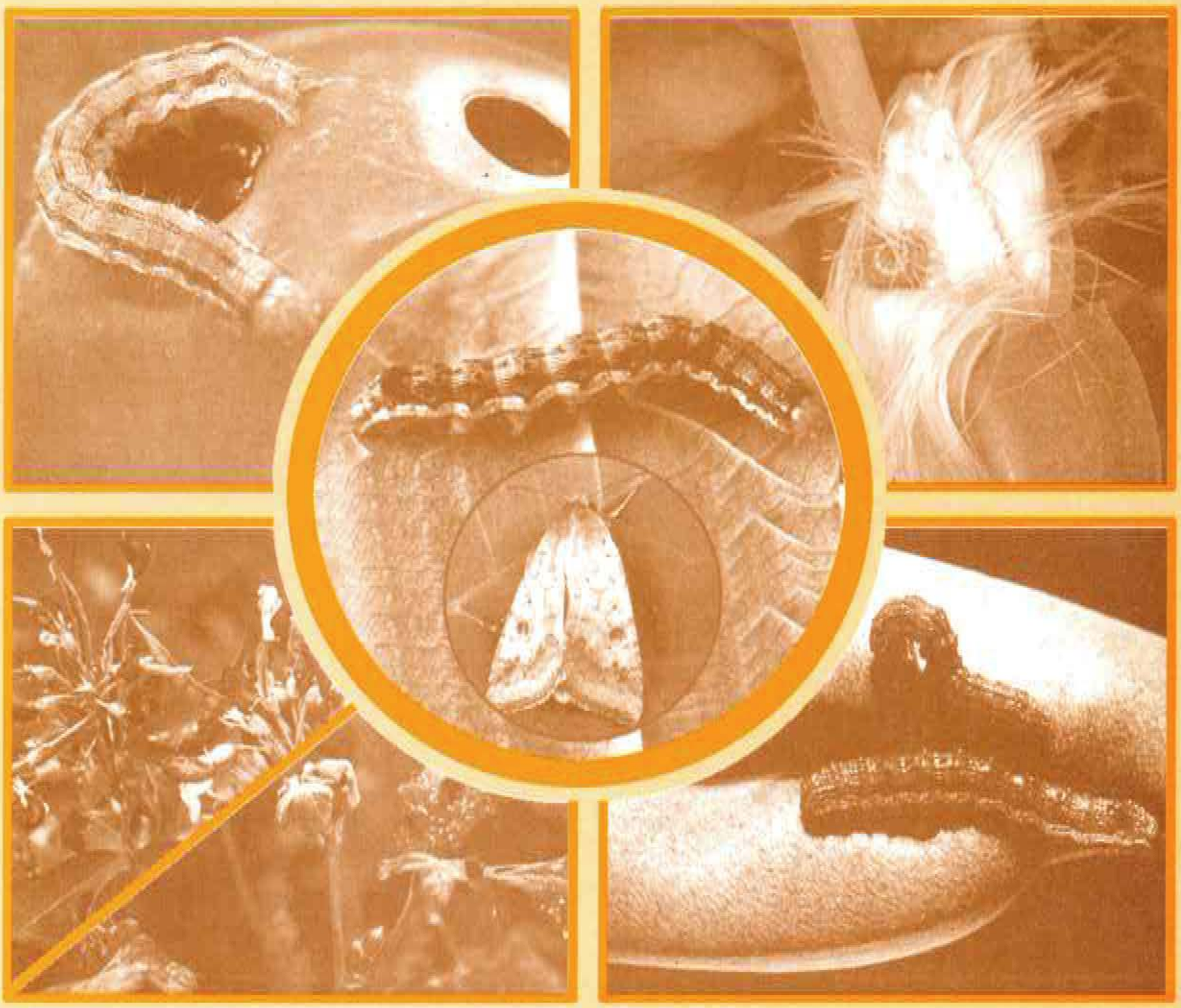


Helicoverpa Management in Kenya

Research Status and Needs

Proceedings
of the
KARI-ICIPE Workshop on Biocontrol-based IPM of the African Bollworm in Kenya

16 November 2002, Nairobi, Kenya

Edited by
S. Sithanantham, C. Kariuki and J. Baya

International Centre of Insect Physiology and Ecology (ICIPE)
Kenya Agricultural Research Institute (KARI)

Helicoverpa Management in Kenya: Research Status and Needs

PROCEEDINGS

of the
KARI-ICIPE Workshop on Biocontrol-based IPM of the African Bollworm in Kenya
16 November 2002, Nairobi, Kenya

Funded by the German Ministry of Technical Cooperation (BMZ)

Edited by S. Sithanantham, C. Kariuki, J. Baya

ICIPE Science Press

Citation: Sithanantham S., Kariuki C. and Baya J. (Eds) (2005) *Helicoverpa Management in Kenya: Research Status and Needs*. Proceedings of the KARI-ICIPE Workshop on Biocontrol-based IPM of the African Bollworm in Kenya. ICIPE Science Press, Nairobi. xii + 113 pp. ISBN: 92 9064 169 X.

Published and printed by:

ICIPE Science Press
P. O. Box 72913-00200
Nairobi, Kenya
Tel: +254 (20) 861680
Fax: +254 (20) 803360

Later in 2005 the telephone and fax lines will change to:
Tel: +254 (20) 3652000
Fax: +254 (20) 3652997/98

Copyediting by D. Osogo
Design and layout by I. Ogendo

Cover photographs:

Front cover clockwise from top left, *Helicoverpa armigera* on tomato and French beans, and adult moth (centre), GTZ-IPM Horticulture Project and ICIPE Plant Health Division. *Helicoverpa armigera* on maize, pigeon pea and okra (top right and bottom left, respectively) and larva (centre), by the ICIPE African Bollworm Biocontrol Project.

Back cover, clockwise from top left: *Trichogramma* quality control in the laboratory before release; on-farm sampling for African bollworm eggs; collecting *Corcyra cephalonica* eggs for *Trichogramma* production; on-station multiple crops for African bollworm monitoring and egg sampling. Photos by ICIPE African Bollworm Biocontrol Project. Centre, *Trichogramma* on egg, Department of Entomology, Tamil Nadu Agricultural University, India.

ISBN: 92 9064 169 X

Contents

Abbreviations and Acronyms

ABW	African bollworm
ASAL	arid and semi-arid lands
AAIS	African Association of Insect Scientists
BMZ	Bundesministerium für Wirtschaftliche und Entwicklung Zusammenarbeit, Federal Republic of Germany (German Ministry of Technical Cooperation)
B. t.	*Bacillus thuringiensis*
CAAS	Chinese Academy of Agricultrual Sciences, China
CBO	community based organisation
CIAT	Centro Internacional de Agricultura Tropical, Colombia
EPN	entomopathogenic nematodes
FAO	Food and Agriculture Organisation of the United Nations, Italy
GIS	geographic information systems
GTZ	Gesellschaft für Technische Zusammenarbeit, Germany
IARC	international agricultural research centres
ICRAF	World Agroforestry Centre
EARO	Ethiopian Agricultural Research Organisation
FIAA	Federal Research Station for Agroecology and Agriculture, Switzerland
FPEAK	Fresh Produce Exporters Association of Kenya
HCDA	Horticultural Crops Development Authority of Kenya
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics, India
IPM	integrated pest management
JKUAT	Jomo Kenyatta University of Agriculture and Technology, Kenya
KEPHIS	Kenya Plant Health Inspectorate Services
KPCPB	Kenya Pest Control Products Board
KSTCIE	Kenya Standing Technical Committee on Imports and Exports
MoA	Ministry of Agriculture, Tanzania
MOALDM	Ministry of Agriculture, Livestock Development and Marketing, Kenya
MRLs	maximum/minimum residue levels
NARES	national research and extension system
NARL	National Agricultural Research Laboratories (KARI centre)
NARO	National Agricultural Research Organisation, Uganda
NARS	national agricultural research systems
NGO	non-governmental organisations
NHRC	National Horticultural Research Centre (KARI centre)
NPV	nuclear polyhedrosis viruses
PCI-BCRL	Pest Control India-Biological Control Research Laboratories, India
UoN	University of Nairobi, Kenya

Tables

Illustrations

Foreword 1

Since its inception, ICIPE has made a committed effort to foster and strengthen collaborative partnerships with the national agricultural research and extension systems (NARES) in countries in which we work. ICIPE and KARI have jointly undertaken several partnership initiatives, of which the Kwale-Kilifi Adaptive Research Project (1992–1996) is an outstanding model. A more recent ICIPE-KARI collaborative programme is the present project on Biocontrol-based Integrated Pest Management (IPM) of the African Bollworm (2001–2004).

This publication documents the proceedings of the KARI-ICIPE Workshop on the Sustainable Management of the African Bollworm (ABW) in Kenya, organised by the two institutions, with funding support from the German Ministry of Technical Cooperation (BMZ). The Workshop was attended by researchers from KARI and ICIPE, representatives from the extension services and farmers' representatives. A major outcome of the workshop was the recognition of the ABW as a priority pest of national importance in Kenya. Other outcomes include the development of a vision for the future in capacity building and appropriate technology for the sustainable management of the ABW across the regions and target crops in Kenya. The section on the potential for the egg parasitoid, *Trichogramma*, for augmentative biocontrol of the ABW in the country, includes a paper on the scope for its utilisation.

It is hoped that these Proceedings will serve as a useful reference book for researchers, extension workers, policy makers and development partners in Kenya and that the information contained herein will influence the utilisation of *Trichogramma* and other IPM methods for the sustainable control of *Helicoverpa* in important smallholder crops in Kenya.

Hans R. Herren
Director General, ICIPE

Foreword 2

The African Bollworm is an important pest of several agricultural crops in Kenya, especially legumes (as a pod borer), vegetables and fruits (as a fruitborer) and cotton (as a bollworm). Farmers and extensionists are keenly looking for more sustainable alternatives to manage this pest, as sole dependence on chemical pesticides for their control has not been economical or effective over time.

The KARI Biocontrol Research Team, based in Muguga, has participated in a regional project led by ICIPE for biocontrol-based management of this pest and has joined hands with ICIPE in convening this national workshop. It is gratifying to note that the papers presented and discussed are focused on assessing the research status and future needs for sustainable management of *Helicoverpa armigera*.

As the Director of the hosting KARI Centre, and as an entomologist, I wish to congratulate Dr. S. Sithanantham and colleagues at ICIPE for this worthy joint effort, leading to this useful reference document for researchers and students. On behalf of the Director KARI, I also wish to thank ICIPE for the continued support and collaboration with national programmes. Allow me also to acknowledge the kind assistance from BMZ that has allowed the implementation and conclusion of this work.

Dr. Charles W. Kariuki
National Coordinator—Cassava Programme
Kenya Agricultural Research Institute

Acknowledgements

Appreciation is extended to the Directors and senior management of Kenya Agricultural Research Institute (KARI) and the International Centre of Insect Physiology and Ecology (ICIPE) for their encouragement and support in bringing together the current knowledge and relevant experience from scientists and other stakeholders towards formulating a vision for sustainable management of the African bollworm in Kenya, with a focus on its biological control.

The workshop organisers (KARI and ICIPE) sincerely thank the funding support availed from the German Ministry of Technical Cooperation (BMZ) through the Regional Network Initiative for Promoting Biocontrol-based IPM of the African Bollworm in Vegetable-based Cropping Systems in Eastern Africa. The advisory input of the collaborators based in Germany (Prof. C. Zebitz, Dr J. C. Monje and Dr S. A. Hassan) is thankfully acknowledged.

The workshop organising team, including S. Njihia and J. Wadenje (KARI), C. M. Matoka, J. Baya, G. Chigunda, A. Wanyonyi, L. Masambu, J. Waweru and J. Mucheru (ICIPE), are sincerely thanked for the committed input.

Appreciation is also extended to Dr Annalee Mengech and the ICIPE Science Press for their valuable contribution in science editing and printing of this document.

S. Sithanantham—Coordinator, Regional African Bollworm Biocontrol Programme for Eastern Africa (ICIPE)

C. Kariuki—Coordinator, National Biocontrol Programme (KARI)

J. Baya—Research Scholar, Dissertation Research Internship Programme (DRIP) (ICIPE)

Executive Summary

The African bollworm, *Helicoverpa armigera* (Hübner.), is an important pest on some smallholder crops in Kenya as well as elsewhere in sub-Saharan Africa. The major crops identified as important targets for African bollworm (ABW) include vegetables (e.g. tomato, capsicum, French bean), food legumes (e.g. pigeon pea, chickpea, beans), cereals (e.g. maize, sorghum), oilseeds (e.g. sunflower, groundnut) and commercial crops (e.g. cotton, tobacco).

This document covers the highlights and outcome of a national workshop held at ICIPE. The objectives were to:

- Assemble local information on the extent of the economic importance of the African bollworm in different regions and across target crops.
- Understand farmers' pest control practices and any constraints to effective management of the African bollworm.
- Identify research gaps and training needs of national research and extension systems (NARES) in biocontrol-based IPM for the African bollworm.
- Develop a stakeholder participatory vision for sustainable management of the African bollworm using *Trichogramma* for biocontrol.

The workshop programme was structured into four technical sessions as follows:

- Session 1: Overview of African bollworm research and management in Kenya
- Session 2: Overview of African bollworm biocontrol elsewhere and KARI collaboration activities
- Session 3: Potential for *Trichogramma* in biocontrol in Kenya and elsewhere
- Session 4: Vision for future research—training and networking

The participants included 10 researchers from KARI, eight from ICIPE, three extensionists and two farmers' representatives.

The invited papers presented by experts covered different themes relating to sustainable African bollworm management based on biocontrol using *Trichogramma* in the country.

There were three lead papers on African bollworm management at national level: one on research status and training needs, one on pest status and extension needs and one on scope for utilisation of *Trichogramma* in biocontrol of African bollworm.

These were followed by papers with a regional and theme focus presented by experts from KARI and from the Ministry of Agriculture, Kenya which provided information on local importance, current practices and constraints as well as future research–extension–training needs for African bollworm management across crops and ecologies.

The ICIPE and KARI partners of the Regional Network Initiative also presented five background papers for improved utilisation of *Trichogramma* for biocontrol-based IPM of African bollworm in eastern Africa.

The workshop participants discussed the potential for and the factors that would influence the future utilisation of *Trichogramma* in Kenya and guidelines were developed to evolve the demand scenario for *Trichogramma* use as a biocontrol agent for African bollworm and other lepidopteran pests control in the country.

The final technical session discussed and developed several recommendations covering future needs for research, extension, training, policy support and collaboration (ref. Annex A for details). Among the important recommendations are policy support by recognition of the African bollworm as a priority pest at national level and the need to encourage private sector investment in local mass production and delivery of *Trichogramma* for promoting its widescale utilisation in biocontrol of the African bollworm.

