away. By survey and calculation, more than 3 million ABW adults were killed in 50mu (3.35ha) of carrot fields by this method (Rouqiu, 1993). And again, trap cropping with marigold planted after every 8 rows of tomato helps attract most of the ovipositing moths of *H. armgiera* on the former crop (Dahaliwal and Arora, 2000). Hence, intercropping of various plants with cotton, chickpea, tomato etc. affects the *H. armigera* variously as indicated in Table 1. In Ethiopia, trials conducted on the possible use of trap crop in bollworm management on haricot bean indicated that lupin, pigeonpea, hyacinth bean, maize and sunflower attracted significantly higher of number of ABW (Tsedeke *et al.* 1985).

Crop Rotation

The potential advantage of crop rotation is to limit a particular pest in space and time from access to its preferred host plants. Rotation of cereals with pulses can reduce the populations of African bollworm (Anonymous, 1999). Bohien (1978) recommended avoiding continuous maize cropping for disrupting the life cycle of *H. armigera*.

Planting Time

The manipulation of planting time can minimize the pest damage due to asynchrony between host plant growth and the pest peaks or synchronizing insect pests with their natural enemies or crop production with available alternate host plants of the pest or by production followed by destruction of crop residues before the insects can enter diapause. If ABW attacks are known to be severe at a particular time in the season, it is possible to adjust the sowing date or to utilize cultivars of appropriate duration to ensure that the flowering and podding stages do not coincide with the peak attack period. *H. armigera* is generally a late season pest and by sowing very early, the target crop can escape damage from this pest (Dhawan, 1999). Rathore and Nwanze (1993) reported that early sowing could be used to minimize pod borer *(H. armigera)* damage to chickpea in north India. According to Tsedeke *et al.*, (1985), early planting of chickpea resulted in significantly higher yields and lower number of *H. armigera* larvae. Moreover, by practising synchronous sowing of the target crop in any area, the available ABW population could be diluted through dispersion across the whole crop area, and thereby reduce the crop damage levels.

Tillage

Often the pupae of *H. armigera* overwinter either in the soil or on stubble of the crops. Deep ploughing can help destroy the *H. armigera* pupae by exposing them to natural enemies and strong sunlight. Fall ploughing is known to help in reducing the over wintering population of *H. armigera* (Dahaliwal and Arora, 2000).

Seed Rate and Plant Spacing

The major basis for spacing in any crop is to maximize the yield per unit area per unit time. But spacing may also influence the population and damage of many insect pests by modifying the microenvironment of the crop or by indirectly affecting the health, vigour and strength of the crop or the pattern and duration of crop growth and development. Larval population of pod borer, *(Heliothis armigera)* on chickpea was four times as large at closet (33 plants/m^2) as at widest (3 plnats/m2) spacing (Dhaliwal, 2000). Preliminary study on the effect of haricot bean spacing on ABW damage showed that pod damage tended to decrease significantly with increasing distances between rows (80 cm) as well as between plants (20 – 25cm) (Tsedeke *et al.*, 1985). Tibebu (1983) observed that there was a negative correlation between plant density and the level of ABW larval infestation on chickpea.

Table 1. Reported effects of intercropping in different target corps on African bollworm, *Helicoverpa armigera*

Major crops	Intercrop plants	Principal effect on ABW	Reference
Cotton	Castor bean	Trap for ABW oviposition; also attracts Spodoptera and other caterpillars	Stoll, 2000
	Maize	Not very attractive to lacewing eggs Trap for ABW oviposition	Stoll, 2000
	Okra	Attracts ABW and other caterpillars	Stoll, 2000
	Pigeonpea	Trap fro ABW oviposition	Stoll, 2000
	Sorghum	Trap for egg laying byABW, high parasitisation	Stoll, 2000
	Sunflower	Attract ABW to lay eggs	Stoll, 2000
	Sweet sorghum	Attractive to natural enemies of ABW	Stoll, 2000
	Umbelliferae	Highly attractive to natural enemies	Stoll, 2000
	Sesame	Attracts parasitoids eg. *Campoletis*	Dahaliwal and Arora, 2000
	Tagetes spp.	Preferred host of ABW oviposition	Dahaliwal and Arora, 2000
	Nicotiana rustica	Preferred host of ABW oviposition	Dahaliwal and Arora, 2000
Tomato	*Tagetes erecta*	Trap for ABW egg laying	Srinivasan *et al*., 1993; 1994
Tobacco	*Tagetes erecta*	Preferred host of ABW	Patel and Yadav, 1992

Conclusions and Recommendations

The utilization of cultural control methods for ABW management appears promising and research on this aspect should become a critical component of integrated pest management. The merits of most cultural control practices are that they demand little or no added cost, and are often mere variations in the timing or manner of performing cultural operations mostly compatible with other components of IPM like resistant varieties, bio control agents and even insecticides. The cultural control methods may be selectively used according to local needs in the regions, since the ABW population build-up and dynamics would differ between each major agro-ecological zone. Therefore, the appropriateness of the cultural control measures should be tested regionally, and integrated with other options to develop an environmentally-friendly, affordable and easy to apply menu of ABW management options. A combination of cultural and other control practices can be of help to lower the general equilibrium position of ABW and similar insect pests. When properly applied some of the cultural practices may even obviate the need for insecticide use in controlling ABW in the major target crops in Ethiopia.

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Potential for Botanicals in Controlling the African Bollworm

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Abstract

The potential of botanicals for effective, eco-friendly and sustainable Helicoverpa armigera management on various crops is described. The likely economical, environmental, technological and other benefits are indicated. Promising plants and recommendations for their optimal and effective use in management of H. armigera are discussed. It is visualized that Ethiopia can gain substantially from increased awareness and use of botanicals in sustainable management of this pest. Future research priority areas are indicated.

Introduction

African bollworm is a polyphagous insect pest attacking a number of important crops. It is a very serious pest of legumes, sorghum, cotton, tomato, pepper, sunflower, safflower, flax and Niger seed. The pest also has alternative hosts like *Guziota scabra*, *Amaranthus* spp., *Hibiscus* spp., and *Gynandropsis gynandra*. In Ethiopia, this pest is found in most places where the host plants are grown. In the Amhara region, the pest is recorded in all administrative and agro- ecological zones except M_{1-8} and M_{3-8} (BOA, 1997). As an initial resort, the farmers have attempted to use conventional insecticides like organochlorines, organophosphates, carbamates and synthetic pyrethroids. However, the development of resistance by *H. armigera* to many insecticides, especially pyrethroids, has been reported from elsewhere (Jaarsveld, 1994; Ahmad, 1994; Gunning, 1994; Armes, 1995) so provide warning signal that this approach is not susutainable. Alternative options for the suppression of *H. armigera* include botanical pesticides (plant products), besides cultural control, mechanical control, physical control, biocontrol and host plant resistance.

Much before the advent of synthetic organic insecticides, neem, pyrethrum, rotenone, nicotine, ryania, sabadilla and number of other lesser-known botanical pesticides were used to protect agricultural crops from the ravages of insect pests in different parts of the world (Dhaliwal and Arora, 2000). They have been used as insecticide in different regions of the world since antiquity. However, after the advent of modern insecticides their role in agricultural production dramatically declined, particularly in the developed countries. The need for botanicals is especially felt by resource-poor farmers in the developing countries due to the high cost and unavailability and/or expiration of insecticides. Plant materials with pesticidal property (botanicals) could therefore play an important role in filling in such need. The objective of the present paper is to review the research work carried out on botanicals with particular emphasis to *Helicoverpa* management and their role in Ethiopian agriculture.

History of Botanicals in Pest Control

According to Flint and van den Bosen (1981), the use of botanicals to control insects began with the development of agriculture, the establishment of permanent settlements, and the introduction of a life-style that required the storage of greater or lesser quantities of food and other items, that concerted efforts to control a large variety of pest organisms became necessary. For instance, by 1200 BC, plant-derived insecticides were developed for seed treatment and fumigation uses in China. Similarly, in 200 BC the Romans Cato used oil sprays, oil and ash ointments as insecticide and false white hellebore (*Veratrum album*, or *V. virides*) as rodenticide. Pyrethrum was used as an insecticide in Persia and Dalmatia in the 18th and 19th centuries. And tobacco plant preparations have been similarly used in the Middle East for nearly two centuries. Moreover, plant derived chemicals such as pyrethrum; rotenone and nicotine were used for pest control in the West for decades (Ahmed and Stoll, 1996).

Promising Botanicals

Botanical pesticides are substances of plant origin and extracted from different parts like seed, flower, leaves, stem, rhizome, bulbs and roots. They may be crude preparations of plant parts ground to produce a dust powder or emulsion that may be used either directly or after dilution in carriers such as clay, talc, diatomaceous earth or water preparations dusts are known to be made from pyrethrum daisy flowers, cube roots (rotenone), Sabadilla seeds, ryania stems or neem leaves, fruits and bark. These extracted chemicals may repel the pest insects, deter them from feeding and oviposition on the plants, disrupt the normal behaviour and physiology of the insects and even prove toxic to the developmental stages, besides acting as synergists in combination with other conventional insecticides.