Background

Helicoverpa armigera (Hübner) (Lepidoptera: Noctuidae) is recognised as a key pest of vegetable crops in Africa (Ikin *et al.*, 1993). In eastern Africa, *H. armigera* is an important pest of tomato (*Lycopersicon esculentum* Mill.), capsicum (*Capsicum annuum* L.) and to some extent, also on French bean (*Phaseolus vulgaris* L.), snowpea (*Pisum sativum* L.) and okra (*Hibiscus esculentus* L.) (Adane-Kassa and Abate, 1995; Farrel *et al.*, 1995; ICIPE, 1998). In addition to direct losses in yield due to reduced fruit set, farmers also lose substantially due to cosmetic damage caused to the produce that leads to reduced marketability.

In an effort to produce blemish-free produce, vegetable farmers have tended to resort to overuse of synthetic pesticides. In Kenya, more than 90% of the vegetable farmers believe that using pesticides is important towards reducing the production losses due to pests. In a survey conducted in four vegetable growing districts in Kenya, it was found that 12–17 applications of pesticides per cropping season were common and some farmers applied up to 19 times (Gathui *et al.*, 1994). Use of pesticide mixtures or cocktails of pesticides as well as increase in spraying frequency on vegetables is not uncommon (Kibata, 1996). The tendency to choose preventive or calendar-based rather than need-based application of pesticides has already led to pesticide resistance problems (Mingochi *et al.*, 1995; Kibata, 1996). This attitude is also resulting in environmental contamination, health risks and unacceptable residue levels in the produce.

In a recent survey of smallholder vegetable farms in four countries in the region —Kenya, Ethiopia, Uganda and Tanzania—the majority of farmers said that pesticide use was largely economical, but has now become uneconomical (Sithanantham *et al.*, 2001a). This reflects the seriousness of the problem and highlights the need to provide smallholder vegetable farmers with 'softer' and efficient pest management alternatives. Egg parasitoids have the potential to control lepidopteran pests before they can cause any direct or indirect damage on the marketable produce, and are used widely for vegetable and other high value crops. Globally, these bioagents are being used successfully in many countries on target crops, covering about 32 million hectares annually (Hassan, 1993).

A symposium on 'Utilisation of Egg Parasitoids as Biocontrol Agents in African Cropping Systems' was convened by ICIPE as part of the scientific conference of the African Association of Insect Scientists in Ouagadougou, Burkina Faso in July 1999. National scientists from several African countries participated and recognised the potential for using trichogrammatid egg parasitoids in Africa for control of *H. armigera* and other lepidopteran pests, based on promising results and experiences so far obtained from elsewhere. This symposium also endorsed a lead role for ICIPE in forging a regional network for research, capacity building and information exchange on use of egg parasitoids for biocontrol. In a recent status paper by Sithanantham and colleagues (2001b) based on worldwide research and scope, the potential of this group of biocontrol agents against *H. armigera* and *Plutella xylostella* L. for utilisation in Africa was documented.

Research on egg parasitoids in eastern and southern Africa is scattered and is mostly limited to occasional records of occurrence (Mohyuddin and Greathead, 1970; Schulten and Feijen, 1978; Feijen and Schulten, 1981; Conlong and Hastings, 1984; Prinsloo, 1984; Newton, 1988; Pintureau and Babault, 1988; Ochiel, 1989; Guang and Oloo, 1990; van Hamburg and Kfir, 1991; Kfir, 1990, 1991, 1995; van den Berg and Cock, 1993 a, b; Chambers *et al.*, 1995). Research on biocontrol potential of egg parasitoids (mainly *Trichogramma*) has been limited to studies at ICIPE and initially focused on cereal stemborers (Ngi-Song, 1990;

Guang and Oloo, 1990; ICIPE, 1990). A recent study of native egg parasitoid species occurring on *H. armigera* and the diamondback moth *P. xylostella* has been conducted in Kenya (Haile *et al.*, 1999).

Project Description

This workshop was a joint initiative of the Kenya Agricultural Research Institute (KARI) and the International Centre of Insect Physiology and Ecology (ICIPE) as partners in an on-going regional network project for popularising the utilisation of egg parasitoids in biological control of the African bollworm *Helicoverpa armigera* in vegetable-based cropping systems in eastern Africa. The initial phase is for three years (2001–2004) and is funded by the German Ministry for Technical Cooperation (BMZ).

To assess the potential of egg parasitoids in the region, the project aims at achieving three main objectives:

1. To develop and implement a biocontrol-based integrated pest management (IPM) programme through improved utilisation of egg parasitoids for the fruit borer (*H. armigera*) on important vegetable crops in eastern Africa.
2. To improve regional collaboration among the national agricultural research and extension systems (NARS) with international agricultural research centres (IARCs) and advanced research institutions for strengthening IPM-linked biocontrol research in the region.
3. To enhance capacity within NARS to develop and implement egg parasitoid-based biocontrol programmes.

The following were the start-up initiatives of the project with the hope that they would lead to private sector investment in mass production and utilisation of egg parasitoids in the region: (i) to complement on-going and up-coming regional IPM initiatives to build up an effective biocontrol programme; (ii) determine and catalogue the diversity of commonly occurring native egg parasitoid species in vegetable-based cropping systems in the region; (iii) identify species with desirable biological attributes and adaptation to major climate stresses; (iv) develop optimum egg parasitoid release patterns and rates for a priority vegetable crop; (v) undertake experimental cage and open field releases to assess the impact in a chosen country; (vi) conduct risk assessment on the impact of egg parasitoids on non-target species; (vii) assess and conduct a study on the commercial potential of egg parasitoid use to devise delivery systems adapted to Kenyan conditions; (viii) undertake training of NARES partners in survey methodologies and mass production of egg parasitoids and (ix) establish a regional network for information exchange and scientific collaboration in utilisation of egg parasitoids.

Overview of this regional initiative has been presented at the Biennial Conference of the African Association of Insect Scientists at Addis Ababa, Ethiopia in 2001 (Sithanantham *et al.*, 2001). Recently an update on this initiative was also presented at the International Symposium on Egg Parasitoids at Perugia, Italy in 2002 (Sithanantham *et al.*, 2002).

References

Adane-Kassa T. A. and Abate T. (1995) Experience in biological control of insect pests in Ethiopia: A review, p. 20. In *Integrating Biological Control and Host Plant Resistance*. Proceedings of a CTA/IAR/IIBC Seminar, Addis Ababa, Ethiopia, 9–14 October 1995. The Technical Centre for Agricultural and Rural Cooperation (CTA), Wageningen, the Netherlands.

Newton P. J. (1988) Inversely density-dependent egg parasitism in patchy distribution of the citrus pest *Cryptophlebia leucotreta* (Lepidoptera: Tortricidae) and its agricultural efficiency. *Journal of Applied Ecology* 25, 145–162.

Ngi-Song A. J. (1990) A model of parasitism by *Trichogramma* sp. nr *mwanzai* Schulten and Feijen (Hymenoptera: Trichogrammatidae) on the stalk borer, *Chilo partellus* Swinhoe (Lepidoptera: Pyralidae) on sorghum. M. Phil. Thesis, Rivers State University of Science and Technology, Nkpolu, Port Harcourt, Nigeria. 134 pp.

Ochiel G. R. S. (1989) Biology of *Trichogramma* sp. nr *exiguum* Pinto and Platner (Hymenoptera: Trichogrammatidae) on some lepidopterous hosts in South Nyanza, Kenya. M. Phil. Thesis, River State University of Science and Technology, Nkpolu, Nigeria. 140 pp.

Pintureau B. and Babault M. (1988) Systematics of African species of the genera *Trichogramma* Westwood and *Trichogrammatoidea* Girault (Hym. Trichogrammatidae). *Colloques-de-l'INRA* No. 43, 97–120.

Prinsloo G. L. (1984) An illustrated guide to the parasitic wasps associated with citrus in the Republic of South Africa. *Department of Agriculture Science Bulletin* No. 402. University of Natal, South Africa.

Schulten G. G. and Feijen H. R. (1978) Two new species of *Trichogramma* (Hymenoptera: Trichogrammatidae) from Malawi: Egg parasitoids of *Diopsis macrophthalma* Dalman (Diptera: Diopsidae). *Entomologie Berichte, Deel* 38, 25–29.

Sithanantham S., Monje C., Zebitz C. P. W., Hassan S., Baumgärtner J., Overholt W., Löhr B., Osir E., Nangayo F., Mulugeta N., Ogwang J. and Mgoo V. (2001a) Collaborative research initiatives towards improved understanding and utilization of the native egg parasitoids for biocontrol of *Helicoverpa armigera* in eastern Africa, p. 51. In *Integrated Pest and Vector Management and Sustainable Development in Africa (Abstracts).* Proceedings of 14th Biennial Conference of the African Association of Insect Scientists (AAIS), 4–8 June 2001, Addis Ababa, Ethiopia. African Association of Insect Scientists (AAIS).

Sithanantham S., Abera T. H., Baumgärtner J., Hassan S. A., Löhr B., Monje J. C., Overholt W. A., Paul A. V. N., Zebitz C. P. W. and Wan F. H. (2001b) Egg parasitoids for augmentative biological control of lepidopteran vegetable pests in Africa: Research status and needs. *Insect Science and Its Application* 21, 198–205.

Sithanantham S., Monje C., Zebitz C. P. W., Hassan S., Baumgärtner J., Overholt W., Löhr B., Osir E., Nangayo F., Mulugeta N., Ogwang J., Mgoo V. and Matoka C. M. (2002) Collaborative research initiative towards improved understanding and utilization of the native egg parasitoids for bio-control of *Helicoverpa armigera* in eastern Africa, p. 61. In *Egg Parasitoids for Biological Control of Insect Pests:* Proceedings of the 6th International Egg Parasitoid Symposium, 15–18 September 2002, Perugia, Italy. University of Perugia, Italy.

van den Berg H. and Cock M. J. W. (1993a) Stage-specific mortality of *Helicoverpa armigera* in three smallholder crops in Kenya. *Journal of Applied Ecology* 30, 640–653.

van den Berg H. and Cock M. J. W. (1993b) *African Bollworm and Its Natural Enemies in Kenya.* International Institute of Biological Control (Kenya Station) and Natural Resources Institute (Overseas Development Administration), UK. CAB International, UK. 81 pp.

van Hamburg H. V. and Kfir R. (1991) The relative abundance of *Telenomus ullyetti* (Hymenoptera: Scelionidae) and *Trichogrammatoidea lutea* (Hymenoptera: Trichogrammatidae), parasitising the eggs of *Heliothis armigera* on cotton in South Africa. *Colloques de l'INRA* 56, 49–52.

Overview of African Bollworm Research and Management in Kenya

Workshop Papers

National Importance of the African Bollworm and Future Extension Needs for Its Management in Kenya

D. K. Njeru
Plant Protection Division, Ministry of Agriculture,
P. O. Box 14733, Nairobi, Kenya

Abstract

The African bollworm (ABW), *Helicoverpa armigera* (Hb.) is found to occur in all parts of Kenya and more predominantly in medium altitude, arid and semi-arid ecologies. The yield loss caused by ABW is about 10 to 30%, across the common target crops, which include cotton, maize, sorghum, tomatoes, capsicum, beans, pigeon pea, garden peas, groundnut, citrus, sunflower and carnations. Currently, farmers adopt chemical control (e.g. cypermethrin, deltamethrin, carbaryl), cultural control (e.g. rotation, weeding, crop residue disposal) and mechanical methods (e.g. hand-picking). The major constraints to effective management of ABW include high cost of the pesticides and application equipment, and lack of knowledge among farmers on safer alternative control methods. The training needs of extensionists and farmers, as well as scope for research–extension are indicated. Potential areas for priority research themes for the national extension system (Ministry of Agriculture) and lead research institution (KARI) to collaborate with ICIPE are also highlighted.

Key words: *Helicoverpa armigera*, extension, cotton, tomato, legumes, Kenya

Importance of the African Bollworm (*Helicoperva armigera*) on Target Crops

The African bollworm *Helicoverpa* (*Heliothis*) *armigera* (Hb.) is a polyphagous pest, found in almost all parts of the country. It is more predominant in medium altitude areas (coffee zone) and arid and semi-arid lands (ASAL). There is no 'outbreak' of this pest at any time, but it is almost always found to occur in different crops in varying levels of severity since it is highly mobile and polyphagous.

Target Crops

The main target crops for ABW are cotton, maize, sorghum, tomato, beans, pigeon pea, garden pea, groundnut, citrus, sunflower, carnations and capsicum (Hill, 1983; Alejandro Ortega, 1987).

Extension reports indicate that cotton, tomatoes and legumes are more susceptible to this pest than other crops. Depending on the crop, the yield losses caused by the pest can range from 10 to 30% (NRI, 1981, 1983; Hill, 1983; de Pury, 1985).

According to agricultural extension workers in the field, this pest can be ranked highly on priority list of pests that cause considerable damage on cotton and pulses grown by small-scale farmers (Alejandro Ortega, 1987).

Occurrence in Provinces

The pest has been reported in all provinces (Nairobi, Coast, Western, Central, Rift Valley, Nyanza, Eastern and North Eastern provinces) of Kenya with varying degree of severity depending on host crop, season, weather, agroecological zone and control measures used.

Current Control Strategies for African Bollworm Management

Chemical Control

Initially endosulfan and carbaryl were recommended for control of ABW. Currently, pyrethroids are being recommended to farmers because they are environmentally safe and have low residue levels (Hill, 1983). These pesticides tend to be more effective if they are applied up to the third instar (small- to medium-size) larvae.

The products currently being recommended include cypermethrin, deltamethrin and carbaryl. The recommendation also discourages continuous use of one product for a long time to avoid development of resistance (Horowitz *et al.*, 1993).

Cultural Methods

Crop rotation, clean weeding and destroying/burning of infested fruits and crop residues are the recommended cultural methods.

Other Practices

One common practice adopted by farmers in addition to the above is the mechanical method (e.g. hand-picking) and subsequent destruction of the caterpillar.

Constraints

The following constraints have been experienced in the management of this pest:

1. High cost of chemicals and application equipment.
2. Lack of adequate knowledge by farmers on the seriousness of this pest and the appropriate control measures that need to be applied.

Future Needs for Improved African Bollworm Management

It is important that research addresses the following areas as a matter of priority:

1. Use of plant extracts for the control of bollworms.
2. Effectiveness of parasitoids as a control method.
3. Breeding for resistant/tolerant crop varieties.

Training/Extension Needs

National and Regional Training

National and regional training should be organised for the master trainers at the provincial level, who would in return train the district officers. The district officers should then link up with the frontline extension workers at the divisional level. This training should involve a multidisciplinary approach.

Training of Frontline Extension Workers

There is a need to train frontline extension workers on the following topics: (i) identification of the pest, (ii) damage assessment, (iii) control options available and (iv) safe and effective use of pesticides.

Training of Farmers

The training approach should be to use field days and field tours with focus on: (i) identification of the pest, (ii) control options available with emphasis on cost-effective measures, and (iii) safe and effective use of pesticides.

Scope for Linkages in Research-Extension

There is need for strengthening linkages between research-extension and the farming community. This will have the following impacts.

1. Enable rapid transmission of improved technologies developed by the research sector to the farmers.
2. Enable feedback from the farmers to the research community on the performance of these technologies.
3. Research will be responsive to farmers' problems.