Ahmed and Stoll (1996) and Vyas *et al* (1999) have reported that more than 2400 plant species around the world are known to possess pest control properties. The plant species identified belong to 235 plant families differing greatly in the pests they control or are alleged to control, the type of pest control activity they exhibit, and their complementary uses. Using these plant species, about 2402 pests (including animal diseases) have been known to be controlled. Some of the promising pesticidal plants along with their known effects against *H. armigera* on respective crops as known in literature are listed in Table 1.

Sundararajan (2001) evaluated the effect of leaf methanolic extract of *Alstonia venenata, Ailanthus excelsa, Abutilon indicum, Achyranthes aspera* and *Azima tetracantha* under laboratory conditions against this pest on tomato. *A. venenata* gave up to 73% larval mortality, whereas *A. tetracantha* resulted in the lowest (51%) larval mortality. Babu *et al* (2000) reported the synergistic effect of methanolic neem seed kernel, *Pongamia pinnata* seed and *Vitex negundo* leaf extracts on *Helicoverpa* in cotton. Although the effectiveness of neem seed kernel extract alone was high, its mixture with the other extracts increased feeding deterrency, mortality, delayed the metamorphosis and decreased the fecundity of this pest.

Extracts *Annona squamosa, Catharanthus roseus* and *Nerium oleander* were evaluated under laboratory condition against *H. armigera*. The results revealed that *A. squamosa* was more lethal than the other plant species (Sonkamble *et al*, 2000). Sundararajan and Kumuthakalavalli (2001) showed that *Toddalia asiatica* had more antifeedant and mortality effect activity than *Gnidia glauca*. Vyas *et al* (1999) evaluated the influence of methanolic seed extracts of *A. squamosa, Jatropha curcas, Bassia latifolia* and *Madhula longifolia* on *H. armigera, Spodoptera litura* and *Earias vittella* vis-à-vis commercial neem formulation (Achook). The result was that individual plant extracts were highly effective in affecting the biology of the insects and among the insect species tested *H. armigera* and *E. vittella* appeared to be more susceptible compared with *S. litura*. Similarly, essential oils from *Cymbopogon flexuous, C. martini, C. winterianus, Tagetus minuta, Ocimum basilicum, O. gratissimum,* and *O. sanctum* resulted in high reduction in feeding activity of the second instar of *H. armigera* on cotton and chickpea under laboratory condition (Rao, *et al*, 2000). Moreover, *Derris elliptica, D. malaccenis* and *D. wiginosa* are perceived as promising in controlling *Helicoverpa* (Stoll, 2000). Dusting of chilli powder plus ash powder into the leaf sheath is also reported to be effective for the suppression of African bollworm (Stoll, 2000).

Research in Botanicals for ABW Control in Ethiopia

In Ethiopia, about 30 plant species are recorded as pesticidal plants used by the farmers traditionally and most of them are used for the management of storage pests (BOA, 1997; Tesfahun *et. al*. 2000; Tesfaye and Gautam, 2001).

A study was carried out to evaluate the efficacy of some plant species in controlling *Helicoverpa* in chickpea at Debre Zeit Agricultural Research Center. The results revealed that crude neem seed kernel extract (from Melkawerer) significantly reduced % pod damage due to *H. armigera*. This was followed by cow dung and endod seed extracts in combination with half dose of Endosulfan. Based on grain yield, however, the highest grain yield was obtained from chickpea treated with cow urine combined with half dose of Endosulfan (Table 2). The independent effects of products like cowdung or urine in pest suppression and crop growth promotion need to be quantified, so to assign roles for their overall effect on pod damage and yield.

- Modern agriculturalists tend to believe that pest problems can all be solved with chemical pesticides. This tendency has a definite negative impact on the use of botanicals as insecticides.
- Lack of facilities for formulating and extracting botanicals and shortage of qualified researchers in entomology is also a constraint.

Neem Botanical Pesticide

Neem is a fast growing tree, which is native to Indian subcontinent, but now distributed across more than 50 countries in the world (Asia, Africa and Central America). It grows well in climates from semi arid to semi humid and thrives even in places with less than 500mm of rain per year. The soil requirements are modest and neem grows equally well on poor, shallow, sandy or stony ground (Rankin, 1985). The trees can bear fruits when they are 4-5 years old, on average giving 30 – 50kg of fruit per tree. The effective ingredients are present in all parts of the tree but are most highly concentrated in the seeds (Saxena, 1981). Neem has diverse mechanisms of biological effects on insects. No synthetic chemical or plant origin material is known to occur which has such diverse biological effects on insects as neem. Till today, 450 to 500 species of insects have been tested with neem products at global basis and 413 of these are reportedly susceptible at different concentrations. Among the various biological effects, antifeedant and growth retardant effects of neem are very important. In general, different neem formulations have been recommended for control of *H. armigera* occurred in various crops (Table 2). For instance, using neem seed extracts in chickpea, Sehgal and Ujagir (1990) obtained significantly lower pod damage than in the untreated plots. Similarly, Sadawarte and Sarode (1997) found neem to be effective at 5 or 6 % in controlling the same pest and they concluded that neem seed kernel extract can be used in place of the highly toxic synthetic insecticides because of its safety to beneficial insects and its lowest cost. Moreover, Lingappa *et al* (2000) achieved high reduction in damage by *Helicoverpa* to fruiting bodies of cotton, through using a neem based formulation containing 0.3% azadirachtin (econeem) alone or in combination with *Bacillus thuringiensis* or nuclear polyhedrosis virus. Ma *et al* (2000) obtained a similar result on upland cotton in Australia and as opposed to the synthetic insecticides, the botanicals used were found to be safer to the predators, including coccinellids, chrysopids, Araneae and Hemiptera.

Abdullah *et al* (2001) observed that the application of neem extract against *H. armigera, S. litura, S. exigua, Melanagromyza sojae, Lamprosema indicata* and *Etiella zinckenella* did not affect their incidence in soybean. Also, the use of neem alone or in combination with *B. thuringiensis* or broad-spectrum conventional insecticides failed to check the incidence levels of *Helicoverpa* in cotton (Gupta *et al* 1999). Similarly Kulta *et al* (1999) reported a similar result on neem seed extract applied on chickpea to control this pest. The differential content of azadirachtin and dose rate adopted may be the major reason for such results; besides possible genetic or management variations among the neem, trees from which the seeds were obtained and the lack of specific information on the horticultural and climatic conditions that maximize its potency (NRC, 1992).

Neem can be prepared as aqueous extracts, neem oil, neem kernel powder, and neem press cake. Neem products of RD-9 Replin (1 and 2%), Neemark (0.5 and 0.75%) and Neemrich 20EC (0.1 and 0.15%) have been compared with quinalphos (0.2%) as standard for their control action against young larvae of *H. armigera* in cotton. Replin and Neemrich at the highest concentrations were more effective than Neemark in the crop spraying experiments (mortality levels of 70, 70 and 66.7%, respectively), but less effective than quinalphos (mortality of 100%) (Dhawan and Simwat, 1995). Manoharan and Uthamasamy (1993) found that addition of *A. indica* oil to endosulfan and phosalone increased the mortality of *H. armigera* larvae by 16.7 and 25.0%, respectively as compared with insecticide alone, while addition of sesame oil to fenvalerate, cypermethrin and alpha- cypermethrin increased the mortality by 35.0, 20.0 and 41.7%, respectively. For the control of *H. armigera* at the prepupa and pupa stages, the pupation site was treated with 0.5– 6% neem seed powder on a W/W basis. Abnormal adult emergence and death during the prepupal stage increased with increasing NSP concentration. The ED_{50} (median effective dose) for suppressing adult emergence was calculated to be 2.902% of NSP in soil on a w/w basis (Gupta *et. al.*, 1998).

Garlic and Ginger as Botanicals

Garlic *(Allium sativum)* is a cosmopolitan plant, which grows in temperate zones as well as in the tropics and subtropics. It is easy to cultivate in the field, garden and backyard, on a wide range of soils. The extract products are best used preventively. The plant parts used for insect control are bulbs, whereas the effective range would be insecticidal, repellent, antifeedant, bactericidal, fungicidal, nematicidal and effective against ticks. For the best management of insects, garlic can be used as aqueous garlic extract, garlic emulsion, garlic-pepper extract and garlic green-chilli extract (Stoll, 2000). Farmers have found that 500g of garlic-cloves crushed and mixed with some kerosene and left overnight then filtered the next day and again mixed with 100 ml of liquid detergent, which then forms the stock solution. For field application, 25 ml of this stock solution diluted in 16 liters of water has been found to be highly effective against cotton bollworm and pod borer (Rahudkar, 1993). Ginger (*Zingiber officinale*) has also been used as a mixture with garlic and chilli (Vijayalakshmi *et. al*, 1997).

Scope for Botanicals in IPM of *H. armigera*

First, unlike insecticides, which affect the nerve system of the insect, botanicals often have wide modes of action, which helps minimize the likelihood of developing resistance to it. For instance, neem leaf extract adversely affects the gonadal weight, fecundity rate, egg fertility, and chitin content of *H. armigera* (Sharma *et al*, 1999a, b). Also, Padmaja and Rao, (1999, 2000a, b) found that application of *Artemisia annua*, *Ageratum conyzoides* and neem oil on *Helicoverpa* reduced the overall mean protein concentration in the blood and haemolymph than the untreated larvae. Second, botanicals are compatible with themselves or microbial pesticides (Lingappa *et al*, 2000). Thirdly, botanicals are friendly to the natural enemies of *H. armigera* (NRC, 1992, Ma *et al*, 2000). For instance, Qi *et al* (2001) reported that when predators (ladybird beetle, *Mallada signatus*) feed on prey (*Helicoverpa*) treated with azadirachtin, the pupation of the predator was delayed i.e. the duration of the larval stage was extended. This in turn increased the number of *Helicoverpa* larvae consumed per individual predator. Besides, botanicals are affordable and readily available than commercial insecticides; also, they provide shade, wood for construction, fuel, fencing etc and protect soils from erosion. Thus, these merits make them readily acceptable as an integral component of IPM by small-scale farmers.

For implementation of IPM, there are options of various tactics like cultural, mechanical, host plant resistance, biocontrol agents that can be integrated with botanicals. However, the ideal situation would be if the methods to be integrated help conserve the natural enemies and selectively suppress *H. armigera* on our high values and staple crops. It is generally believed that neem extracts could help conserve natural enemies and hence neem is recommended even where the predators/parasitoids are active in the crops. In general, botanicals tend to be broadly compatible with other components (cultural, mechanical, host plant resistance, and biocontrol agents) of IPM.

Table 1. List of promising plant species repeated to show pesticidal properties against African bollworm, *H. armigera* in some target crops

Crops	Plant species	Plant parts used	Range of control action
Cotton	*Derris elliptica*	Roots	Insecticidal, repellent, Contact and stomach poison
	Allium sativum	Bulbs	Insecticidal, repellent, antifeedant
	Azadirachta indica	Seeds, leaves, stem, bark	Insecticidal, repellent, growth inhabiting
	Chrysanthemum cinerariefolium	Flowers	Insecticidal, repellent, antifeedant
	Rynia speciosa	Stem, Roots	Contact and stomach poison, antifeedant
	Tephrosia vogelii	Leaves, Roots	Antifeedant, insecticidal, ovicidal
	Zingiber officinale	Rhizome	Repellent, insecticidal
	Melia azadarach	Leaves, Bark and fruit	Repellent, Oviposition deterrent, antifeedant, insecticidal, growth inhabiting
	Tinospora crispa	Full grown vine stem either dried or fresh	Ovicidal, antifeedant, insecticidal, growth inhabiting
Maize	*Derris elliptica*	Roots	Insecticidal, repellent, Contact and stomach poison
	Allium sativum	Bulbs	Insecticidal, repellent, antifeedant
	Azadirachta indica	Seeds, leaves, stem, bark	Insecticidal, repellent, growth inhabiting
	Chrysanthemum cineraefolium	Flowers	Insecticidal, repellent, antifeedant
	Rynia speciosa	Stem and roots	Contact and stomach poison, antifeedant
Chickpea	*Azadirachta indica*	Seeds, leaves, stem, bark	Insecticidal, repellent, growth inhabiting
Pigeon pea	*Azadirachta indica*	Seeds, leaves, stem, bark	Insecticidal, repellent, growth inhabiting

Source: Stoll, 2000

Table 2. Examples of recommendations of neem based pesticides for *H. armigera* management.

Neem products	Crop	Dose rate range	Reference
Formulation containing *Azadirachtin* 0.03%(300ppm)	Cotton Chickpea Cowpea Field bean	0.5 – 3.75 litres 1.2 – 1.5 litres 1.6 – 2.0 litres 0.8 – 1.5 litres	Sehgal and Singh, 2001
Formulation containing *Azadirachtin* 0.15%(1500ppm)	Cotton Tomato Field bean	0.5 – 5 litres 3.25 litres 2.0 litres	Sehgal and Singh, 2001
Formulation containing *Azadirachtin* 0.3%(3000ppm)	Cotton	2.5 litres	Sehgal and Singh, 2001
Formulation containing *Azadirachtin* 0.5%(5000ppm)	Cotton Tea Tobacco	0.375 – 1.0 litres 0.2 litres 0.2 litres	Sehgal and Singh, 2001
Fresh leaves of *A. indica*	Beans	350gm/liter of water	Schmutterer, 1995
NSKE with soap mixture	Chickpea	NSKE50% with 1% soap	Srivastava, 1999

Research Gaps and Needs for Promoting Botanicals

Currently, adequate attention is not given to the use of botanicals, while there is now new awareness emerging on the potential use of insecticidal plant species in Ethiopia. Therefore, survey and identification of pesticidal potential of plants needs to be undertaken. We should focus on optimizing the dose rates and ascertain the active compounds responsible for *H. armigera* control among known botanicals, which occur in Ethiopia. Efforts are to be made to develop formulations that can be stored and used. There is a need to identify effective surfactants, emulsifiers and carriers for use in combination with botanical insecticides. Efficacy evaluation of botanicals at laboratory, green house and field conditions against ABW, should be undertaken on major target crops and followed up by large scale multilocational validation/demonstration to popularize the use of promising plant products. In addition, media coverage to generate awareness is quite important. Developing suitable guidelines for registration of botanical pesticides could facilitate quality control. Training and equipment are also required for establishing a good botanical pesticides laboratory within the country.

Conclusion

The ultimate objective of applied research is to commercialise the plant product, which may range from consultancy to manufacturing the product. In short, we should be in a position to exploit plant products available even in the marginal areas. National research and developmental institutions involved in *H. armigera* management should jointly seek for suitable opportunities to utilise botanicals.

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Use of Pheromone Traps for *Helicoverpa armigera* Management

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Abstract

Monitoring the populations of a highly mobile and polyphagous pest like Helicoverpa armigera requires holistic approach to the components of the target cropping systems. Pheromone technology for H. armigera has been shown to assist in pest population monitoring as well as in other methods including mass trapping, enhancing biocontrol impact and pesticide resistance monitoring. Deployment of pheromone traps is useful in understanding the adult population trends in H. armigera. There is scope for refining the trap type and positioning of traps in relation to the location of target crops. The major factors which to influence the trap catches could be studied and suitable corrections worked out to evolve a dynamic model. Correlation of the trap data with the egg and larval density on the target crops should be undertaken with due consideration of crop phenology and relative abundance of target crops grown in the vicinity. Research conducted elsewhere on H. armigera pheromone trapping has shown potential for taking decisions on preventive and curative interventions, especially the need for using pesticides. In Ethiopia, limited efforts were made on pheromone research mainly in relation to cotton and chickpea. Recent pheromone trap observations in Debrezeit and Akaki under EARO-ICIPE-ICRISAT collaboration provide a basis for inter-site comparisons. A national grid of pheromone traps could be established in Ethiopia with benchmark sites, which can also be involved in assessing the relationship between weather factors, trap catches and pest load on selected target crops. Besides providing baseline information, which could lead to short-term predictions of pest severity, monitoring with traps can also be utilized in building up awareness and motivation about H. armigera management among the farmers.

Monitoring and Forcasting

Pest monitoring is regarded as a useful tool in decision-making by farmers at the grassroot level. While crop inspection/scouting provides direct information for control interventions (curative), monitoring the adults of the pest with traps could provide advance information (short-term forecasting) leading to suitable decisions on preventive and/or curative control actions. It is aimed at detecting the dynamics of a particular pest, timing of control measures, or assessing the risk posed by the target pest. The process of monitoring/ detection includes, early warning of pest incidence, survey to define infested areas and arrival of quarantine pests in pest-free areas (Wall, 1990). With regards to insect pest management, the population dynamics of a pest species may not be precisely known but long term monitoring can help to elucidate patterns in population life cycles. These patterns can then be combined with the known biology of the insect to define the parameters of an effective control campaign. Pest population must be regularly monitored in pest management programs in order to decide when to apply control measures. Monitoring systems for pests and their natural enemies must be designed to suit the pest in question and must be practical in terms of time and labor involved. Therefore, cost of monitoring is an important factor in any pest management program.