Priority Themes for MOALDM-KARI-ICIPE Collaboration

Some of the priority themes for future collaboration of MOALDM and KARI with ICIPE are: (i) country-wide survey to establish the spread and severity of this pest, (ii) monitoring of the African bollworm using pheromone traps, and (iii) implementation of an IPM strategy in the management of this pest.

Because the pest attacks a wide range of crops and often causes appreciable losses across the country, there is a need for priority support for research–extension activities towards promoting IPM for this pest so as to benefit the farmers who grow the target crops. The relevant expertise available with ICIPE and KARI should be availed through MOALDM-KARI-ICIPE collaboration.

References

Alejandro Ortega C. (1987) *Insect Pests of Maize (A Guide for Field Identification).* Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT), Mexico DF. 106 pp.

de Pury J. M. S. (1985) *Crop Pests of East Africa.* Oxford University Press, East Africa. 240 pp.

Hill D. S. (1983) *Agricultural Insect Pests of the Tropics and Their Control.* 2nd edition. Cambridge University Press, London, UK. 746 pp.

Horowitz A. R., Seligman I. M., Forer G., Bar D. and Ishaaya I. (1993) Preventive insecticide resistance strategy in *Helicoverpa (Heliothis) armigera* (Lepidoptera: Noctuidae) in Israeli cotton. *Journal of Economic Entomology* 86, 205–212.

NRI [Natural Resources Institute] (1981) *Pest Control in Tropical Grain Legumes.* Natural Resources Institute (NRI), Centre for Overseas Pest Research (COPR), London.

NRI [Natural Resources Institute] (1983) *Pest Control in Tropical Tomatoes.* Natural Resources Institute (NRI), Centre for Overseas Pest Research (COPR), London.

The Status of the African Bollworm, *Helicoverpa (Heliothis) armigera* Hübner (Lepidoptera: Noctuidae), and Future Research Needs for Its Management in Kenya

G. N. Kibata

Kenya Agricultural Research Institute-National Agricultural Research Laboratories (KARI-NARL), P. O. Box 14773, Nairobi, Kenya

Abstract

The African bollworm is an important pest of many crops in the tropics and subtropics. It has a host range of over 180 cultivated and wild plants in Australia, Africa, Asia and Europe. Control strategies have mainly relied on chemical pesticides, which readily become unsustainable in terms of cost, pest resistance and environmental pollution. Other strategies such as companion cropping, host plant resistance, use of natural enemies, biopesticides and biotechnology have been partially explored. Future prospects for enhancing use of environmentally benign pest management strategies for the bollworm may depend on better utilisation of effective biocontrol agents. This paper discusses the status of the African bollworm (ABW) and prospects for developing appropriate pest management strategies in Kenya.

Key words: *Helicoverpa armigera*, tomato, cotton, pigeon pea, cut flowers, Kenya

Introduction

The African (formerly American) bollworm is recognised as a major polyphagous pest of crops in Africa, Asia, Australia and Europe (IIE, 1993). Most of the research effort to develop coping strategies has been on chemical pesticides, host resistance, habitat management, biological control and more recently biotechnology through genetically modified crops. ABW undoubtedly causes widespread economic losses especially on food and fibre crops in Africa. Crop losses at farm level in Kenya have been estimated at > 50% on cotton and pigeon pea, > 20% on sorghum and millet and > 2 million stems on cut flower (Table 1). Losses in the milling quality of wheat due to ABW damage through altering of the rheological properties (viscosity, deformation and texture of dough) have also been reported (Van Lill *et al.*, 1994).

Several consignments of cut flowers from Kenya have been intercepted for ABW infestation in European ports (Tremewan, 2000). This in turn has led to loss of revenue from Kenyan horticultural exports to Europe. As a result, the need to develop sustainable pest management strategies for ABW is underscored.

Table 1. Known extent of damage/loss due to the African bollworm in different crops in Kenya

Crop	Year(s)	Location/ region	Extent damage	(%) Yield loss	Reference
Tomato	1980–1998	Mwea, Kibwezi	Medium	20	Kibata G. N. (pers.
Pigeon pea	1976–2000	Katumani, Kiboko	High	50	commun.) from Ministry
Cotton	1976–1992	Mwea, Giaki	High	50	of Agriculture reports
Cut flowers	1980–2000	Naivasha	Medium	10	and farmer records

Management of the African Bollworm

The African bollworm (ABW), *Helicoverpa armigera* Hübner, is a polyphagous pest of over 180 cultivated and wild plants in the tropics and subtropics (Manjunath *et al.*, 1989). In Kenya, the larvae of the ABW have been recorded on cotton, pulse crops, tomato, sunflower and cereals (Wheatley and Crowe, 1967; De Lima, 1976; Rens, 1977a). Most of the research to develop coping strategies was focused on screening chemical pesticides especially on cotton (Minja *et al.*, 2000; Kibata, 2002). The earliest recommendations for ABW were based on organochlorine pesticides, e.g. DDT, toxaphene. These were later replaced by carbamates and organophosphates, while more recently synthetic pyrethroids have been widely used (Table 2). The latest scenario is the use of cocktails of organophosphates and pyrethroids that is believed to help delay the development of pesticide resistance in target ABW populations. *Bacillus thuringiensis* (Bt)-based biopesticides, botanicals and benzoylureas are also in use in eastern Africa (Table 2). The criteria to apply the pesticides should ideally be based on good knowledge of the economic threshold of ABW for the target crops. This approach requires sound scientific data as well as intensive farmer training, an aspect that is largely ignored, except in the case studies of Zimbabwe, South Africa and Tanzania (van Hamburg and Kfir, 1982; Gledhill, 1982; Kabissa, 1989; Nyambo, 1989). However, while pest surveillance and scouting may lead to reduced use of chemical pesticides, the pest gradually develops resistance necessitating more applications or drastic shift to other classes of pesticides (Basson *et al.*, 1979). Currently, there is widespread occurrence of resistance to popular synthetic pyrethroids in ABW populations in Africa and elsewhere (Van Jaarsveld *et al.*, 1998). The mechanisms of resistance to pyrethroids have been identified as primarily metabolic resistance (MFO), some extent of target modification (Kdr), and esterases following repeated exposure (Martin *et al.*, 2000).

Several studies have indicated that companion cropping could exacerbate the bollworm problem, especially where the crops are all suitable hosts, while habitat management could alleviate the impact of ABW (Rens, 1977b; van den Berg et al., 1993). However, use of trap crops has enormous potential (Abate, 1988).

Table 2. Pesticides used against the African bollworm on different crops in the East African region

Type of pesticide	Common names
Organochlorines	Endosulfan
Organophosphates	Malathion, diazinon, dichlorvos, fenitrothion, fenthion, trichlorphon, azinphos-methyl, quinalphos, pirimiphos–methyl, chlorpyrifos, triazophos, profenofos, omethoate, phosphamidon, isoxathion
Carbamates	Carbaryl, methomyl
Bacteria	*Bacillus thuringiensis (B.t.)* subsp. *kurstaki*, *B.t. aizawai*
Botanicals	Azadirachtin
Pyrethroids	Permethrin, cypermethrin, bifenthrin, deltamethrin, alpha-cypermethrin, beta-cyfluthrin, lambda-cyhalothrin, fenvalerate, esfenvalerate, flucythrinate, fenpropathrin
Benzoylureas	Lufenuron, diflubenzuron

Crop host resistance in many crops offers little hope for successful management of bollworms on cotton (Pauly and Vaissayre, 1980). Possibilities of utilising genetic traits in finger millet to reduce ABW attack have been indicated in a field study at Kiboko (Sharma *et al.*, 1998). Related investigations of utilising genetic traits in finger millet to reduce ABW attack have been indicated in a field study at Kiboko (Sharma *et al.*, 1998). Related investigations on sorghum varieties have also been undertaken in Eastern Sudan (Azrag *et al.*, 1993). Similar evaluation of pigeon pea genotypes indicated that some varieties were less damaged by ABW (Minja *et al.*, 1999) in Kenya. However, there is no durable resistance to the bollworm for crop host resistance being successfully exploited, and is yet to be demonstrated as a management option.

Habitat management and the use of mulches have been demonstrated as promising means of reducing crop damage by the bollworm (Uvah *et al.*, 1989). Very elaborate studies have demonstrated the valuable role of natural enemies in the suppression of bollworms under various cropping systems (Nyambo, 1990; van den Berg *et al.*, 1990; van den Berg *et al.*, 1993; van den Berg and Cock, 1993 a, b, 1995; van den Berg *et al.*, 1997). Major predators of ABW were ants (*Pheidole* spp., *Myrmicaria* spp. and *Camponotus* spp.) and anthocorid bugs (*Orius albidipennis, O. thripoborus* and *Geocoris amabilis*). Other predators were mainly coccinellids and *Chrysoperla* spp. Some of the parasitoids included *Trichogramma* spp. and the tachinid fly, *Linnaemya longirostris*. Pintureau and Babault (1988) have developed the systematics of African species of the genera *Trichogramma*. Endemic strains of *B. t.* have been isolated from cadavers of ABW (Brownbridge and Onyango, 1992). Possibilities of using local or exotic granulosis virus against ABW have been demonstrated in several African countries (McKinley, 1971; Whitlock, 1974, 1977).

Numerous studies have been undertaken with a view to developing integrated pest management for the ABW (Abate, 1988; Nyambo, 1988). However the ABW still remains an intractable problem in major food crops, horticulture and fibre crops. The scope for biological control agents, appropriate habitat management packages, benign pesticides and crop host resistance in the suppression of ABW is substantial. Augmentative releases of biocontrol agents and habitat manipulation conducive to enhancing the role and abundance of natural enemies should be a key element in the successful management of the African bollworm (Sithanantham *et al.*, 2001). Reliable data on economic thresholds for the traget crops should be generated as a vital decision tool for control interventions especially where pesticides are to be used.

References

Abate T. (1988) Experiments with trap crops against African bollworm, *Heliothis armigera* in Ethiopia. *Entomologia Experimentalis et Applicata* 48, 135–140.

Azrag A. K., Seifelnasr Y. E. and Cooters R. J. (1993) Evaluation of sorghum entries for resistance to *Helicoverpa armigera* Hübner (Lepidoptera: Noctuidae) under natural field conditions. *International Journal of Pest Management* 39, 312–316.

Basson N. C. T., Van Ark H. and van den Berg H. (1979) On the possible development of resistance to endosulfan by the American bollworm on cotton. *Journal of the Entomological Society of Southern Africa* 42, 61–64.

Brownbridge M. and Onyango T. (1992) Screening of exotic and locally isolated *Bacillus thuringiensis* (Berliner) strains in Kenya for toxicity to the spotted stem borer, *Chilo partellus* (Swinhoe). *Tropical Pest Management* 38, 77–81.

De Lima C. P. F. (1976) *A Guide to the Biology and Control of the Pests of Field Crops and Stored Produce in Kenya.* National Agricultural Laboratories, Ministry of Agriculture, Nairobi, Kenya.

Gledhill J. A. (1982) Progress and problems in *Heliothis* management in tropical southern Africa, pp. 375–384. In *Proceedings of the International Workshop on* Heliothis *Management* 15–20 November 1981, ICRISAT Centre, Patancheru, India (Edited by W. Reed and V. Kumble). ICRISAT, Patancheru, AP, India.

IIE (International Institute of Entomology) (1993) *Distribution Maps of Pests* No. 15, 2nd revision, 6 pp. International Institute of Entomology, London.

Kabissa J. C. B. (1989) Evaluation of damage thresholds for insecticidal control of *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) on cotton in Eastern Tanzania. *Bulletin of Entomological Research* 79, 95–98.

Kibata G. N. (2002) Insecticides/Miticides: Recommendations for the Control of Cotton Pests During 2002/3. Kenya Agricultural Research Institute. 18th September 2002. 6 pp. Unpublished mimeograph.

Manjunath T. N., Bhatnagar V. S., Pawar C. S. and Sithanantham S. (1989) Economic importance of *Heliothis* spp. in India and assessment of their natural enemies and host plants, pp. 197–228. In *Proceedings of the International Workshop on Biological Control of* Heliothis 11–15 November, 1985 New Delhi, India (Edited by E. G. King, R. D. Jackson and V. Kumble). USDA-FERRO Office, New Delhi, India.

Martin T., Ochou G. O., Hala N., Klo F., Vassal J. M. and Vaissayre M. (2000) Pyrethroid resistance in the cotton bollworm, *Helicoverpa armigera* (Hübner) in West Africa. *Pest Management Science* 56, 549–554.

Mckinley D. T. (1971) Nuclear polyhedrosis virus of the cotton bollworm in Central Africa. *Cotton Growers Review* 48, 297–303.

Minja E. M., Shanower T. G., Silim S. N. and Singh L. (1999) Evaluation of pigeon pea, pod borer and pod fly tolerant lines at Kabete and Kiboko in Kenya. *African Crop Science Journal* 7, 71–79.

Minja E. M., Shanower T. G., Silim S. N. and Karuru O. (2000) Efficacy of different insecticides for pigeon pea pest management in Kenya. *International Chickpea Pigeon Pea Newsletter* 7, 53–55.

Nyambo B. T. (1988) Studies in the bollworm, *Heliothis armigera* Hübner *(Helicoverpa armigera)*, the key cotton pest in Tanzania, as a basis for improved integrated pest management. PhD thesis, University of London, UK. 276 pp.

Nyambo B. T. (1989) Use of scouting in the control of *Heliothis amigera* in cotton in Tanzania. *Crop Protection* 8, 310–317.

Nyambo B. T. (1990) Effect of natural enemies on the cotton bollworm *Heliothis armigera* Hübner (Lepidoptera: Noctuidae) in Western Tanzania. *Tropical Pest Management* 36, 50–58.

Pauly G. and Vaissayre M. (1980) Present state of progress of the work on the selection of resistance characters in the cotton plant to bollworms in Central Africa. *Coton-et-Fibres-Tropicales* 35, 209–216.

Pintureau B. and Babault M. (1988) Systematics of African species of the genera *Trichogramma* Westwood and *Trichogrammatoidea* Girault (Hym. Trichogrammatidae). *Colloques-de-l'INRA* No. 43, 97–120.

Rens G. R. (1977a) *Cotton Pests of Kenya*. National Agricultural Laboratories, Ministry of Agriculture, Kenya. 26 pp.

Rens G. R. (1977b) Interrelations and control of insects attacking cotton and food crops, with particular reference to *Heliothis armigera*, pp. 80–84. In *Advances in Medical, Veterinary and Agricultural Entomology in Eastern Africa*. Proceedings of the 1st East African Conference on Entomological Pest Control, 6–10 December 1976, Nairobi, Kenya (Edited by C. P. F. De Lima). East African Literature Bureau, Kenya.

Sharma H. C., Mukuru S. Z. and Kibuka J. (1998) *Helicoverpa armigera* incidence in finger millet (*Eleusine coracana* Gaertn.) at Kiboko, Kenya. *International Sorghum and Millet Newsletter* No. 39, 147–149.

Sithanantham S., Abera T. H., Baumgärtner J., Hassan S. A., Löhr B., Monje J. C., Overholt W. A., Paul A. V. N., Zebitz C. P. W. and Fang Hao W. (2001) Egg parasitoids for augmentative biological control of lepidopteran vegetable pests in Africa: Research status and needs. *Insect Science and Its Application* 21, 189–205.