Pest monitoring has been used in pest management for:

- Preventative actions - through prediction of impending seasonal severity
- Curative interventions - for deciding on 'whether' and 'when' to intervene

Some of the monitoring tools for arthropods pest include:

- Physical sampling: Net sweeps, dislodging
- Physical trapping: Sticky traps, pitfall traps, pan traps
- Attraction trapping: Bait traps, light traps, pheromone traps

If forecast could indicate the extent of severity of the pest in the season, it is possible to plan to intervene with preventive practices like:

- Planting tolerant cultivars, if target pest is likely to be severe
- Encouraging cost effective prophylactic application (e.g. Seed coating)

Pheromone for *H. armgiera*

Major Components

In general, *H. armigera* pheromones are known to be made up of two main compounds, (Z) – 11 – hexadecenal and (Z) – 9 – hexedecenal and their ratios are in the range of 10:1 to 97:3. The composition of its pheromone was first discovered by Piccardi *et al.* (1977) who published evidence that (Z)- 11-hexadecnal is a component of the female sex pheromone in this species and he suggested that additional components were probably present. Based on this suggestion, Nesbitt *et al.* (1979) reported the identification of up to five pheromone components in abdominal tip extracts of female *Heliothis armigera* and in volatiles emitted by the virgin female moth. These were (Z)-11-hexadecenal (I) the major component previously identified by Piccardi *et al.* (1977), (Z)-11-hexadecen-1-ol (II), (Z)-9-hexadecenel (III), Hexadecenel (IV) and 1-hexadecenel (V). Later, Campion and Nesbit (1981) listed the identified and synthesized sex pheromones of twelve moth species including *H. armigera*. These synthetic pheromones have been field tested in traps and, in most cases, have been shown to be comparable in attractancy with the virgin female moth.

Use of Pheromone

Pheromone technology for *H. armigera* has been used for different purposes such as:

- Mating disruption (e.g. Cotton – Brazil, Pakistan),
- Trapping for population monitoring (e.g. Tomato, maize – New Zealand)
- For insecticide resistance monitoring (e.g. Israel, New Zealand)
- Use in activating parasitoids (e.g. *Trichogramma* – India, USA)

Pheromone trap collected *H. armigera* moths in cotton fields of Israel were used to assess the insecticide resistance against major group of insecticides (Horowitz *et al.*, 1993) in Israel and in New Zealand in 1991 (Cameron *et al.*, 1995). Sex pheromone of *H. armigera* (Helilure) was found to attract the egg parasitoid, *Trichogramma chilonis* Ishii (Padmavathi and Paul, 1996) and *H. zea* attracted *Trichogramma pretiosum* Riley when tested under laboratory conditions (Noldus *et al.*, 1990).

Types of Pheromone Traps/ Septa

Laboratory and field studies carried out Hebei, Shandong and Shanxi Provinces of China revealed that Z-11-hexadecan-1-ol and Z-9-hexadecen-1-ol were the main pheromonal components and when baited with green septa impregnated with 1.94 and 0.06 mg of the above components, resulted in two to three fold reductions in pesticide application (Zebitz, 1997). The catches of *H. armigera* were found to be more during 0200 to 0400 and 1000 to 0200 hours with optimum blend ratio of 97:3 (Kumari and Reddy, 1992). In Haryana, field tests with chickpea revealed that sleeve traps were as effective as the double cone trap having 10 cm diameter and 3 cm clearance between the collar and hood, placed 1.0 to 2.2 m above the ground level with lures impregnated with 5 mg each of pheromonal components (Sinha and Mehrotra, 1993). Pheromone dispensers made of rubber and cork septa were found to catch more males than cigarette and filter paper when loaded at the rate of 1 mg per septa than with lower concentrations (Krisha Kant *et al.*, 1998) and higher concentrations of sex pheromone were inhibitory and delayed peak catches by 2 to 5 days. The efficacy of funnel, sleeve types and sticky traps was tested in the fields of Tikamgarh, India during 1992-1994 (Rai *et al.*, 2000). The pheromone at 4 mg/trap lasted for more than 30 days having little difference between plastic and rubber dispensers with either water trough or sticky traps (Yong *et al.*, 1989). In Australia, Wilson and Morton (1998) reported that using cone trap and placing it within the crop led to a higher catch of *H. armgiera* than funnel trap and placing them at the edge of the crop. They also identified among the factors affecting trap catch as trap location, aspects, wind speed, and insecticide applications. Traps placed in the edges of tomato field and wind speed have been found to affect the trap catches of *H. armigera* in New Zealand (Herman *et al.*, 1994).

Commercial Dispensers of Pheromones

Commercial dispensers of pheromones are available for different purposes:

- For monitoring - Rubber septa, Polythene vials, Polyvinyl chloride dispensers
- For mating disruption - Plastic hollow fibres, Plastic laminate flakes, Plastic tubes dispenses, Polymeric aerosol suspensions, Twist – tie Shin Etsu ropes

Assuming that the major technical difficulties associated with the production and formulation of pheromones are being over come, then as control agents, pheromones have the potential advantage of low mammalian toxicity, they are moreover less likely than conventional pesticides to lead to the development of resistant insect strains. Also, they are inexpensive method of control (Campion and Nesbitt 1981). Moreover, mating disruption with pheromones or mass trapping is important in IPM because beneficial insects are more numerous compared with areas treated with insecticides (Table 1).

Enhancing the Potential of Pheromone Traps

Sex pheromone traps against *H. armigera* with 97:3 mixtures of Z-11- hexadecenal and Z-9-hexadecenal in pigeonpea and chickpea were found effective in predicting the forthcoming field population (Lal *et al.*, 1985). Saturation of air with pheromone components at 1:10 mixture of Z-9-hexadecenal and Z-11-hexadecenal at 100 mg/ha, 3-5 or 60-70 cm above ground level resulted in disorientation of insects towards traps in cotton fields of Tajik SSR, USSR (Bulyginskaya *et al.*, 1989). The optimum dose of microencapsulated formulation coated with either single or double coating of polyamide and gelatin was 50 mg/ha of 1:10 mixture of Z-9-hexadecenal and Z-11-hexadecenal for duration of 17-18 days (Shamshev *et al.*, 1989). Difference in male attraction among the four commercial formulations when used in sweet corn at 9 sites in Connecticut, Massachusetts and Rhode Island was observed by Gauthier *et al.* (1991). The need for reference standards in management programmes that use pheromones to monitor the population was suggested.

Pheromone *vs* Light Traps

Light trap and pheromone traps are important tools in ecological research and pest management with *Helicoverpa* species. Pheromone traps are used as a means of insect monitoring and control in different parts of the world. Pheromone traps have the advantages over the conventional light traps that only the target species is attracted and a trained entomologist is not therefore required to identify the trap contents. Moreover, they are easier to operate than light traps and require no source of electricity; these are of particular importance in remote areas.

Monitoring *H. armigera* by Pheromone Trapping

Most of the research on use of pheromone technology for trapping of *H. armigera* has so far been in China, India, Israel, New Zealand and Russia (Dunkelblum *et al.*, 1980; Kehat and Dunkelblum, 1993; Kehat *et al.*, 1998; Natarajan *et al.*, 2002 unpubl.). The development of sex pheromone trapping of *H. armigera* under a national level grid was pursued by ICRISAT in the 1980s in India (Pawar *et al.*, 1998). Attempts were also made in Tanzania (Nyambo, 1989).

Pheromone Trapping for Timing of *H. armigera* Management

Use of pheromones for monitoring *H. armigera* in tomato and maize fields in New Zealand resulted in reduced crop inspection time and more accurately timed insecticide application (Walker and Cameron, 1990). Short term forecast for 5 days could be worked out based on the moth catches of *H. armigera* in Azerbaidzhan, USSR and time the release of *Trichogramma* spp against bollworm (Mamedova *et al.*, 1988). A total of 30-40 males of *H armigera* trapped in 3 days were found to a reliable indicator of exceeding threshold level of 3-5 larvae/ 100 cotton plants in Tadzhik, USSR indicating the need for intervention measures (Grechanov, 1986). Prasad *et al.* (1993) found that action for controlling *H. armigera* in cotton was to be taken when seven adults per sleeve trap was caught. Initiating integrated pest management practices against *H. armigera* when 7 moths per trap per night per 40 hectare area was observed, was found to be superior in terms of both cost versus benefit and environmental safety over that of farmers practice of using conventional insecticides (Reddy and Manjunatha, 2000).

Pheromone trap catches were used to study the phenology of *H. armigera* in chickpea crop in Pakistan (Anwar and Shafique, 1994). In Pakistan, research was made on pheromone to control the three species of cotton bollworms present in Punjab region. As a result, there are now two pheromone formulations available with which it is possible to control the three major bollworm species of cotton in Pakistan. Trials have demonstrated clearly that larval infestation by these three species can be reduced and yield of seed cotton increased by a single early season application of either of the formulations containing both pheromones. Numbers of insecticide application to control secondary pests are also reduced. These resulted in an increased number of beneficial insects in the pheromone treated areas, which contributed to reduced level of attack by potentially serious pests such as *Helicoverpa armigera* and *Bemisia tabaci* (Chamberlain *et al.* 1994).

Indian Experience of *Helicoverpa armigera* Monitoring with Pheromone Traps

In Andhara Pradesh, India, small rubber burette stoppers with 2 mg of pheromone serving for four weeks for getting more catches of *H. armigera* with a white funnel trap (ICRISAT trap) by placing above the crop canopy in sorghum, millet, pigeon pea, chickpea and groundnut were recommended (Pawar *et al.*, 1988). *H. armigera* was found to be active throughout the year except during summer months (Naik *et al.*, 1993; 1996) by using traps developed by ICRISAT, Ecomax and Pest Control India (Kulkarni and Patil, 1996) in Karnataka, India. Maximum moth catches were observed in the months of November to January with significant role of weather factors in the fields of Karnataka (Patil *et al.*, 1992).