Tremewan W. G. (2000) A record of *Helicoverpa armigera* (Hübner, 1808) (Lepidoptera: Noctuidae) reared from roses imported from Kenya. *Entomologists' Gazette* 52, 70.

Uvah I. I., Ajayi O. and Olarewaju J. D. (1989) Evaluation of insecticides and mulching materials for control of the tomato fruit worm, *Helicoverpa (Heliothis) armigera* Hübner at Kadawa, Nigeria. *Nigerian Journal of Entomology* 10, 35–40.

van den Berg H. and Cock M. J. W. (1993a) Stage-specific mortality of *Helicoverpa armigera* in three smallholder crops in Kenya. *Journal of Applied Ecolology* 30, 640–653.

van den Berg H. and Cock M. J. W. (1993b) Exclusion cage studies on the impact of predation on *Helicoverpa armigera* in cotton. *Biocontrol Science and Technology* 3, 491–497.

van den Berg H. and Cock M. J. W. (1995) Natural control of *Helicoverpa armigera* in cotton:

Assessment of the role of predation. *Biocontrol Science and Technology* 5, 453–463.

van den Berg H., Cock M. J. W. and Oduor G. I. (1997) Natural control of *Helicoverpa armigera* in sunflower: Assessment of the role of predation. *Biocontrol Science and Technology* 7, 613–629.

van den Berg H., Cock M. J. W., Oduor G. I. and Onsongo E. K. (1993) Incidence of *Helicoverpa armigera* (Lepidoptera: Noctuidae) and its natural enemies on smallholder crops in Kenya. *Bulletin of Entomological Research* 83, 321–328.

van den Berg H., Nyambo B. T. and Waage J. K. (1990) Parasitism of *Helicoverpa armigera* (Lepidoptera: Noctuidae) in Tanzania: Analysis of parasitoid–crop associations. *Environmental Entomology* 19, 1141–1145.

Van Hamburg H. and Kfir R. (1982) Tests of threshold levels on larval counts for chemical control of cotton bollworms. *Journal of the Entomological Society of Southern Africa* 45, 109–121.

Van Jaarsveld M. J., Basson N. C. J. and Marais P. (1998) Synthetic pyrethroid resistance in field strains of *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) in South Africa. *African Plant Protection* 4, 15–18.

Van Lill D., Miles C., Scott D. B. and Le Roux J. (1994) Reduction in hard bread wheat quality caused by American bollworm *Heliothis armigera* (Lepidoptera) damage. *Journal of Cereal Science* 19, 283–289.

Wheatley P. E. and Crowe T. J. (1967) *Pest Handbook (The Recognition and Control of the More Important Pests of Agriculture in Kenya)*. Government Printer, Nairobi. 33 pp.

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

Whitlock V. H. (1977) Failure of a strain of *Heliothis armigera* (Hubn.) (Noctuidae: Lepidoptera) to develop resistance to a nuclear polyhedrosis virus and granulosis virus. *Journal of the Entomological Society of Southern Africa* 40, 251–253.

Overview of Past Research on *Trichogramma* in Kenya and Future Needs

G. R. S. Ochiel[1†] and S. Sithanantham[2]

[1]*Kenya Agricultural Research Institute, National Fibre Research Centre, P. O. Box 1490, Kisumu, Kenya;*

[2]*International Centre of Insect Physiology and Ecology (ICIPE), P. O. Box 30772-00100 Nairobi, Kenya*

Abstract

In Kenya, considerable basic information has been assembled on native trichogrammatid species. Surveys of eggs of lepidopteran hosts have led to the recording of the occurrence of several trichogrammatid species, mainly on *Chilo partellus*, *Helicoverpa armigera* and *Plutella xylostella*. Monitoring of natural parasitism levels (both on-farm and on-station) has also been undertaken in coastal Kenya on *C. partellus*, while on-station assessments have also been made on eggs of *H. armigera* and *P. xylostella*. Biological laboratory studies have been made on *Trichogramma* sp. nr *exiguum* with several lepidopterous hosts. The potential impact of *Trichogramma* sp. nr *mwanzai* over a range of parasitoid: host ratios has also been evaluated at different densities of the host (*C. partellus*). Eggs of the silkworm, *Bombyx mori*, are not found to be parasitised by *T.* sp. nr *mwanzai* even under a no choice situation. In addition to on-going research under the ICIPE-led regional initiative on egg parasitoids of *H. armigera*, there are additional research needs, including capacity building, which should be considered in our future efforts in popularising the utilisation of *Trichogramma* as a biocontrol agent for important lepidopteran pests of crops, including *H. armigera*, in Kenya.

Key words: *Trichogramma*, Lepidoptera, biocontrol, IPM, capacity building, Kenya

Introduction

Advanced use of the egg parasitoid wasps, *Trichogramma* spp. (Hymenoptera: Trichogrammatidae), has been reported in China, the former Russia (USSR) and the United States. More than 32 million hectares of crops and trees have been treated annually with *Trichogramma* to control diverse lepidopteran pests (Li, 1994). In Kenya, pioneering studies on *Trichogramma* were by Ochiel (1989), who studied the biology of *T.* sp. nr *exiguum* Pinto & Platner on several lepidopteran pests, followed by Guang and Oloo (1990), who investigated *T.* sp. nr *mwanzai* Schulten and Feijen. Ngi-Song (1990) assessed the impact of *T.* sp. nr *mwanzai* Schulten and Feijen on *Chilo partellus* Swinhoe (Lepidoptera: Pyralidae). There was a gap in *Trichogramma* research until Abera (2001) took up further work. A collaborative project was initiated later by ICIPE (2002) on the African bollworm (ABW) management, with emphasis on horticultural crops, so as to provide farmers with a wider range of options.

A range of biological control agents of ABW is known to exist in Kenya (van den Berg *et al.*, 1988) and there is plenty of scope to use them as part of an integrated pest management (IPM) strategy. Parasitic wasps, predators, viruses and fungi have been recorded on *Helicoverpa armigera* Hübner (Lepidoptera:

[†] *Deceased.*

Noctuidae) infesting cotton (Cock *et al.*, 1991). Ochiel (1989) reported parasitism of *H. armigera* by *Trichogramma* sp. nr *exiguum* under laboratory conditions. No attempts have been made so far to mass rear and release biological control agents against *H. armigera*. ICIPE is pioneering efforts to control *H. armigera* using *Trichogramma* spp. in the region.

Previous studies in coastal Kenya have shown that field parasitism of *C. partellus* eggs by trichogrammatids could reach above 80% (Bonhof, 2000) and these studies have added to the trichogrammatid species record, besides assessing field parasitism on *P. xylostella* eggs.

Major Contributions from Past Research in Kenya

Species Occurring on Different Hosts

The different trichogrammatid native species occurring on lepidopteran pests in Kenya under the two genera *Trichogramma* sp. and *Trichogramatoidea* (Table 3) offer good scope for selective utilisation on pests and in major target crops systems. Abera (2001) has attempted studies using conventional and molecular tools for identifying the native trichogrammatids occurring in Kenya.

Table 3. The known natural hosts of trichogrammatid parasitoid species in Kenya

Trichogrammatid species	Host	Crop	Reference
Trichogramma sp. nr. *exiguum* Pinto & Platner	*Chilo partellus*	Maize	Ochiel (1989)
Trichogrammatoidea lutea Girault	*Chilo partellus*	Maize	Oloo (1989)
Trichogrammatoidea armigera Nagaraja	*Chilo partellus*	–	Nagaraja (1978)
	Helicoverpa armigera	–	Van den Berg (1993)
Trichogrammatoidea eldanae Viggiani	*Helicoverpa armigera*	–	Van den Berg (1993)
Trichogrammatoidea simmondsii Nagaraja	*Helicoverpa armigera*	–	Van den Berg (1993)
Trichogramma sp. nr *mwanzai* Schulten & Feijen	*Chilo partellus*		
	Helicoverpa armigera	Sorghum, kale, pigeon pea	Abera (2001)
Trichogramma sp. *bournieri* Pintureau & Babault	*Helicoverpa armigera*	–	Van den Berg (1993)
Trichogrammatoidea sp. nr *lutea* Girault	*Helicoverpa armigera*	Pigeon pea	Abera (2001)
	Plutella xylostella	Kale	Abera (2001)
Trichogramma sp. nr *brune* Nagaraja	*Chilo partellus*	Sorghum	Abera (2001)

Monitoring of Natural Parasitism Levels in Coastal Kenya on Chilo partellus

Although trichogrammatids are causing high mortality to eggs of *C. partellus* in coastal Kenya, apparently there is need for augmenting them, so as to effectively control their infestation levels to below economic damage as the pest is also found to occur in very severe levels in this region due to favourable climate factors (Table 4). Abera (2001) estimated the field parasitism on *C. partellus, H. armigera* and *P. xylostella* in coastal Kenya.

Host Range for Trichogrammatid Species

Table 4. Extent of natural parasitism by trichogrammatids in crop systems in Kenya

Target pest	Location/ Region	Percent parasitism	Reference
Chilo partellus	Coastal Kenya	19–76	Bonhof *et al.* (1997)
Chilo partellus	Coastal Kenya	93	Mathez (1972)
Heliothis armigera	Kibos	Up to 20	Van den Berg (1993)
Sesamia calamistis	Coastal Kenya	97	Bonhof *et al.* (1997)

Limited information is available on the host range of two trichogrammatid species. Ochiel (1989) found *T.* sp. nr *exiguum* could successfully develop on eggs of *C. partellus*, *Busseola fusca* Swinhoe and *H. armigera*. Guang and Oloo (1990) found that *T.* sp. nr *mwanzai* accepted the eggs of *C. partellus* and *Sesamia calamistis* Hampson, but did not accept the eggs of silkworm, *Bombyx mori*. Abera (2001) reported *T.* sp. nr *mwanzai* also parasitising *H. armigera*, while *Trichogramatoidea* sp. nr *lutea* Girault was also found parasitising *C. partellus* and *Plutella xylostella*, besides *H. armigera*.

Role of Host Plants on Trichogrammatid Performance

The extent of mortality caused by egg parasitoids (mostly trichogrammatids) on *H. armigera* has been shown to differ with the host plant (van den Berg, 1993).

Temperature Adaptation

Trichogramma sp. nr *mwanzai* has been found to produce higher progeny than another native species, *T. bourneri*, as well as two exotic species—*T. chilonis* Ishii and *T. evanescens* (Abera, 2001)—at warmer temperature (34 °C).

Optimisation of Trichogramma *Release Ratios*

Ngi-Song (1990) studied the interaction of host egg density and ambient temperature on the extent of parasitisation of *C. partellus* by *T.* sp. nr *mwanzai* and reported that the different parasitoid population densities used were positively correlated with the number of eggs and egg batches parasitised. As pest density increased, significant variations were observed in the rate of parasitism. Also, the maximum and minimum temperatures on the day of parasitoid release showed an inverse relationship with the number of eggs and egg batches parasitised, while the relative humidity of the same day was positively correlated.

Constraints in *Trichogramma* Research

Identification of Trichogrammatid Species

There was no local expertise in trichogrammatid taxonomy. During the initial stages, the problem was in dealing with identification of unknown species. Much effort and shipping of samples to experts elsewhere was required for the identification of this parasitoid group. For instance, accurate identification of *T.* sp. nr *exiguum* in Kenya required specimens to be sent to Dr Nagaraja in India. At present, this problem has been resolved and it is possible to distinguish between the two common genera, *Trichogramma* and *Trichogrammatoidea*.

The Host Range of Trichogrammatid Species

Trichogramma species are known to attack several lepidopteran insect pests. Ochiel (1989) found that *T.* sp. nr *exiguum* laid eggs successfully on *C. partellus* Swinhoe, *Busseola fusca* and *H. armigera* under laboratory conditions. Under certain circumstances, this quality may be beneficial. Where two or more lepidopteran pests are involved, the parasitoid could suppress populations of multiple insect pest species. For example, where tomato is intercropped with kales (*Brassica*), *Trichogramma* can parasitise both *H. armigera* on tomato and *Plutella xylostella* on kale. The host range of trichogrammatid species needs further study, both for deploying in mixed cropping systems, as well as in assessing effects on non-target Lepidoptera.

Choice of Rearing Hosts

Trichogramma may be reared on a variety of lepidopteran host eggs. The Indian meal moth, *Corcyra cephalonica* (Stainton), is the host of choice. As continuous mass rearing on facultative hosts may lead to loss of vigour in later generations, switching of rearing to the original host should be planned prior to use for releases.

Lack of Detailed Information on Biology and Ecology

To be able to use *Trichogramma* successfully, detailed information on their biology and ecology is necessary. *Trichogramma* species are known to be highly adaptable to a wide range of geographical locations and cropping systems and have different eco-climatic requirements. The more knowledge we have about them the better the results of utilising the egg parasitoids would be.

Other Areas Requiring Attention in Future

1. DNA fingerprinting of *Trichogramma* species to help in accurate identification of the species.
2. Laboratory screening of *Trichogramma* species against specific Lepidoptera to determine the effective strains for field releases.
3. Determination of the potential impact of *Trichogramma* species on non-target Lepidoptera, particularly economically important butterflies and silkworms.
4. Integration of *Trichogramma* with other IPM strategies (chemical pesticides, bacteria, e.g. *Bacillus thuringiensis*, viruses, e.g. nuclear polyhedrosis virus, nematodes, e.g. *Steinernema* spp. and fungi, e.g. *Nomurea rileyi*) and bollworm-resistant varieties (both conventional and genetically modified).
5. Standardisation of mass rearing technology, with emphasis on quality control.
6. Capacity building in *Trichogramma* handling for researchers, extensionists and farmers.
7. Collaborative linkages and networking of *Trichogramma* specialists, locally, regionally and internationally.
8. Private sector and non-governmental involvement in commercial *Trichogramma* production.

References

Abera T. H. (2001) Studies on native *Trichogramma* (Hymenoptera: Trichogrammatidae) for biocontrol of selected lepidopteran pests in Kenya. PhD Thesis, Kenyatta University, Nairobi. 190 pp.

Bonholf M. J. (2000) The impact of predators on maize stem borers in coastal Kenya. PhD thesis. Wagenigen Agricultural University, The Netherlands. 181 pp.

Bonhof M. J., Overholt W. A., Van Huis A. and Polaszek A. (1997) Natural enemies of cereal stem borers in East Africa: A review. *Insect Science and Its Application* 17, 19–35.

Cock M. J. W., van den Berg H., Oduor G. I. and Onsongo E. K. (1991) The population ecology of *Helicoverpa armigera* in smallholder crops in Kenya with emphasis on its natural enemies. Final Report, Phase II: April 1988–March 1991. International Institute of Biological Control, Ascot, UK. 179 pp.

Guang L. Q. and Oloo G. W. (1990) Host preference studies on *Trichogramma* sp. nr *mwanzai* Schulten and Feijen (Hymenoptera: Trichogrammatidae) in Kenya. *Insect Science and Its Application* 11, 757–763.

ICIPE [International Centre of Insect Physiology and Ecology] (2002) *ICIPE Annual Scientific Report Summaries 2000–2001.* ICIPE Science Press, Nairobi, Kenya. Pages 28–30.

Li Li-Ying (1994) Worldwide use of *Trichogramma* for biological control on different crops: A survey, pp. 37–53. In *Biological Control with Egg Parasitoids* (Edited by E. Wajnberg and S. Hassan). CAB International, Oxon, UK.

Nagaraja H. (1978) Studies on *Trichogrammatoidea* (Hymenoptera: Trichogrammatidae). *Oriental Insects* 12, 13–31.

Ngi-Song A. J. (1990) A model of parasitism by *Trichogramma* sp. nr *mwanzai* Schulten & Feijen on the stalk borer *Chilo partellus*. M. Phil thesis, Rivers State University of Science and Technology, Nkpolu, Port Harcourt, Nigeria. 134 pp.

Mathez F. C. (1972) *Chilo partellus* Swinh., *Chilo orichalcociliellus* Strand and *Sesamia calamistis* on maize in coastal Kenya. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 45, 276–289.

Ochiel G. R. S. (1989) Biology of *Trichogramma* sp. nr *exiguum* Pinto & Platner on some lepidopterous hosts in South Nyanza, Kenya. M. Phil thesis, Rivers State University of Science and Technology, Nkpolu, Port Harcourt, Nigeria. 140 pp.

Oloo G. W. (1989) The role of natural enemies on population dynamics of *Chilo partellus* (Swinhoe) under subsistence farming systems in Kenya. *Insect Science and Its Application* 10, 243–251.

van den Berg (1993) Natural control of *Helicoverpa armigera* in smallholder crops in Kenya. PhD thesis. Wageningen Agricultural University, The Netherlands. 233 pp.

van den Berg H., Waage J. K. and Cock M. J. W. (1988) *Natural Enemies of Helicoverpa armigera in Africa: A Review.* CAB International, Institute of Biological Control, Ascot, UK. 81 pp.

Potential for *Trichogramma* in Biocontrol in Kenya and Elsewhere

Biological Control of *Helicoverpa armigera*: Global Scenario and Scope in Africa

S. Sithanantham and J. Baya
International Centre of Insect Physiology and Ecology
P. O. Box 30772-00100, Nairobi, Kenya

Abstract

The African bollworm, *Helicoverpa armigera* (Hb.), is a highly polyphagous and mobile pest, currently known to occur in most parts of Africa, Asia, Europe and Australia. Integrated pest management (IPM) is becoming increasingly recognised globally as the appropriate approach for sustainable management of this pest. The utilisation of natural enemies for biocontrol of *H. armigera* offers adequate scope as a key component of IPM.

This pest is a major source of yield loss among a range of smallholder crops—including vegetables (e.g. tomato), legumes (e.g. chickpea), cereals (e.g. sorghum), fibres (e.g. cotton) and oilseeds (e.g. sunflower)—in Africa. Biocontrol is a potentially promising IPM component for this pest, across the major cropping systems in Africa. However, current research efforts for promotion of biocontrol and the knowledge status on the locally occurring natural enemies appear to be limited. The scope for future initiatives in filling research gaps and technology dissemination towards popularising biocontrol of this pest in Africa is discussed.

Key words: *Helicoverpa armigera*, 'silver bullet', biocontrol, IPM, natural enemies, tomato, peas, pigeon pea, European Union, Africa, Europe, Asia, Australia

Introduction

The African bollworm, *Helicoverpa armigera* (Hb.), is widely distributed across most of Africa, Europe, Asia and Australia. The importance of this pest as a source of yield loss has been documented on a wide range of crops of agricultural importance in all the four continents where it occurs (Sharma, 2001). There is an increasing realisation globally that resorting to pesticide use is not sustainable, and there is need to conserve and/or utilise the natural enemies, as a key component of sustainable management of this pest. This highly polyphagous and mobile pest is often a challenge for crop protectionists, as it is difficult to manage it sustainably through a 'silver bullet' option.

The first International Workshop on biocontrol of *Heliothis* (*Helicoverpa*) held in India in 1985 (King and Jackson, 1989) pointed out the scope for this method as a key component of IPM for this widely occurring pest. Biocontrol of *H. armigera* has received considerable attention in Asia and Australia in recent years. A recent workshop on progress and future research needs of *Heliothis armigera* management held at ICRISAT, Hyderabad, India in 2001 reconfirmed the importance of utilising natural enemies, as a key component of IPM for this pest in the tropics.

Helicoverpa armigera: The Global Scenario

Introduction of New Natural Enemies

Efforts on introductions so far have been directed at parasitoids, especially those attacking the larval stages (Hedlund, 1989; Carl, 1989). Successful establishment following introductions has been reported in USA (Powell, 1989), Australia (Michael, 1989), New Zealand (Cameron and Valentine, 1989) and India (Nagarkatti and Singh, 1989) (Table 5).

Table 5. Introductions of natural enemies for biocontrol of *Helicoverpa armigera* elsewhere

			Attempted introductions		
	From	To	Year(s)	Results	Reference
Trichogramma pretiosum	USA	Australia	1973–1975	Adapted for mass release	Michael (1989)
Trichogramma brasiliensis	USA	India	1968, 1982	Found to be well adapted for mass release	Sithanantham and Paul (1989)
Cotesia kazak	Europe	New Zealand	1977	Established	Cameron and Valentine (1989)
Campoletis chlorideae	Pakistan	Australia	1982–1983	Established	Michael (1989)
Chelonus blackburni	USA	India	1976	Established	Nagarkatti and Singh (1989)
Eucelatoria bryani	USA	India	1969, 1978	Established	Nagarkatti and Singh (1989)

Augmentation of Natural Enemies

Relatively more attention has been given to this component. The focal target biocontrol agents include egg parasitoids (e.g. *Trichogramma*), predators (e.g. *Chrysopa*), baculoviruses (e.g. nuclear polyhedrosis virus) and bacterial pathogens (e.g. *Bacillus thuringiensis*).

In Asia, mass produced *Trichogramma* have been shown to be a useful component in *H. armigera* biocontrol, especially in cotton and tomato crops (Sithanantham and Paul, 1989; Fang *et al.*, 1989). Mass release of chrysopid predators has also gained considerable acceptance in these regions, among the same target crops and also in some legume crops in India.

Popularising of the nuclear polyhedrosis virus as a key component of *H. armigera* IPM is being actively pursued on cotton, where there is increasing pressure to reduce pesticide use (Jayaraj, 1989). Demonstration of the potential for *B.t.* as a complementary option for biocontrol of this pest has also been recently given some attention in Asia and Europe.

An example of the crops and regions where *H. armigera* biocontrol by augmentation approach using *Trichogramma* has been shown to be promising in India is furnished in Table 6.

Conservation of Natural Enemies

Conservation of natural enemies has so far not been given adequate attention. However, there are recent initiatives to validate and refine this option in some countries. It would be important to give some more research attention to this approach, which tends to have greater chances of adoption due to its relatively low cost.

The Current Status of Research in Africa

Natural Enemy Spectrum Assessment

Several reports are available on the range of natural enemies known to occur on the developmental stages of *H. armigera* in Africa (Table 7). However, in most

Table 6. Examples of potential of 'inundative' releases of trichogrammatid egg parasitoids for biocontrol of *Helicoverpa armigera* in India

Target crop	Biocontrol agent released	Dosage (lakhs/ha)*	Results	Reference
Tomato	*Trichogramma brasiliensis*	2.5	20–71% parasitism	Mani and Krishnamoorthy (1983)
	T. brasiliensis	3.0	78.4% parasitism	Singh (1991)
	T. pretiosum	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.* (1994)
Potato	*T. chilonis*	2.5	69% reduction in *H. armigera* larvae	Yadav *et al.* (1985)
Cotton	*Trichogramma achaeae*	Inundative releases	22% parasitism	Sundaramoorthy and Babu (1985)
	T. chilonis	1.0; 3 releases	As effective as insecticides	Dhandapani *et al.* (1992)
	T. chilonis	1.5	>60% parasitism	Singh *et al.* (1994)
	T. brasiliensis	1.5–2.0	Egg parasitism was 23.2 to 64.6%	Muthukrishnan (1995)
	Trichogrammatoidea armigera	2.5 at 2 m spacing	Effective	Singh *et al.* (1994)

*1 lakh = 100,000 units.

Table 7. Natural enemies of *Helicoverpa armigera* recorded in Africa

Natural enemy	Family	Country	Reference
Parasitoids			
Trichogramma pretiosum	Trichogrammatidae	Sudan	Munir *et al.* (1992)
Trichogramma evanescens	Trichogrammatidae	Egypt	Abbas (1990)
Trichogramma voegelei and *T. bourarachae*	Trichogrammatidae	Morocco	Mimouni (1991)
Trichogramma chilonis	Trichogrammatidae	South Africa	Kfir (1994)
Trichogramma bournieri and *T.* sp. nr *mwanzai*	Trichogrammatidae	Kenya	Abera (2001)
Trichogramma spp. (*T. bourarachae, T. bournieri, T. mandelai*)	Trichogrammatidae	Across Africa	Pintureau and Babault (1988)
Trichogrammatoidea spp. (*T. lutea* and *T. nana*)	Trichogrammatidae	Across Africa	Pintureau and Babault (1988)
Trichogrammatoidea lutea	Trichogrammatidae	South Africa	Kfir and Van Hamburg (1988)
Microplitis rufiventris Kok.	Braconidae	Egypt	Hassanein and El-Heneidy (1991)
Cardiochiles spp. (*C. calvus, C. coelofrons, C. nixoni, C. sahelensis*)	Braconidae	Sahel (W. Africa)	Huddleston and Walker (1988)
Cardiochiles variegatus	Braconidae	Sahel	Bhatnagar (1988)
Telenomus ullyetti	Scelionidae	South Africa	Kfir and Van Hamburg (1988)
Tetrastichus howardi	Eulophidae	South Africa	Moore and Kfir (1995)
Predators			
Pheidole spp., *Myrmicaria* spp. and *Camponotus* spp.	Formicidae	Kenya	Van den Berg *et al.* (1997)
Dorylus helvolus, Aenictus sp., *Astylus atromaculatus, Heteronychus arator*	Formicidae	South Africa	Watmough and Kfir (1995)
Myrmicaria spp., *Camponotus* spp. and *Pheidole* sp.	Formicidae	Kenya	Van den Berg (1993)
Mallada desjardinsi (Navas) and *Chrysoperla congrua*	Chrysopidae	Tanzania	Kabissa *et al.* (1995)
Mallada desjardinsi (Navas) and *Chrysoperla* sp.	Chrysopidae	Tanzania	Kabissa *et al.* (1996)
Orius albidipennis, O. thripodorus	Anthocoridae	Kenya	Van den Berg (1993)
Praomys natalensis	Mammalia	South Africa	Watmough and Kfir (1995)
Pathogens			
Bacillus thuringiensis	Bacillaceae	Kenya	Brownbridge and Onyango (1992)
Bacillus thuringiensis	Bacillaceae	Nigeria	Lutwama and Matanmi (1988)
Bacillus thuringiensis	Bacillaceae	Egypt	Abou-Bakr *et al.* (1986)
Nucleopolyhedrovirus (*H. armigera*)	Baculoviridae	Kenya	Baya *et al.* (2001)
Nucleopolyhedrovirus (*H. armigera*)	Baculoviridae	Egypt	Abbas (1990)
Nucleopolyhedrovirus (*H. armigera*)	Baculoviridae	Cameroon	Montaldo (1991)
Nucleopolyhedrovirus (*Heliothis*)	Baculoviridae	Egypt	Abou-Bakr *et al.* (1986)
Nucleopolyhedrovirus (*H. armigera*)	Baculoviridae	Nigeria	Lutwama and Matanmi (1988)

cases, they are incidental observations that were recorded on various parts of the continent and crops but are not backed by live cultures that could be availed for further biological evaluations.

Assessing the Relative Importance and Potential of Natural Enemies as Mortality Factors

The relative mortality caused by major natural enemy groups in crop ecosystems was quantified by van den Berg and Cock (1993 a, b) in Kenya and in Tanzania (van den Berg *et al.*, 1990). Studies in South Africa have also provided insight into the potential impact of natural enemies as mortality factors in the field (Pearson, 1958).

Parasitoid Introductions

Some attempts have been made to ship in and release parasitoids of *H. armigera*, mainly on cotton in South Africa and Sudan.

Augmentation Biocontrol

Release of *Trichogramma* for field control of *H. armigera* on tomato has been evaluated and found promising in Egypt (Abbas, 1998). The potential of nuclear polyhedrosis viruses (NPV) for field control of *H. armigera* on peas and pigeon pea has been shown in Kenya (Baya *et al.*, 2001; Minja *et al.*, 2003). The scope for *B.t.* as a biocontrol agent for *H. armigera* has also been evaluated in several countries, but apparently there has been little follow up for its popularisation.

Conservation Biocontrol

This aspect appears to have been neglected. Some reports are available on the relative toxicity of commonly used pesticides to provide a basis for selecting those that are least disruptive to the resident natural enemies. In South Africa, conservation of predators has been shown to enable reduction in the number of applications of synthetic pesticides (cypermethrin) on cotton (Greathead and Girling, 1989). The construction of additional perches for promoting the activity and impact of bird predators was found to provide a good impact as it is promising in *H. armigera* management on pigeon pea in Kenya (Minja *et al.*, 2003).

Utilising the Native Biodiversity

Until recently, efforts were limited to describing the occurrence of species and strains of native natural enemies, and no attempts were made to characterise them as well as to establish live repositories or gene banks.

Existing knowledge on *Heliothis armigera* in Africa

Parasitoids Occurring on H. armigera *in Africa*

Greathead and Girling (1989) listed species among Braconidae (20 species), Ichneumonidae (9 species), Chalcididae (3 species), Eulophidae (1 species), Trichogrammatidae (2 species), Scelionidae (3 species), Bombylidae (1 species), Calliphoridae (2 species) and Tachinidae (12 species) as parasitoids reported on *H. armigera* in Africa. Subsequent additions include Kenya (van den Berg and Cock, 1993c) and a list of trichogrammatids across Africa (Sithanantham *et al.*, 2001).

Predators on H. armigera *in Africa*

Greathead and Girling (1989) have provided a list of predators reported on *H. armigera*. These include three families of Hemiptera namely Anthocoridae

(1 species), Pentatomidae (2 species) and Reduviidae (3 species); three families of Hymenoptera namely Formicidae (3 species), Eumenidae (1 species) and Sphecidae (1 species) besides four species among Neuroptera (Chrysopidae). Van den Berg and Cock (1993c) have provided some additions to this list from Kenya.

Ecosystem/Habitat Interaction

High levels of parasitism and greater intensity of disease (NPV) occurrence have been observed on *H. armigera* on maize and weeds than in cotton (Reed, 1965; Nyambo, 1984).

Interaction with Insecticide Use

Studies on toxicity of pesticides to common field predators (Brettell and Burgess, 1973) have been followed up with preparations for introducing biologically selective pesticidal control of cotton pests (Gledhill, 1982).