H. armigera was found to be abundant during mid March to first week of May (Chaudhry *et al.*, 1995). Maximum flight activity of the insect was observed between 0300 and 0400 h in Kumaon Hill regions of Uttar Pradesh (Prasad, 1996). Male moth catches in cotton fields varied with cultivars used ranging from 5.33 in cv. LRA to 19.67 in TCHB 213 hybrid per trap (Loganathan and Uthamasamy, 1998) and the pheromone dispersion from the carbon free septa was up to 13 days (Loganathan *et al.*, 1999). Sex lures of other cotton bollworms when combined in one trap reduced the trap catches of *H. armigera* than when used alone (Muthukrishan and Balasubramanian, 1999). Trap catches of *H. armigera* were found to differ between new moon and full moon period, and wind velocity and maximum temperature exhibited negative correlation (Rajaram *et al.*, 1999).

ICRISAT, in collaboration with the "All India Coordinated Pulses Improvement Project (AICPIP)", developed a network of pheromone traps in different agro-climatic zones of India in 1981 (Pawar *et al.*, 1983). Almost all of the cooperators were agricultural entomologists who operated the traps on research farms attached to Universities or agricultural institutes. One of the objectives of this network was to monitor *H. armigera* populations throughout the year at many locations in order to determine the seasonal incidence of this pest and the maximum threat periods for target crops in each location. Information was also generated to identify crop durations and sowing dates that might help the crop's most susceptible stage to avoid peak infestations of *H. armigera*.

Spatial and temporal distribution of *H. armigera* with pheromone traps in India revealed that the pattern of catches was similar within any agroclimatic zone, but varied with different latitudinal locations (Srivastava *et al.*, 1990). Performance of light and pheromone traps of *H. armigera* was compared in different parts of India by Srivastava *et al.* (1992) who concluded that at southern locations both the traps were to be used for monitoring and in central and northern locations, pheromone trap catches would give a good prediction. The flight patterns of *H. armigera* as well as the duration and timing of peak catches at individual locations were almost similar over the years, but the magnitude of the peaks varied. Overall, the variability of the data was relatively small, as can be seen from the minimum, maximum and mean standard errors of the mean trap catches for each location (Table 1).

In most southern locations (e.g. Coimbatore and Paiyur), the pheromone trap catches were generally lower than those recorded at northerly locations, and without well defined peaks. At these locations, night temperatures (<10°C) during winter are not low enough to limit *Helicoverpa* activity. *Helicoverpa* populations thus tend to remain active throughout the year.

However, high temperatures in summer may also affect egg, larval and pupal development and survival. The dry summer high temperatures in peninsular India are associated with low humidities. The combined effects of low humidity and high temperature on mating and oviposition may be responsible for the annual population decline observed at all locations. For example, night time relative humidities in Patancheru (zone 13) during April and May (standard weeks 14-22) fall as low as 50%. This is well below the level suggested by Roome (1975) to inhibit mating. In addition to the debilitating effects of the physical environment on the pest's survival during the summer season, the dearth of crop hosts can further limit the abundance of *H. armigera* at this time of the year.

The possibility that moonlight and the different phases of the lunar cycle (within and between months and years) might influence pheromone trap catches was investigated. However, unlike for light traps, moon illuminance levels apparently have no effect of pheromone trap catches (Dent and Pawar, 1988).

The trap relationship between mean pheromone trap catches and larval populations estimated from counts on all hosts are shown for one of the Southern locations in Fig. 1. Correlations between pheromone trap catches and larval populations averaged for 1981-1988 are high and positive: +0.82 for the same week and +0.76 when catches of week (n=1) were related with larval counts for week (n=0) (Table 1). However, when data are analysed on an annual basis a more composite picture emerges. For 3 out of the 7 years for which data are available on the relationship between trap catches and larval population estimates, correlations are poor (Table 2). Good correlations were only observed during the years 1984-1985 to 1987-1988. The pheromone traps therefore provided reliable information for pest monitoring and forecasting only in 4 out of 7 years at Patancheru (zone 13). However, the AICPIP entomologists reported consistent positive relationships between pheromone trap catches and immature stages of *H.*

armigera in the field at Kanpur. In Udaipur (Rajasthan), a good relationship was also found between pheromone trap catches, egg, and early instars of *H. armigera* in chickpea fields (Srivatsava *et al.*, 1990).

The simplistic conclusions derived from *H. armigera* pheromone trap network in India are as below:

- The agro-climatic zones were characterized by almost similar pattern of trap catches
- Almost similar flight patterns as well as duration and timing of peak catches at individual locations were observed over the years, though peaks varied
- There were obvious changes with latitudes in pattern of trap catches
- The distribution and abundance of *H. armigera* in each agro-ecological zone are partly determined by the presence and relative abundance of its preferred host plants.

Past and Ongoing Research in Ethiopia

Light trap Monitoring Undertaken in Werer

Monitoring of African bollworm and other cotton insect pests in Ethiopia was started in 1956 with the establishment of IAR (MWRC), as field observation and light trap catch. Adult moths of important insect pests of crops grown in the Werer Research Center and the vicinity (cotton, groundnut, Sesame, wheat and maize) were monitored using 200watt light trap. The light trap was functional throughout the night starting 6.00 pm. The light trap catch (Table 3), for the 20 years indicated that higher *Helicoverpa* catches were observed starting from June and continued to October with most peak occurring is in August. Onfarm *H. armigera* incidence has also been monitored by a standard sampling procedure, as part of surveys.

Pheromone Trap Monitoring at Werer Research Center

On-station monitoring of adult *H. armigera* as a key pest of cotton has also been undertaken at the Cotton Research Center in Melka Werer. At Werer research center, pheromone trap was used for the first time in 1981/82 cropping season. Pheromone trap was used to monitor adult pink bollworm, *Pectinophora gossypiella*; spiny bollworm, *Earias Insulana/biplaga*, cotton leaf worm, *Spodoptera littralis* and *Helicoverpa armigera* during the main season and armyworm, *Spodoptera exempta* throughout the year. The pheromone trap catch also indicated the same trend of ABW moth catch as for the light trap at the site (Table 4). These catches were consistent with the field count of ABW eggs and larvae (Table 5), (IAR, 1987).

Pheromone Trap Monitoring at Debre Zeit Research Center

Pheromone trap studies were also initiated at Debrezeite Research Center, to monitor seasonal distribution of African bollworm in this region where it is a common pest, during 1988-1989 cropping seasons. The result revealed that during the growing season's sharp population increase was observed from November to January both in 1988-1989 (Fig. 2). After January, moth populations decreased and the lowest record was in April – May. However, moth population increase was again observed in Jun 1989-July 1988. After August, the population began to decline. The pattern of moth activity for both years was similar, but the total moth catch of 1988 was greater than of 1989. From these observations, it appeared that *H. armigera* had two generations a year around Debre-Zeit area (Fikru and Tibebu, 1990).

Under a joint ICIPE-ICRISAT-EARO collaboration in chickpea IPM, ICIPE secured and supplied pheromone traps. EARO scientists at Debrezeit and Akaki, made observations on trap catches. It was possible to plot the seasonal pattern of trap catches in these two chickpea growing sites. The results are given in Fig 3. Observations to link trap catches with *H. armigera* larval numbers on chickpea in onstation plots are being pursued.

Pheromone Trap Monitoring at Ambo Plant Protection Research Center

As part of EARO-ICIPE collaboration on African bollworm biological control, pheromone trap monitoring has been initiated in 2001. Egg number of *H. armigera* is also being monitored weekly on six target crops (tomato, capsicum, okra, cotton, pigeonpea, and sunflower) in two seasons per year.

Table 1. Correlation between pheromone trap catches and larval population estimates of *Helicoverpa armigera* at ICRISAT Center, Patancheru, June 1981 to May 1988

Period	Trap catches	Larval population estimates
1981 - 1982	0.43	0.30
1982 - 1983	0.60	0.53
1983 - 1984	0.42	0.36
1984 - 1985	0.75	0.74
1985 - 1986	0.63	0.59
1986 - 1987	0.73	0.73
1987 - 1988	0.73	0.63

Source: Srivatsava et al (1990)

Table 2. Numbers of predatory insects per hectare sampled by D-vac suction in cotton fields treated with pheromones compared with insecticide treated fields, 1982 in Egypt. *

Insect	Mean number per plot	
	Insecticide treated	Pheromone treated
Coccinellid adults	33	122
Paederus adults	17	322
Scymnus adults	33	55
Chrysoperla adult	100	689
Chrysoperla larvae	17	67
Orius adult	550	1145
Total	749	2400

**Adapted from Matthews (1989).*

Table 3. Light trap catches of African bollworm (*Helicoverpa armigera*) moths, Melka Werer, Ethiopia 1971-88 (monthly total)

	Month												
Year	M	A	M	J	J	A	S	O	N	D	J	F	Total
1971/72	4	19	3	1	3	2	23	27	12	5	9	5	73
1973/74	2	2	0	38	7	3	975	53	34	14	21	5	1154
1974/75	17	2	11	32	0	36	40	19	17	1	8	34	287
1975/76	24	1	5	0	0	0	0	4	7·	2	20	24	87
1976/77	29	0	0	13	35	59	36	38	9	0	20	24	263
1977/78	7	10	3	1	65	34	0	0	19	36	4	3	182
1978/79	0	0	0	0	0	0	0	22	18	0	13	0	60
1979/80	36	3	4	18	21	12	14	16	0	7	6	0	130
1980/81	-	0	29	10	96	350	6	-	-	0	-	-	491
1981/82	1	0	29	5	83	335	7	1	-	0	0	0	461
1982/83	0	-	0	0	2	-	2	3	0	-	1	1	9
1983/84	4	0	0	16	1	0	5	0	0	0	0	0	26
1984/85	1	0	0	8	6	0	34	9	1	0	0	1	63
1985/86	6	0	3	209	172	1231	69	7	3	3	3	5	1708
1986/87	1	0	2	-	-	29	1	4	2	4	1	3	47
1987/88	1	1	4	39	22	84	0	5	0	0	1	0	154
Total	137	39	95	300	555	2177	1217	228	141	73	114	105	5271

***Source:** IAR, 1987; Melka Werer Research Center (MWRC) Progress Report*

Table 4. Monthly total catches of *Helicoverpa armigera* moths in pheromone traps at Melka Werer, Ethiopia, 1981-83 and 2001-02.

Year	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
1981/82	-	-	-	-	-	59	18	8	8	3	0	0
1982/83	-	-	-	-	-	-	-	41	19	0	-	-
2001	-	-	-	-	-	-	7	142	199	41	19	43
2002	49	34	21+	NR	NR	NR	NR	NR	NR	NR	NR	NR

- NR = Not recorded
Source: Unpublished data of Werer Entomology section.

Table 5. Average number of African bollworm, eggs and larvae (based on 400 cotton plants sampled) in different months at
Melka Werer, Ethiopia, 1973 – 1982

ABW	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Egg	4.13	2.38	6.13	9.29	6.75	7.86	43.25	152.88	57.20	9.80	4.88	5.88
Larvae	1.00	2.88	1.00	1.14	0.50	2.00	20.13	46.25	24.30	0.80	6.00	2.22

Adopted from: IAR, 1985. Crop Protection Department Progress Report

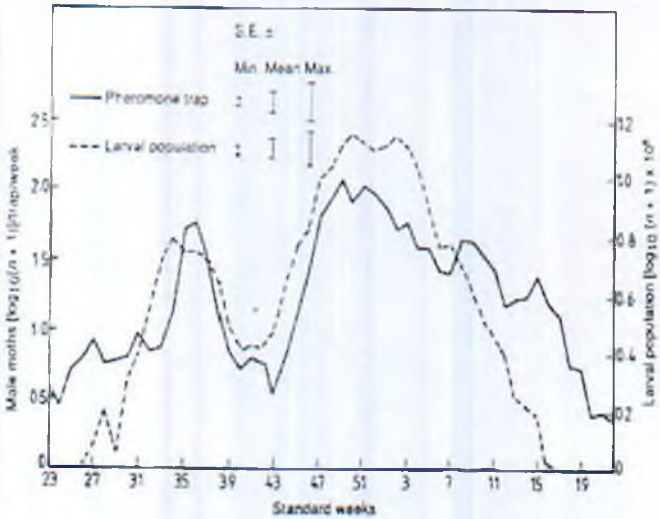

Fig. 1. Mean *H. armigera* trap catches and larval populations estimated from counts on all hosts per standard week, ICRISAT Center, Patancheru, India, 1981 June to 1988 May

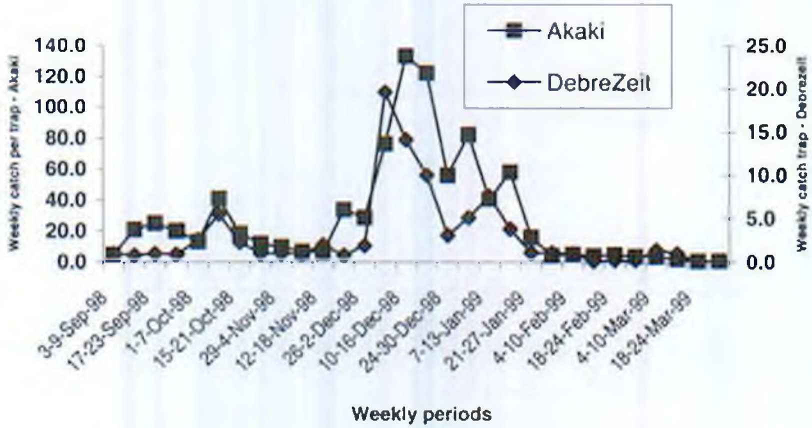

Fig. 2. Weekly average catches of adult *H. armigera* in pheromone trap at Akaki and Debrezeit,Ethiopia, Sept, 98 - April, 99
Source: Srivastava et al,(1990)

Vision

Pheromone Trap Network Monitoring

Based on the national importance of the pest (*H. armigera*) and the past on-station trapping experience, it is visualized that capacity for short to medium term forecasting could be developed by establishing a national network of *H. armigera* adult monitoring by pheromone traps. Because of their simplicity in handling and record, no major financial commitments will be involved except to secure and supply the traps and septa. The regional agricultural research centers and other research institutions could emerge as partners in the network. As the traps could be installed in or near the research centres, existing staff and resources should normally be adequate for recording the daily catches. Electronic/computer facilities presently available in the different network institutions could cater for data compilation. Training of senior–level scientists in data analysis/interpretation could provide the needed human resource back up. The roles that could be handled at different levels are illustrated below:

National lead in:

- Orientation training/capacity building
- Ecological modelling for forecasting

Regional role in:

- Local training for trap operators
- Coordination in trap management
- Liason in trap data compilation

Crop focus role in:

- Relating trap catch to crop damage
- Characterizing benchmark variables

Research and Capacity Building

The research and capacity building needs for establishing a national level pheromone trap monitoring network for *H. armigera* in Ethiopia are listed below:

National task team

1. Establish an advisory panel (including external experts e.g. ICIPE, ICRISAT)
2. Organise trap materials supply and orientation training for crop focus and regional lead scientists

Regional trap grid

1. Identify ecology-based bench mark sites for trap monitoring
2. Train site trap operators in handling and data collectionCrop focus research
1. Study major target crop in relation to planting pattern/crop phenology and associated host – for relating to trap catches
2. Arrange short-term training attachments (e.g. ICRISAT/NCIPM-India)

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Ecosystem Approach for Management of *Helicoverpa armigera* in Eastern Africa

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Abstract

The African Bollworm, Helicoverpa armgiera (Hb.) is a highly polyphagous and very mobile pest in Africa, Asia, Australia and Europe. In Eastern Africa, it is ranked as a key pest of several crops including chickpea, pigeonpea, cotton, tomato, tobacco, sunflower and linseed. From an ecological standpoint, the very wide spatial range of H. armigera populations requires the consideration of spatial and temporal scales. At the local scale, with the extent of a field, the pest population may be defined as a collection of individuals belonging to the same species. Various naturally occurring control factors as part of the life system may have an important role in the spatio-temporal dynamics. At scale extents comprising a farm or a landscape, the population may be defined on more biological grounds and a different set of natural control factors may be operating. Hence, the life system at meso-scale is different from the local scale. At national or regional scales, population definition and life system characteristics may be different. From a pest population management standpoint, the spatial range of population occurrences falls into many man-made management (field, farm, community, country) and organizational levels (farmers, extensionists, researchers, administrators, policy makers). This hierarchical organization justifies the consideration of hierarchy theory for H. armigera population management. At the field level, the control system may be composed of rational pesticide use, of augmentative biological control including the use of NPV and egg parasitoids and of the pest tolerant cultivars. When extending the control program to farm level, cultural methods comprising of the optimum placement of target crops in time and space as well as conservation biological control may be considered. For the community level, cooperation in synchronous planting of target crops and community monitoring of adults by pheromone traps is recommended. For organizational levels beyond the community, weather data, pheromone or light trap catches and larval monitoring in regionally important target corps are to be combined to evolve information technology supported early warning system. The design of an ecosystem approach cutting across different levels will be an important task for IPM specialists in Eastern Africa. It is recommended to initiate the ecosystem based IPM scheme at few pilot sites with the participation of farmers, extensionists and researchers. The experience gained will enable further refinements to facilitate the extension of pilot site approach to the other levels specified earlier.