Use of Entomopathogens

Preliminary trials were taken up with *Bacillus thuringiensis* and NPV preparations in Uganda (Coaker, 1959), Tanzania (Mckinley, 1971) and Botswana (Roome, 1975). In Kenya, surveys of NPV resulted in assembling NPV strains and exploratory bioassays and net house evaluations that have shown their potential for control of *H. armigera* on pigeon pea. Follow up studies by Minja *et al.* (2003) have shown the potential of the NPV to provide control comparable to chemical control on pigeon pea.

Scope for Promoting Biocontrol of *Helicoverpa armigera* in Africa

Demand for Quarantine Regulations from Importing Countries in the European Union

The European Union, which is the major consumer of fresh vegetables exported from Africa, is tightening the regulations regarding risks in the imported produce. *Helicoverpa armigera* larvae have been intercepted in several shipments of vegetables, especially from Kenya (Sharma, 2001; Kibata, 2002).

Demand for Use of Organic Practices and Products in Crop Protection

Both importers and local consumers of crops that are prone to *H. armigera* (such as French bean, tomato, okra, capsicum, pigeon pea, chickpea) are keen that there should be no risks from synthetic pesticide residues. Evidently, one of the safer alternative options is to shift to organic products, especially biocontrol agents and botanicals.

Interest in Investing in Local Mass Production of Biocontrol Agents

In Kenya, Dudutech, a private enterprise has launched an initiative to locally mass-produce the egg parasitoid (*Trichogramma* spp.) (Dudutech, 2002), which can be a useful means of popularising biocontrol.

Scope for Deploying More Adapted Species/Strains

In *Trichogramma*, there is scope for identifying species adapted to cooler or warmer temperature regimes (Abera *et al.*, 2002). Variability in virulence of NPV strains to *H. armigera* larvae has been shown to occur (Baya *et al.*, 2001).

Selective Deployment for Target Crops and Ecologies

The canopy types and plant surface characteristics of target crops (and cultivars) are known to be important factors in the performance of the natural enemies, e.g. *Trichogramma* (Romeis *et al.*, 1999 a, b) and NPV (Rabindra *et al.*, 1992).

Potential for Enhancing the Field Performance of Augmentation Biocontrol Agents

The use of locally available and inexpensive additives (like molasses) for enhancing the field performance of NPV (Baya *et al.*, 2001) could be explored. Scope for auto-dissemination of baculovirus is also worth exploring (Jackson *et al.*, 1992).

Scope for Integrating Biocontrol with Other IPM Options

It would be useful to explore for integrating the use of *Trichogramma* with biorationals (e.g. neem products) in the target crops. Similarly, complementing the deployment of *B.t.* or NPV, along with botanical pesticides, to enhance the extent of mortality of *H. armigera* larvae (Rabindra *et al.*, 1991) may also be considered. Reed and co-workers (1989) have indicated the compatibility of biocontrol with host plant resistance as a component of *H. armigera* management.

Popularisation and Policy Support Initiatives

Adequate resources must be availed to support popularisation of biocontrol. Partnerships with non-governmental organisations (NGOs) and private enterprise should be encouraged. Policy support to motivate private investment in biocontrol products will be crucial and should be adequately extended.

In conclusion, based on the potential shown and knowledge available elsewhere for biological control of *H. armigera*, there appears to be good scope for promoting it as a key component of IPM for the pest in Africa. Further, there is increasing demand at present in the region to wean farmers from synthetic pesticide use on several crops in which *H. armigera* is a key pest and promote IPM strategies. Therefore, promotion of biocontrol of these pests is both timely and opportune in the region. Gaps filling research as well as policy support and popularisation initiatives should adequately be supported as critical means for biocontrol promotion. Human resource capacity building to provide a specialised backup should also be given due attention. There is great need and ample scope to promote biocontrol-based IPM for *H. armigera* in Africa. Suitable regional networking and international collaboration should also be established for significant impact.

References

Abbas M. S. T. (1998) Mass production and utilization of *Trichogramma evanescens* Westw. as a biocontrol agent against tomato fruit worm, *Heliothis armigera* Hbn. in Egypt, pp. 119–123. In *Egg Parasitoids*. Proceedings of the 5th International Symposium, International Organisation for Biocontrol, Cali, Colombia, March 1998. (Edited by S. A. Hassan). International Institute of Biological Control (IIBC), Cali, Colombia.

Abbas M. S. T. (1990) Interaction between host, egg and larval parasitoids and nuclear polyhedrosis virus. *Bulletin of the Entomological Society of Egypt* 16, 133–141.

Abera T. H. (2001) Studies on native *Trichogramma* (Hymenoptera: Trichogrammatidae) for biocontrol of selected lepidopteran pests in Kenya. PhD Thesis, Kenyatta University, Nairobi. 190 pp.

Abera T. H., Hassan S. A., Ogol C. K. P. O., Baumgärtner J., Sithanantham S., Monje J. C. and Zebitz C. P. W. (2002) Temperature-dependent development of four egg parasitoid *Trichogramma* species (Hymenoptera: Trichogrammatidae). *Biocontrol Science and Technology* 12, 555–567.

Abou-Bakr I. E., El-Husseini M. M. and Tawfik M. F. S. (1986) Studies on the entomopathogenic bacterium *Bacillus thuringiensis* isolated from larvae of the American bollworm, *Heliothis armigera* (Hbn.) in Egypt. *Bulletin of the Entomological Society of Egypt* (Economic Series 1984–1985) 14, 23–28.

Baya J., Sithanantham S., Mueke J., Kariuki C., Rao G. V. R., Osir E. and Baumgärtner J. (2001) Natural occurrence, characterization and biological potential evaluation of nuclear polyhedrosis virus (NPV) on *Helicoverpa armigera* in Kenya, pp. 6–7. In *African Entomology* (Edited by T. Olckers and D. Brothers). Proceedings of the 13th Entomological Congress, 2–5 July 2001, Pietermaritzburg, South Afirca. Entomological Society of Southern Africa, Hatfield, South Africa.

Bhatnager V. S. (1988) New records of *Cardiochiles* (Braconidae: Hymenoptera) on *Heliothis armigera* (Hb.) and *Raghuva albipunctella* de Joannis in the Sahel. *Current Science* 57, 904–905.

Brownbridge M. and Onyango T. (1992) Screening of exotic and locally isolated *Bacillus thuringiensis* (Berliner) strains in Kenya for toxicity to the spotted stem borer, *Chilo partellus* (Swinhoe). *Tropical Pest Management* 38, 77–81.

Brettell J. H. and Burgess M. W. (1973) A preliminary assessment of effects of some insecticides on predators of cotton pests. *Rhodesia Journal of Agricultural Research* 70, 103.

Cameron P. J. and Valentine E. W. (1989) Importation and establishment of predators and parasitoids of *Heliothis* into New Zealand, pp. 397–410. In *Proceedings of the Workshop on Biological Control of* Heliothis: *Increasing the Effectiveness of Natural Enemies* 11–15 November 1998, New Delhi, India (Edited by E. G. King and R. D. Jackson). Far Eastern Regional Research Office, US Department of Agriculture, New Delhi, India.

Carl K. P. (1989) Attributes of effective natural enemies, including identification of natural enemies for introduction purposes, pp. 351–361. In *Proceedings of the Workshop on Biological Control of* Heliothis: *Increasing the Effectiveness of Natural Enemies* 11–15 November 1998, New Delhi, India (Edited by E. G. King and R. D. Jackson). Far Eastern Regional Research Office, US Department of Agriculture, New Delhi, India.

Coaker T. H. (1959) Investigations on *Heliothis armigera* in Uganda. *Bulletin of Entomological Research* 50, 484–506.

Cameron P. J. and Valentine E. W. (1989) Importation and establishment of predators and parasitoids of *Heliothis* into New Zealand, pp. 397–410. In *Proceedings of the Workshop on Biological Control of* Heliothis: *Increasing the Effectiveness of Natural Enemies* 11–15 November 1985 (Edited by E. G. King and R. D. Jackson). Far Eastern Regional Research Office, United States Department of Agriculture, New Delhi, India.

Dhandapani N., Kalyanasundaram M., Sundara Babu P. C. and Jayaraj S. (1992) Experiments on management of major pests of cotton with bio-control agents in India. *Journal of Applied Entomology* 114, 52–56.

Dudutech (2002) Collaboration and consultancy. *Dudutech Newsletter* No. 4, May 2002. Dudutech, Naivasha, Kenya. 3 pp.

Fang C. Y., Wen S. G. and Hu F. Q. (1989) Protection and utilization of the principal natural enemies to control *Heliothis armigera* in China, pp. 441–448. In *Proceedings of the Workshop on Biological Control of* Heliothis: *Increasing the Effectiveness of Natural Enemies* 11–15 November 1998, New Delhi, India (Edited by E. G. King and R. D. Jackson). Far Eastern Regional Research Office, US Department of Agriculture, New Delhi, India.

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

Greathead D. J. and Girling D. J. (1989) Distribution and economic importance of *Heliothis* and their natural enemies and host plants in southern and eastern Africa, pp. 329–345. In *Proceedings of the Workshop on Biological Control of* Heliothis: *Increasing the Effectiveness of Natural Enemies* 11–15 November 1985, New Delhi, India (Edited by E. G. King and R. D. Jackson). Far Eastern Regional Research Office of International Cooperation and Development, United States Department of Agriculture, New Delhi, India.

Hassanein F. A. and El-Heneidy A. H. (1991) Comparative study of the parasitism by *Microplitis rufiventris* Kok. (Hymenoptera: Braconidae) and *Peribaea orbata* Wied (Diptera: Tachnidae) on main lepidopterous pests in vegetable crop fields in Egypt. *Bulletin of the Entomological Society of Egypt (Economic Series* 1988–1989) 17, 127–135.

Hedlund R. C. (1989) Exploration, importation and establishment of new effective natural enemies of *Heliothis*, pp. 347–350. In *Proceedings of the Workshop on Biological Control of* Heliothis: *Increasing the Effectiveness of Natural Enemies* 11–15 November 1985, New Delhi, India (Edited by E. G. King and R. D. Jackson). Far Eastern Regional Research Office of International Cooperation and Development, United States Department of Agriculture, New Delhi, India.

Huddleston T. and Walker A. K. (1988) *Cardiochiles* (Hymenoptera: Braconidae) a parasitoid of lepidopterous larvae, in the Sahel of Africa, with a review of the biology and host relationships of the genus. *Bulletin of Entomological Research* 78, 435–461.

Jackson D. M., Brown G. C., Nordin G. L. and Johnson D. W. (1992) Auto dissemination of a baculovirus for management of tobacco budworm, (Lepidoptera: Noctuidae) on tobacco. *Journal of Economic Entomology* 85, 710–719.

Jayaraj S. (1989) Integration of biological control into crop production systems, pp. 515–518. In *Proceedings of the Workshop on Biological Control of* Heliothis: *Increasing the Effectiveness of Natural Enemies* 11–15 November 1985, New Delhi, India (Edited by E. G. King and R. D. Jackson). Far Eastern Regional Research Office of International Cooperation and Development, United States Department of Agriculture, New Delhi, India.

Kabissa J. C. B., Kayumbo H. and Yarro J. G. (1995) Comparative biology of *Mallada desjardins* (Navas) and *Chrysoperla congrua* (Walker) (Neuroptera: Chrysopidae), predators of *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) and *Aphis gossypii* (Glover) (Homoptera: Aphididae) on cotton in eastern Tanzania. *International Journal of Pest Management* 41, 214–218.

Kabissa J. C. B., Kayumbo H. V. and Yarro J. G. (1996) Seasonal abundance of chrysopids (Neuroptera: Chrysopidae) and *Aphis gossypii* (Glover) (Homoptera: Aphididae) on cotton in eastern Tanzania. *Crop Protection* 15, 5–8.

Kfir R. (1994) Attempts at biological control of the stem borer *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae) in South Africa. *African Entomology* 2, 67–68.

Kfir R. and Van Hamburg H. (1988) Interspecific competition between *Telenomus ullyetti* (Hymenoptera: Scelionidae) and *Trichogrammatoidea lutea* (Hymenoptera: Trichogrammatidae) parasitizing eggs of the cotton bollworm *Heliothis armigera* in the laboratory. *Environmental Entomology* 17, 664–670.

Kibata G. (2002) Status of research on biocontrol and IPM of *Helicoverpa armigera* in Kenya. *In Helicoverpa* Management in Kenya: Research Status and Needs. Proceedings of KARI–ICIPE Workshop on Biocontrol-based IPM of African Bollworm in Kenya, 16 November 2002, ICIPE, Nairobi, Kenya (Edited by S. Sithanantham, C. Kariuki and J. Baya). ICIPE Science Press, Nairobi (These proceedings).

King E. G. and Jackson R. D. (Eds) (1989) *Proceedings of the Workshop on Biological Control of* Heliothis: *Increasing the Effectiveness of Natural Enemies* 11–15 November 1998, New Delhi, India. Far Eastern Regional Research Office of International Cooperation and Development, United States Department of Agriculture, New Delhi, India.

Lutwama J. J. and Matanmi B. A. (1988) Efficacy of *Bacillus thuringiensis* subsp. *kurstaki* and baculovirus *Heliothis* foliar applications for suppression of *Helicoverpa armigera* (Hubner) (Noctuidae) and other lepidopterous larvae on tomato in south-western Nigeria. *Bulletin of Entomological Research* 78, 173–179.

Mani M. and Krishnamoorthy A. (1983) Recovery of two exotic parasites *Trichogramma brasiliensis* (Ashm.) and *Eucelatoria bryani* Sabrosky from *Heliothis armigera* (Hübn.) in tomato fields. *Entomophaga* 28, 401–406.

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

Michael P. J. (1989) Importation and establishment of new natural enemies of *Heliothis* spp. into Australia, pp. 363–373. In *Proceedings of the Workshop on Biological Control of* Heliothis: *Increasing the Effectiveness of Natural Enemies*, 11–15 November 1985, New Delhi, India (Edited by E. G. King and R. D. Jackson). Far Eastern Regional Research Office of International Cooperation and Development, United States Department of Agriculture, New Delhi, India.

Mimouni F. (1991) Genetic variations in host infestation efficiency in two *Trichogramma* species from Morocco. *Redia* 74, 393–400.

Minja E., Sithanantham S., Baya J. M., Songa J. M., Karuru O. and Chole T. (2003) Field evaluation of nucleopolyhedrosis virus for control of *Helicoverpa armigera* on pigeon pea in Kenya, p. 82. In *Integrated Pest and Vector Management (IPVM) in the Tropics: Perspectives and Future Strategies: Abstracts*. Proceedings of the 15th Biennial Congress of the African Association of Insect Scientists (AAIS), 9–13 June 2003, ICIPE, Nairobi, Kenya (Edited by J. Bahana, A. B. Bal, D. Dakouo and C. O. Omwega). ICIPE Science Press, Nairobi.

Montaldo T. (1991) Microbiological control in cotton crops in North Cameroon: Conclusions from studies carried out from 1979 to 1988. *Coton et Fibres Tropicales* 46, 217–229.

Moore S. D. and Kfir R. (1995) Aspects of the biology of the parasitoid *Tetrastichus howardi* (Olliff) (Hymenoptera: Eulophidae). *Journal of African Zoology* 109, 455–466.

Munir B., Abdelrahman A. A., Mohammed A. H., Stam P. A. and Teng P. S. (1992) Introduction of *Trichogramma pretiosum* Riley against *Heliothis armigera* (Hb.) in the Sudan, pp. 70–73. In *Proceedings of the 3rd International Conference on Plant Protection in the Tropics*, Genting Highlands, Malaysia, 20–23 March 1990. (Edited by P. A. C. Ooi and G. S. Lim). Malaysian Plant Protection Society, Kuala Lumpur, Malaysia.

Muthukrishnan N. (1995) Mass production techniques of *Trichogramma chilonis* Ishii (Hymenoptera: Trichogrammatidae) and field performance of *Trichogramma* sp. in cotton ecosystem. PhD Thesis. Tamil Nadu Agricultural University, Coimbatore, India.

Nagarkatti S. and Singh S. P. (1989) Importation and establishment of new natural enemies of *Heliothis* spp. (Lep.: Noctuidae) into India, pp. 375–385. In *Proceedings of the Workshop on Biological Control of* Heliothis: *Increasing the Effectiveness of Natural Enemies*. 11–15 November 1985, New Delhi, India (Edited by E. G. King and R. D. Jackson). Far Eastern Regional Research Office of International Cooperation and Development, United States Department of Agriculture, New Delhi, India.

Nyambo B. T. (1984) The development of integrated pest management of *H. armigera* —Current status and future possibilities in Eastern and Central Africa, pp. 135–141. In *Advancing Agricultural Production in Africa* (Edited by D. L. Hawksworth). Commonwealth Agricultural Bureaux, Farnham Royal, UK.

PDBC [Project Directorate of Biological Control] (1999) *Project Directorate of Biological Control–Indian Council of Agricultural Research (PDBC-ICAR) 1998–1999 Annual Report*. Project Directorate of Biological Control, Bangalore, India. 217 pp.

Pearson E. O. (1958) *Insect Pests of Cotton in Tropical Africa*. Empire Cotton Growing Corporation and Commonwealth Institute of Entomology, London, UK. 355 pp.

Pintureau B. and Babault M. (1988) Systematics of African species of the genera *Trichogramma* Westwood and *Trichogrammatoidea* Girault (Hym. Trichogrammatidae). *Colloques de l'INRA* No. 43, 97–120.

Powell J. E. (1989) Importation and establishment of predators and parasitoids of *Heliothis* into USA, pp. 387–395. In *Proceedings of the Workshop on Biological Control of* Heliothis: *Increasing the Effectiveness of Natural Enemies* 11–15 November 1985, New Delhi, India (Edited by E. G. King and R. D. Jackson). Far Eastern Regional Research Office of International Cooperation and Development, United States Department of Agriculture, New Delhi, India.

Rabindra R. J., Balasaraswathy S. and Jayaraj S. (1991) Combined use of NPV with certain botanicals for the control of *Heliothis armigera* on chickpea. *Journal of Biological Control* 5, 85–87.

Rabindra R. J., Sathiah N. and Jayaraj S. (1992) Efficacy of nuclear polyhedrosis virus against *Helicoverpa armigera* (Hbn.) on *Helicoverpa* resistant and susceptible varieties of chickpea. *Crop Protection* 11, 320–322.

Reed W. (1965) *Heliothis armigera* in Western Tanganyika II. Ecology and natural and chemical control. *Bulletin of Entomological Research* 56, 127–140.

Reed W., Lateef S. S. and Sithanantham S. (1989) Compatibility of host plant resistance and biological control of *Heliothis* spp. (Lep., Noctuidae), pp. 529–539. In *Proceedings of the Workshop on Biological Control of* Heliothis: *Increasing the Effectiveness of Natural Enemies*. 11–15 November 1985, New Delhi, India (Edited by E. G. King and R. D. Jackson). Far Eastern Regional Research Office, United States Department of Agriculture, New Delhi, India.

Romeis J., Shanower T. G. and Zebitz C. P. W. (1999a) *Trichogramma* egg parasitism of *Helicoverpa armigera* on pigeon pea and sorghum in southern India. *Entomologia Experimentalis et Applicata* 90, 69–81.

Romeis J., Shanower T. G. and Zebitz C. P. W. (1999b) Why *Trichogramma* (Hymenoptera: Trichogrammatidae) egg parasitoids of *Helicoverpa armigera* (Lepidoptera: Noctuidae) fail on chickpea. *Bulletin of Entomological Research* 89, 89–95.

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

Sharma H. C. (2001) *Cotton Bollworm/Legume Pod Borer* H. armigera *(Hübner) (Noctuidae: Lepidoptera): Biology and Management.* Commonwealth Agricultural Bureaux International, Wallingford, Ox10, United Kingdom. 77 pp.

Singh S. P. (1991) Natural enemies of *Heliothis armigera* with particular reference to studies made in India. Paper presented at ICAR/IRRPM/USDA Joint Project Development Group Meeting on Managing Insecticide Resistance with Focus on *Heliothis* Resistance Management in India held at Directorate of Rice Research, Hyderbad, 15–17 October 1991.

Singh S. P., Jalali S. K., Bhumannavar B. S., Bakthavatsalam N. and Pushpalatha N. A. (1994) Production and Use of Trichogrammatid Egg Parasitoids. Project Directorate of Biological Control, Indian Council of Agricultural Research, Technical Bulletin 11, Bangalore.

Sithanantham S. and Paul A. V. N. (1989) Control of *Heliothis* species (Lep.: Noctuidae) by augmentative releases of predators and parasites in India, pp. 427–439. In *Proceedings of the Workshop on Biological Control of* Heliothis*: Increasing the Effectiveness of Natural Enemies.* 11–15 November 1985, New Delhi, India (Edited by E. G. King and R. D. Jackson). Far Eastern Regional Research Office, United States Department of Agriculture, New Delhi, India.

Sithanantham S., Romeis J., Singh S. P. and Matoka C. (2001) Biological control of *Helicoverpa armigera* with entomophagous insects: Research status, constraints and opportunities. Proceedings of the workshop on *Heliothis* management, December, 2001, ICRISAT, Patancheru, A. P. India. ICRISAT, Hyderabad, India.

Sundaramoorthy V. T. and Babu A. K. (1985) Management of cotton insect pests in polycrop system in India. *Outlook on Agriculture* 14, 79–82.

van den Berg (1993) Natural control of *Helicoverpa armigera* in smallholder crops in Kenya. PhD thesis. Wageningen Agricultural University, The Netherlands. 233 pp.

van den Berg H. and Cock M. J. W. (1993a) Stage-specific mortality of *Helicoverpa armigera* in three smallholder crops in Kenya. *Journal of Applied Ecology* 30, 640–653.

van den Berg H. and Cock M. J. W. (1993b) Exclusion cage studies on the impact of predation on *Helicoverpa armigera* in cotton. *Biocontrol Science and Technology* 3, 491–497.

van den Berg H. and Cock M. J. W. (1993c) *African Bollworm and Its Natural Enemies in Kenya.* International Institute of Biological Control (Kenya Station) and Natural Resources Institute (Overseas Development Administration), UK. CAB International, UK. 81 pp.

van den Berg H., Cock M. J. W. and Oduor G. I. (1997) Natural control of *Helicoverpa armigera* in sunflower: Assessment of the role of predation. *Biocontrol Science and Technology* 7, 613–629.

van den Berg H., Nyambo B. T. and Waage J. K. (1990) Parasitism of *Helicoverpa armigera* (Lepidoptera: Noctuidae) in Tanzania: Analysis of parasitoid–crop associations. *Environmental Entomology* 19, 1141–1145.

Watmough R. H. and Kfir R. (1995) Predation on pupae of *Helicoverpa armigera* Hbn. (Lep., Noctuidae) and its relation to stem borer numbers in summer grain crops. *Journal of Applied Entomology* 119, 679–688.

Yadav D. N., Patel R. C. and Patel D. S. (1985) Impact of inundative releases of *Trichogramma chilonis* Ishii against *Heliothis armigera* (Hbn.) in Gujarat (India). *Journal of Entomological Research* 9, 153–159.

Regional Initiatives for Promoting the Utilisation of Native Egg Parasitoids for Biocontrol of the African Bollworm in Vegetable-Based Cropping Systems in Eastern Africa

S. Sithanantham[1], C. P. W. Zebitz[2], J. C. Monje[2], S. Hassan[3], C. Matoka[1], C. Kariuki[4], S. Njihia[4], J. Ogwang[5], D. Mohamed[6], B. Pallangyo[7] and E. Ensami[7]

[1]*International Centre of Insect Physiology and Ecology (ICIPE), P. O. Box 30772-00100, Nairobi, Kenya;*
[2]*University of Hohenheim, Institute of Phytomedicine, Department of Entomology, 70593 Stuttgart, Germany;*
[3]*Federal Biological Research Centre, Institute of Biological Plant Pest Control (BBA), Heinrischstr. 243, 64287 Darmstadt, Germany;*
[4]*Kenya Agricultural Research Institute (KARI), National Agricultural Research Centre (NARC)-Muguga, P. O. Box 30148, Nairobi, Kenya;*
[5]*National Agricultural Research Organisation (NARO), Namulonge Agricultural Research Centre, P.O. Box 7084, Namulonge, Uganda;*
[6]*Ethiopian Agricultural Research Organisation (EARO), Plant Protection Research Centre, P. O. Box 37, Ambo, Ethiopia;*
[7]*Ministry of Agriculture and Fisheries (MoAF), National Biocontrol Centre, Kibaha, Tanzania*

Abstract

A regional network initiative for promoting the use of native egg parasitoids for biocontrol of the African bollworm (ABW), *Helicoverpa armigera*, in vegetable-based cropping systems in eastern Africa is currently ongoing with partnership with the national biocontrol teams in Ethiopia, Kenya, Tanzania and Uganda.

A 'start up' consultation workshop, involving the partners and collaborators, was convened in the first year (2001) that facilitated the development of common methodologies for on-farm survey of the native egg parasitoids. By mid year 2 (September, 2002), six collections of *Trichogramma* and 28 of *Trichogrammatoidea* had been obtained from on-farm surveys. Pesticide-free plots of tomato, capsicum, okra, pigeon pea, cotton and sunflower, which are potential *H. armigera* hosts, had been planted at benchmark on-station sites. These are helpful in estimating egg load of *H. armigera* on the target crops, besides supplementing the survey collections. Exploratory assessments in Kenya have shown that the egg load of ABW was found to be greater on tomato than on okra and capsicum in medium and high altitude sites, while okra appeared to attract greater oviposition by ABW than the other two crops in low altitude sites. On-station pheromone trap monitoring of adult populations of *H. armigera* egg parasitoids through pheromone trapping was done in the benchmark on-station sites. In Kenya, during 2002, peaks in adult catches were observed during the months of June and July.

Studies are in progress in both laboratory and field conditions towards improved understanding of the diversity among native egg parasitoid species, especially trichogrammatids, in relation to host insect and host habitat adaptations, besides interactions with other commonly used pest control products and practices. Variability has been observed among native trichogrammatid species/strains for adaptation to temperature and humidity regimes. Laboratory studies have indicated that some of the trichogrammatid species/strains also attack the eggs of some of the cereal stemborers (e.g. *Busseola fusca, Sesamia calamistis*) as well as those of *H. armigera*. Further studies on the role of host plants on egg parasitism of ABW are in progress. Linkages have also been established with development projects (GTZ-IPM, Tanzania), private enterprises (Dudutech, Kenya) and vegetable farmers' groups (Muguga, Mwea in Kenya). It is visualised that the present phase (2001–2004) would establish the required baseline information for launching a large-scale popularisation programme in a follow up phase.

Key words: *Helicoverpa armigera, Trichogramma, Trichogrammatoidea,* network, biocontrol, tomato, okra, maize, capsicum, egg load, eastern Africa

Introduction

The African bollworm, *Helicoverpa armigera* (Hb.), is widely occurring on a range of agriculturally important crops across Asia (41 countries), Oceania (20 countries), Europe (27 countries) and Africa (48 countries) (Sharma, 2001). It has been recognised as a key pest on vegetable crops in Africa (Ikin *et al.*, 1993).

The International Centre of Insect Physiology and Ecology (ICIPE), based in Kenya, convened a symposium on African Bollworm Biocontrol, at Ouagadougou, Burkina Faso in 1999, as part of the Scientific Conference of the African Association of Insect Scientists (AAIS). This symposium recommended a regional collaborative network initiative to promote biocontrol of the African bollworm, especially in smallholder crops like vegetables, legumes and cotton in Africa (Sithanantham *et al.*, 1999). A status paper on the potential for utilising egg parasitoids in augmentative biocontrol of lepidopteran pests, including *H. armigera*, in Africa was also prepared (Sithanantham *et al.*, 2001).

In consultation with expert collaborators in Germany, ICIPE formulated a sub-regional project for assessing the potential for *Trichogramma* utilisation in biocontrol of *H. armigera* in vegetable-based cropping systems in eastern Africa (Sithanantham *et al.*, 2002). This project was accepted for funding by the German Ministry of Technical Cooperation (BMZ) for a pilot phase (3 years: 2001–2004).

The main goal and objectives of this regional initiative are shown in Table 8.

Partners and Collaborators

ICIPE is leading and linking up the research and training activities in the network with partners from the four national biocontrol teams from Kenya, Ethiopia, Tanzania and Uganda. The coordinator is Dr Srinivasan Sithanantham assisted by C. M. Matoka.

The base locations of the lead and partner institutions of the regional ABW biocontrol network in eastern Africa are in Addis Ababa (Ethiopia), Kampala (Uganda), Thika (Kenya) and Arusha (Tanzania).

Collaborators in Germany:

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

Table 8. Objectives and outputs of the project for assessing the potential for *Trichogramma* utilisation in biocontrol of *Helicoverpa armigera* in vegetable-based cropping systems in eastern Africa

Summary of objectives and outputs	Verifiable indicators
Overall objective: Enhance sustainable horticultural production.	
Long-term purpose: Promote biocontrol of key pests on vegetables in Africa.	• Less use of synthetic pesticides in major urban/export vegetable production in the region.
Phase 1 objective: Generate scientific base for a successful biological control programme using egg parasitoids 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: Determine and catalogue the diversity of native egg parasitoid species in vegetable-based cropping systems.	• Surveys of native egg parasitoids occurring in focal sites in the major ecologies in the partner countries completed by mid-2002. • Species identification by conventional taxonomic techniques completed by end 2002 and molecular characterisation, species distribution and mapping completed by mid-2003.
Identify egg parasitoid species and strains with desirable biological attributes in lead partner country.	• Egg parasitoid species that show favourable biological attributes identified by end 2002. • The extent of pesticide tolerance among strains of the most promising species assessed by end 2003.
Optimise egg parasitoid release rates and undertake exploratory field release and impact assessment of one target crop in lead partner country.	• Parasitoid release rate in one target crop optimised by mid-2003. • 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 early 2004.
Quantify local demands, identify delivery systems and establish pilot production unit for demonstration 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 early 2004.
Undertake assessment of risk to non-target Lepidoptera.	• Laboratory testing of risk to beneficial non-target Lepidoptera completed by end 2002. • Field assessment of risk to beneficial non-target Lepidoptera completed by end 2003.
Establish regional collaborative network for egg parasitoid utilisation and undertake promotion of biocontrol awareness.	• NARS partners participate actively and benefit from network activities identified at the initial partners workshop in early 2001.