Status and Constraints of *H. armigera* Management

Helicoverpa armigera (Hübner) (Lepidoptera: Noctuidae) is an economically important pest that causes severe losses on high value crops. This species is widely distributed from Asia Pacific, Australia, through Southeast and South Asia, the Middle East and southern Europe to Africa (Sharma, 2001). The pest is highly polyphagous (Bilapate, 1981; Zalucki *et al.*, 1986), attacking a great variety of agricultural crops. It is a major pest on cotton, tomato, tobacco, sunflower, linseed, legumes and cutflowers in the Eastern Africa region. Adults are strongly attracted to crops, which provide honeydew or nectar, and such feeding extends their lifespan. Their damage is frequently localized to nitrogen-rich reproductive plant parts, thus influences the crop yield directly. As the larvae of *H. armigera* usually live hidden within fruiting parts of the plant, it makes them less vulnerable to control by insecticides. Due to the severe damage levels caused on high-value crops such as cotton, tomato, tobacco and cut flowers, the farmers tend to resort to heavy and regular use of insecticides. Such pesticide use leads to destruction of natural enemy complexes, and so disrupts the natural balance that exists between pests and their natural enemies (Eveleens *et al.*, 1983). This pest is known to quickly to develop resistance to frequently used insecticides (Collins and Hooper 1984), and cases of development resistance of *H. armigera* to organochlorines and pyrethroids in the field has been reported in several parts of the world (Gledhill, 1982; Eveleens, 1983; Collins, 1986; McCaffery and Walker, 1991).

Importance of *H. armigera*

Geographical Distribution

The geographical distribution of *H. armigera* is among 41 countries in Asia, 48 in Africa, 20 in Oceania and 27 in Europe, except in the Americas. The potential for active migration of *H. armigera* adults has been well documented in studies by ICRISAT in India (Sharma, 2001). Fig. 1 illustrates the currently known distribution of this pest.

Extent of Loss

The extent of production losses caused by *H. armigera* is apparently high, but variable across regions and seasons. In the Tropics, the total annual loss on legumes, cereals, vegetables and cotton may exceed $1000million. Expenditure on insecticides used for *H. armigera* control may be nearly $500 million. In India, the total annual loss caused on pulse crops is estimated at $300 million and $23 million on cotton, the overall estimate being $530 million. In Tanzania, the total annual loss on cotton exceeded $20million while in Kenya the yield loss on tomato is about 25%.

H. armigera in Eastern Africa

An illustration of crop-wise importance of the pest in Africa is provided in Table 1. The economic importance of this pest among several crops and different regions has been document in several papers in this workshop proceeding. The major target crops include legumes (eg. chickpea and pigeonpea), Vegetables (eg. tomato and capsicum), oilseeds (e.g sunflower and linseed) and cotton, among others.

Features of the Ecosystem Approach

Hierarchy theory is a theory on the observer's role in any formal study of complex systems. In order to describe adequately a complex system several levels have to be addressed simultaneously (Ahl and Allen, 1996).

The essential features of the ecosystem approach for *H. armigera* management would involve selective deployment of IPM options applicable to different levels – crop, farm, community and regional within their existing linkages of the National Agricultural Research Extension Systems (NARES). The selection of options should be based on their compatibility to conservation and sustainable utilization of the beneficial species (such as pollinators, predators, parasitoids) in the target agroecosystem. The focus shall be to encourage 'preventative' rather than 'curative' control options, wherever appropriate. The size of the spatial range (or its extent) and the number of man-made levels (field, farm, community, region, continent) affected requires the consideration of *Hierarchy Theory* for *Helicoverpa* population studies and management.

Options at Different Levels

Crop specific pest control options

Emphasis on crop specific options includes safer alternatives to chemical pesticide use, besides rationalizing pesticide use. Promoting the cultivation of adapted/compensating crop varieties, which are tolerant to *H. armigera* damage may be encouraged. Augmentation biocontrol involving the use of entomopathogens (e.g. *Bacillus thuringiensis*, baculovirus) and egg parasitoids (*Trichogramma*) could be promoted. Motivating the farmers to undertake scouting for egg/larval incidence would be useful in encouraging need-based application of pesticides.

Specific pest control options

At farm level, the optimum mix of target crops of *H. armigera* should be considered (in space and time) so as to minimize the build up and shift within the farm. Crop rotation and companion cropping which favour reduction in the pest build up should be given attention. Conservation biocontrol through providing nectar sources and refugia in farm boundaries could promote the activity of parasitoids/predators.

At the community (village) level, actions that could minimize the severity of *H. armigera* include choice of cultivars of similar maturity. Wherever possible, the planting dates for the target crop should be synchronised to fall in a narrow bracket. By these steps, it would be possible to 'dilute' the severity of the pest. Keeping light or pheromone traps by the community for monitoring the adult *H. armigera* population levels could provide local guidance on expected peaks in egg/larval incidence, to plan enable them to jointly timely and simultaneous interventions. Community Based Organizations (CBOs) could be suitably trained and involved at this level.

At regional level, the research-extension officials are likely to play roles that are more prominent. Integration of data, cropping areas, climatic factors with information assembled from a grid of pheromone traps could provide a basis for short-term predictions of impending severity of *H. armigera* infestation among different target crops. Potential exists for evolving an integrated population monitoring and early-warning system, which can help advising the extensionists of improving levels and timing of *H. armigera* peak infestations.

Thoughts on the Scope of the Approach

Appropriateness of ecosystem approach

The ecosystem approach is indeed highly relevant to such polyphagous pest as *H. armigera*. The capacity of this pest to utilize a wide range of host plants, which include crops and weeds in the farm and off-farm host including shrubs, should be borne in mind in developing a strategy for area-based suppression of its population build up. This would include restricting the access to host plants and enhancing the role of natural mortality factors. Since the pest is highly mobile, there is need to ensure that unnecessary use of chemical pesticides in minimized, as it is possible that resistance built up in one crop source will manifest also when the pest moves to other crops in which pesticide use is seldom affordable.

Strategy to promote ecosystem approach

Involving the motivation and cooperation among farming community (groups) is very important in promoting improved practices under ecosystem approach. For instance, community participation in planting the same maturity group of crop variety and planting them within a brief spell will confer the benefit of pest dilution. Farmers' groups should also be empowered to evaluate, and if needed refine, these improved *H. armigera* management options. The training / orientation should extend to the continuum between farmers, communities, extensionists and researchers. While farmers could be trained on crop and farm level interventions like rational pesticides use, botanicals, biopesticide products and cultural practices, communities could be motivated or oriented in cooperative activities like planting varieties of same duration and limiting the planting dates to 1-2 weeks, to bring about dilution pest infestation. They could also be involved in handling and upkeep of pheromone based bait traps for autodissemination of adults (moths). Extensionists to be trained in training of farmers' cadre trainers and community leaders for promoting IPM activities at farm and community levels. Researchers should prepare suitable training materials and extension bulletins needed for IPM awareness building among end users.

Table 1. Examples of target crops and countries in which *H. armigera* is known as key pest in East Africa

Crop	Countries in which it has as key pest
Cotton	Egypt, Sudan, Kenya, Tanzania, Mozambique, Uganda, Zimbabwe and Ethiopia
Chickpea	Ethiopia, Kenya
Pigeon pea	Kenya, Uganda, Tanzania
Tomato	Egypt, Sudan, Ethiopia

Fig. 1. Known global distribution of *Helicoverpa armigera*
Source: Sharma (2001)

Vision

Ecosystem Approach Models

In Eastern Africa, Sudan has set an example of farmer-participatory IPM awareness building, under FAO involvement during the 1990s by implementing the Farmers Field School (FFS) system of group learning. Recently, Eritrea has conducted a national level IPM awareness planning workshop and developed multi-tier system of training of IPM trainers and preparing suitable training materials. There is need for national level initiatives to provide a basis for implementing *H. armigera* management under the ecosystem approach. In Eastern Africa, national level *H. armigera* IPM task teams should be established to be able to coordinate capacity building and networking activities at different levels.

Promoting Ecosystem Approach

Expert panels for planning and implementing *H. armigera* management should be constituted at national and regional levels to coordinate the research-extension linkages with farmers in managing the pest more sustainably. The panels should identify and train model farmers' groups in different ecologies or provinces where *H. armigera* is regarded a key pest.

Research and Capacity Building

Lead researchers in the national system should be trained in advanced institutions, where the ecosystem approach is being promoted for *H. armigera* management, such as in USA and Australia. They also link up with International Agricultural Research Centres such as ICIPE, ICRISAT and ICARDA in promoting collaboration in research and training on *H. armigera* management. The extensionists should also be trained as master trainers at different levels to be able to train extensionists and farmers' cadre trainers in *H. armigera* management.

Conclusion

The ecosystem approach for *H. armigera* management in Eastern Africa is so important that it should be implemented at the earliest opportunity. Nevertheless, a realistic and need-based strategy should be developed in harmony with farmers' priorities and resources. Ecosystem approach offers the common - sense basis to a tackling a highly polyphagous and mobile pest such as *H. armigera*. It is visualized that NARES in the Eastern Africa region are able to atleast start experimenting this method in pilot sites across the countries in which is *H. armigera* is regarded as a key pest, especially in vegetable based cropping system. Based on the experience gained in these pilot studies, a refined approach could emerge for promoting it over space and time to cover ore beneficiaries.

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Assessment of Economic Importance of African Bollworm in Ethiopia

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Abstract

In the present national workshop on African Bollworm (ABW) management in Ethiopia, there was interest shown to document the 'importance and damage' or 'loss' caused by the target pest, Helicoverpa armigera among several crops and across different region. ABW has been recognised as a national priority pest due to its wide range of target crops and causing damage to crops all the regions. The need for systematic, coordinated and year-wise assessment and documentation of the relative economic importance of ABW has been endorsed. A network of benchmark sites to pursue this task as a continuing activity is suggested. Some perceptions on utilizing the existing information to provide an economic tag to the crop loss estimates, on an empirical basis, are discussed.

Introduction

The African bollwrom (ABW), *Helicoverpa armigera* is recognized as 'important' pest on a range of agricultural crops grown in Ethiopia. Very often such importance is expressed as causing 'wide-spread' damage that can occur on several crops grown in the same season. Based on the perceived importance of ABW in relation to other pests in individual target crops, the EARO-Entomology Vision document has assigned ranking, to provide a basis for research prioritization (Table 1). The available onstation estimates of 'avoidable losses' are expressed as % loss and/or loss in quantity per unit area of crop, based on yield difference between 'protected' and 'non-protected' plots. Onfarm surveys generally represent the proportion of crop area damaged (distribution) and/or the severity (intensity) of damage. Nevertheless, the economic importance of the pest (ABW) should also be presented in terms of the monetary loss caused. The monetary investments needed to protect the individual target crop(s) to avoid the loss also need to be estimated. This is indeed not an option for researchers, but an important requirement, since policy makers need to be assisted with suitable figures for enabling grasping the 'relative importance' of the pest as a basis for assigning priorities and/or allocating resources for research, extension, training and physical capacity building. This paper provides some perceptions of the authors on this aspect, based on discussions held in different sessions and with several experts during the current national workshop on African bollworm management in Ethiopia.

Criteria for Assessing Economic Importance

Extent of Crop Area Damaged

This information is presently limited to occasions of out break (as observed in recent years in sorghum) and baseline surveys (mostly limited to 1–2 years on a crop for a specific purpose or project). To assemble such information more systematically, we need to combine with extensionists in the region.

Extent of Yield Loss in Unit Crop Area

In on-station plots, we compare the yield between protected (pest-free) and non-protected (natural pest infestation) plots and express the differences as 'avoidable loss'. The units of loss are '%' and/or 'weight per unit area' (sq. m/ hectare). This simplistic estimate, derived from researcher managed crop plots, is at best indicative. To improve comparability of these estimates across sites, researchers working on individual target crops (like vegetables, legumes, cotton, sorghum) should plan to conduct these trials on an agreed plan of layout, management and data collection and share/assemble the results periodically. In addition, onfarm plots with cooperating farmers, should also be utilized, so to get the estimates from the real world.

Extent of Yield Loss at Varying Pest Intensities

This information is important for developing action thresholds and thereby providing a basis for local decision-making on control. This requires laboratory facilities for rearing the pest and for infesting the target crop at different phenological stages and with varying larval numbers. Alternatively, adjustments in planting dates and/or protection intensity can also be used to achieve desired ABW infestation/damage levels. Nevertheless, such a work is adequate to be done periodically (say once in 5 –10 years) so to capture any major shifts due to changes in varieties, climate and crop management practices. It is preferable to include such studies under M.Sc./Ph.D research projects, as it would require considerable time spent. Presently, in Ethiopia, the priority crops for this study could be chickpea, cotton and tomato.

Cost of Investment for Controlling the Pest

Presently, most crop protection against ABW is done by insecticide use and only occasionally supplemented by indigenous / cultural practices. There is need to assemble information at benchmark sites on the number of pesticide applications that are required to be able to provide adequate (satisfactory) and intensive (maximum) protection from yield loss. Crop researchers should identify benchmark sites, which represent the major production areas. They should also work out the cost of pesticide and associated labour for application. In addition, the extensionists in each such area/region should be provided with plans for documenting the variation in number of applications (and dose rates) being adopted by farmers.

Assigning Economic Tag to Yield Loss

Assumptions and Guidelines

For assigning an economic tag to the loss caused by ABW at national level, it is assumed that there is need for an interim or indicative monetary value, while efforts should be made to assemble loss estimates more systematically and on a continuing basis. In dealing with such scattered source of yield loss estimates, even for an empirical monetary tag to be assigned, caution should be exercised to represent them as 'guess' estimates, backed up by guidance. In the following sections, the authors share some of the thoughts on pursing this delicate but important task of deriving monetary value for the loss caused by ABW, just as an interim need.

Avoidable Loss Estimates for Target Crops

The value of produce lost per unit crop area should be derived from avoidable loss (%) and the average farm gate price for the unit crop produce in the season. For the loss estimates, where the average from a range is not available, the use of midpoint may be considered. From the data published and available at this workshop, the range of 30-60% for tomato could provide a midpoint of 45 %. Similarily, mid points for cotton 48% (range 36-60%), for field pea 37 % (range 32– 42 %) for hot pepper 19% (range 11–27 %), and for chickpea 29% (25-33%) and haricot bean 21 % are considered.

Monetary Value According to Area Grown at National and Regional Levels

Data on the total area grown for each target crop (as an average over the recent 2 – 3 years) is assembled from Central Statitics Authority sources (2000, 2002 and 2003). By multiplying the average monetary loss per unit crop area (acre/hectare), which could be derived using the guidelines in the preceding section, with the total area grown at regional/national levels, the monetary loss due to ABW in each crop could be worked out at regional and national levels. Where such estimates need to be given as a combined loss across crops, besides adding up the estimates from available crops, the statement should indicate that not all crops have been included for the monetary value estimate, be it regional or be it national.

Estimates for Monetary Loss at National Level

Simply based on the need for an 'interim' and 'indicative' estimate for crops and overall at national level, an illustration for deriving such ' guess' estimates of monetary loss due to ABW is presented in Table 2.

Table 1. Priority ranking for African bollworm in major target crops in Ethiopia *

Crop	National ranking among other pests	Agro-ecologicies
Cotton	First	A_1, A_2, SA1, SH_1, SH_2
Tomato	First	A_1, SA_2, M2, SH_2 SM_2
Hot pepper	Second	
Chickpea	First	SM_1, SM2, SM3, M1, M2, M3, SH1, SH2, SH_3,
Faba bean	Second	
Field pea	Second	
Haricot bean	Second	A_2, SM1, SA_2, SM_2, SH_2

** Source: EARO – Entomology – Vision 2000 – Document)*

Table 2. Illustration of derivation of "guess estimate" of economic loss due to ABW in some crops in Ethiopia

Crop	% Yield loss (a)	Quantity lost Kg/ha (b)	Average farm gate price per Kg in birr (c)	Monetary loss per unit area (rn/ha (d)	National average area grown (ha) (e)	Estimate monetary loss at national level in Birr (f)
Tomato	45	5724	1.50	8586	2423.00	20803878.00
Cotton	48	720	5.00	3600	12070.00	43452000.00
Chickpea	29	278	1.80	500.40	204175.00	10216917.00
Hot pepper	19	266	12.00	3192	55289.66	176484594.70
Faba bean	12	145	2.00	290	400618.50	116179365.00
Field pea	14	295	2.50	737.50	205221.50	151350856.30
Haricot bean	21	163	1.30	211.9	198147.50	41987455.25
Overall				17117.8	1077945.16	560475066.25

(a) Based on scattered data and assumption
(b) Base on average yield/ha (last 2 – 3 years)
(c) Based on approximate price (Birr/Kg) at farm gate in the crop marketing season (last 2 - 3 years)
(d) By multiplying the figures in columns 'b' and 'c'
(e) Derived from official records of area grown (last 2 –3 years)
(f) By multiplying figures in columns'd' and 'e'

Conclusion

The acknowledged 'high' importance of ABW as a pest at national level, damaging many crops grown by smallholder farmers in the country, should be supported by quantification of and assigning monetary value to the yield losses in major target crops. To cater to an interim need for national level losses, "guess estimate" of the monetary value is provided, simply as an indicative and adhoc effort. The need to replace this empirical estimate by a more systematic estimates based on periodical yield loss data collection is obvious. It is important that ABW be declared as national priority pest, so to justify adequate allocation of research-extension resources for assisting farmers to manage it sustainably.

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Accronyms

SM_1=	Hot to warm sub moist lowlands
SM_2=	Tepid to cool sub moist mid highlands
SM_3=	Cold to very cold sub moist sub-afro -alpine to afro-alpine
M_1=	Hot to warm moist low lands
M_2=	Tepid to cool moist mid highlands
M_3=	Cold to very cold moist sub-afro alpine to afro-alpine
SH_1=	Hot to warm sub humid low lands
SH_2=	Tepid to cool sub humid mid highlands
SH_3=	Cold to very cold sub humid sum afro-alpine to afro-alpine
H_1=	Hot to warm humid low lands
A_1=	Hot to warm arid lowland plains
A_2=	Tepid to cool arid mid high lands
SA_1=	Hot to warm semi-arid low lands
SA_2=	Tepid to cool semi-arid mid high lands

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