NARS partners:

- National Biocontrol Programme, KARI, Kenya: Dr Francis Nang'ayo (until August 2001); Dr Charles Kariuki and Mr Samuel Njihia (September 2001 onwards).
- National Biocontrol Programme, NARO, Uganda: Dr J. Ogwang.
- National Biocontrol Programme, MoA, Tanzania: Mr V. Mgoo and Ms B. Pallangyo.
- National Biocontrol Programme, EARO, Ethiopia: Mr Mulugeta (until November 2001); Dr D. Mohammed (December 2001 onwards).

Collaborating scientists (for co-supervision of PhD/MSc projects):

Dr W.A. Overholt (biocontrol–field ecologist) (ICIPE); Dr A. Ngi-Song (biocontrol–tritrophic interactions) (ICIPE); Dr E. Osir (molecular techniques) (ICIPE); Dr S. Kimani-Njogu (parasitoid biosystematics) (ICIPE); Prof. J. Mueke (parasitoid adaptation) (Kenyatta University); Dr L. Gitonga (parasitoid–ecosystem interaction) (Jomo Kenyatta University of Agriculture and Technology; Dr E. Seyoum (parasitoid–host selection) (University of Addis Ababa); Dr J. Romeis (non-target studies) (Swiss Federal Research Institute for Agriculture and Agroecology, Zurich); Dr S. K. Jalali (pesticide tolerance/adaptation) (Project Directorate for Biological Control, Bangalore, India).

Progress Made and Experiences Gained in Surveys

The 'Start Up' Workshop

The project was launched with a 'start up' consultation workshop in early 2001. This workshop discussed the three-year activity plans including the mutual roles of the partners. Experts from Germany and ICIPE participated and provided useful inputs in refining the guidelines as well as the experimental methodologies. The methodologies to be adopted during surveys of *Trichogramma* were discussed and standardised. The national partners were also given the basic orientation relating to *Trichogramma* survey collections, handling and documentation. A document on project plans and methodologies was prepared on the basis of the discussions. This served as a source of ready reference in implementing the agreed project activities.

'Start Up' Sessions for Egg Parasitoid Surveys

The ICIPE project staff participated in practice 'start up' survey sessions with each national team in Kenya, Ethiopia, Tanzania and Uganda. This joint exercise provided an opportunity for the national teams to acquire 'hands on' experience in these specialised surveys, in preparation for undertaking the follow-up surveys in their countries during the first two years.

On-farm Surveys

In the first year, on-farm surveys for egg parasitoids of ABW in the four countries generally met with problems in collecting adequate egg samples of ABW for recovering the native egg parasitoids. This was mainly because the farmers were intensively spraying the target vegetable crops, which rendered it difficult to locate and secure minimum sample eggs of the ABW. In Year 2, efforts were made to secure small tomato plots (5 x 5 m or 10 x 10 m size) of some vegetable farmers, to be kept without pesticide spraying during the flowering stage. This helped to augment the on-farm survey collection of egg parasitoids of ABW in Year 2.

The progress made in on-farm surveys up to mid second year (September 2002) and the egg parasitoid recoveries made are summarised in Table 9. The majority of the recoveries were made through joint ICIPE-KARI surveys in Kenya, besides collections from partners in Tanzania and Uganda.

Table 9. On-farm survey collections of *Helicoverpa armigera* egg parasitoids in target crops at three altitude levels (low, medium and high) in Kenya, Tanzania and Uganda, June 2001–September 2002

Crop/Altitude	*Trichogramma*	*Trichogrammatoidea*	Other species
Crop			
Tomato	7	34	9
Okra	0	4	4
Maize	2	2	2
Sunflower	0	0	1
Pigeon pea	0	0	2
Altitude			
Low (< 700 masl)	0	14	4
Medium (701–1200 masl)	6	12	6
High (> 1200 masl)	3	14	8
Total per group	**9**	**40**	**18**

During the on-farm surveys, information on the altitude and location (GIS data) for each site, as well as crop management information, was collected through standard data sheets. These are being logged into a database.

Gene Bank Establishment

Permission of the concerned agencies (KSTCIE and KEPHIS) has now been secured for establishing a gene bank at ICIPE for conserving the survey collection made by ICIPE and the project partners. Details of live cultures available presently in the gene bank are summarised in Table 10 a, b.

Table 10a. Live cultures of *Helicoverpa armigera* collections from on-station bench mark sites in Kenya (November, 2002)

Altitude	Site	Crop	Host insect	Mixed culture	Isofemale line
Low	Muhaka (ICIPE) Field Station	Okra	*Helicoverpa armigera*	2	2
		Cotton	*H. armigera*	0	2
		Kale	*Plutella xylostella*	4	4
		Sorghum	*Chilo* sp.	20	14
	Kilifi Institute of Agriculture and Technology	Tomato	*H. armigera*	4	7
		Pigeon pea	*H. armigera*	0	1
		Sunflower	*H. armigera*	3	3
		Okra	*H. armigera*	4	6
		Capsicum	*H. armigera*	1	1
		Cotton	*H. armigera*	7	8
		Sorghum	*Chilo* sp.,	3	3
			H. armigera	0	1
		Kale	*P. xylostella*	1	1
Medium	KARI-Kiboko	Pigeon pea	*H. armigera*	1	1
	KARI-Mwea	Okra	*H. armigera*	2	2
		Pigeon pea	*H. armigera*	1	0
		Kale	*P. xylostella*	1	1
High	JKUAT (Juja)	Tomato	*H. armigera*	1	2
		Okra	*H. armigera*	3	3
		Kale	*P. xylostella*	1	1
	NARC-Muguga	Tomato	*H. armigera*	1	1
		Pigeon pea	*H. armigera*	1	1
	KARI-Kitale	Okra	*H. armigera*	1	1
		Kale	*P. xylostella*	1	1
			Overall	63	67

Table 10b. Live cultures of *Helicoverpa armigera* collections from on-farm survey sites in Kenya (November, 2002)

Altitude	Site	Crop	Mixed culture	Isofemale line
Low	Msabaha (Malindi)	Tomato	1	1
	Kisiwani (Malindi)	Tomato	1	2
	Kilifi	Tomato	1	2
	Shimba Hills (Kwale)	Tomato	2	2
	Kaloleni (Voi)	Tomato	4	4
	Subtotal		**9**	**11**
Medium	Elerai (Loitokitok)	Tomato	1	1
	UoN Irrig. Farm (Kibwezi)	Okra	1	1
	Kwa Chai (Kibwezi)	Tomato	2	2
	Kimbimbi (Mwea)	Tomato	2	2
		Maize	0	1
	Subtotal		**6**	**7**
High	Maili Saba (Meru)	Tomato	1	1
	Kiarokongo (Meru)	Tomato	1	1
	Undiri (Kikuyu)	Tomato	2	2
	Ebuhayi (Kakamega)	Tomato	1	1
	Chakol (Teso)	Tomato	1	1
	Maturu (Lugari)	Tomato	1	0
	Subtotal		**7**	**6**
	Total		**22**	**24**

Table 11. Relative abundance of *Helicoverpa armigera* eggs among three crops according to altitude grouping of the sites in Kenya

	Mean *Helicoverpa armigera* egg numbers		
Crop	Low altitude	Mid altitude	High altitude
Tomato	0.3263 bC	0.8990 aB	0.7387 aB
Okra	0.6477 bB	1.4557 aA	0.4683 bC
Capsicum	0.0405 cD	0.666 aC	0.1758 bD

Means followed by the same small letters within the rows are not significantly different, while means within the columns are not significantly different when followed by the same capital letters.

Studies on Adaptation and Field Release Methodologies

Adaptation to Climate Factors

Variability has been observed among native trichogrammatid species/strains for adaptation to temperature and humidity regimes.

Compatibility with Commonly Used Pest Control Products

Studies are in progress to categorise the commonly used chemical and botanical pesticides of the adult and immature stages of chosen native trichogrammatid species.

On-station Monitoring of ABW Oviposition

Pesticide-free plots of potential target crops of ABW—tomato, okra, capsicum, cotton, pigeon pea, sunflower—were planted in chosen on-station (benchmark) sites to permit monitoring the seasonal ABW oviposition (egg load) on these crops. Data assembled from seven benchmark sites in Kenya have shown that the relative ABW egg load on tomato, okra and capsicum tends to be affected by the altitude of the sites (Table 11). Exploratory assessments in Kenya have shown that the egg load of ABW was found to be greater on tomato than on okra and capsicum in medium and high altitude sites, while okra appeared to attract greater oviposition by ABW than the other two crops in low altitude sites. The data collection on the relative abundance of ABW eggs on the target crops will assist in planning release impact trials for *Trichogramma*.

On-station Monitoring of ABW Adults in Pheromone Traps

The monitoring at the same benchmark on-station sites of ABW adults was also undertaken by installing pheromone traps. Figure 1 shows the trap catches at one of the sites in Kenya (Mwea). It is visualised that based on these studies, the year long pattern of occurrence of ABW adults at these sites can be characterised, which will form useful baseline information for planning future biocontrol evaluations.

Mass Production and Popularisation of Trichogramma

Presently, a pilot unit for demonstrating the methodology of mass production of the substitute (factitious) host (*Corcyra cephalonica*) and the egg parasitoid (*Trichogramma* spp.) has been established at ICIPE for the purpose of training and demonstration.

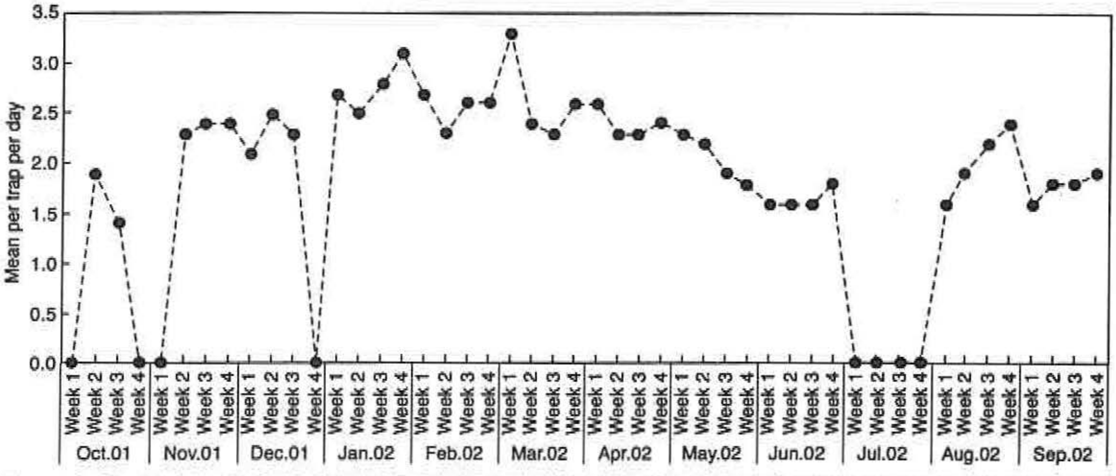


Figure 1. Weekly trap catches of African bollworm adult moths, Mwea, Kenya, October 2001–September 2002

All the four national partners have initiated pilot units for rearing the host insect (*Cocyra/Ephestia*) at their base laboratories. These are to back up the *Trichogramma* cultures (isofemale lines and mixed collections) as well as demonstration activities.

Networking and Linkages

ICIPE provides a back up for scanning the relevant current literature/research information and sharing it among the national partners.

Presently, Dudutech, a private biocontrol products enterprise in Kenya has approached ICIPE for technical support for their plans to establish a commercial scale *Trichogramma* production facility.

Exploratory efforts are being made to build up linkage with vegetable farmers' groups as a pilot activity in Kenya. The experience gained will be used for participatory initiatives with farmers using egg parasitoids as a component.

References

Ikin R., Schulten G. G. M. and Borhegyi I. D. E. (1993) Report of the Regional Seminar on the Development and Application of Integrated Pest Management on Vegetables in Africa, 23–30 November 1992, Dakar, Senegal. *FAO Plant Protection Bulletin* Rome 41, 155–160.

Sharma H. C. (2001) *Cotton Bollworm/Legume Pod Borer;* H. armigera *(Hubner) (Noctuidae: Lepidoptera): Biology and Management.* Commonwealth Agricultural Bureaux International, Wallingford, Ox10, United Kingdom. 77 pp.

Sithanantham S., Waiganjo M. M., Ssekyewa C., Akemo C., Swai I. and Gashabweza A. (1999) Towards improved information dissemination on integrated pest management among smallholder vegetable farmers: An ICIPE-NARES network initiative in eastern Africa, pp. 3–4. In *Integrated Pest and Vector Management and Sustainable Development in Africa: Abstracts.* Proceedings of the Joint Congress of the African Association of Insect Scientists (13th Congress) and the Entomological Society of Burkina Faso, Ouagadougou, Burkina Faso, 19–23 July 1999 (Edited by D. Giga and M. Ali Bob). ICIPE Science Press, Nairobi.

Sithanantham S., Abera T. H., Baumgärtner J., Hassan S. A., Löhr B., Monje J. C., Overholt W. A., Paul A. V. N., Fang Hao W. and Zebitz C. P. W. (2001) Egg parasitoids for augmentative biological control of lepidopteran vegetable pests in Africa: Research status and needs. *Insect Science and Its Application* 21, 189–205.

Sithananatham S., Zebitz C. P. W., Monje J. C., Hassan S., Kariuki C. M., Njihia S., Ogwang J., Sekematte B., Mohammed D., Mulugeta N., Mugoo V., Pallangyo B. and Matoka C. M. (2002) Initiative for promoting biocontrol of *Helicoverpa armigera* with native egg parasitoids in eastern Africa, p. 61. In *Egg Parasitoids for Biocontrol of Insect Pests* (Abstracts). 6th International Egg Parasitoid Symposium, 15–18 September 2002, Perugia, Italy. University of Perugia, Italy.

Mass Production and Utilisation of *Trichogramma* for Biocontrol of Caterpillar Pests: Experiences Elsewhere and Future Kenyan Scenario

S. Sithanantham[1], C. Kariuki[2], C. Matoka[1], J. Baya[1], L. Ochiel[3†] and Louise Labuschagne[4]

[1]*International Centre of Insect Physiology and Ecology (ICIPE), P. O. Box 30772-00100, Nairobi, Kenya;*
[2] *Kenya Agricultural Research Institute (KARI), National Agricultural Research Centre (NARC)-Muguga, P. O. Box 30148, Nairobi, Kenya;*
[3] *Kenya Agricultural Research Institute (KARI)-Kibos Research Centre, P. O. Box 1490, Kisumu;*
[4]*Dudutech (K) Ltd, P. O. Box 1927-20117, Naivasha, Kenya*

Abstract

Trichogramma wasps are mass-produced commercially in many countries across the world to control a range of lepidopteran hosts. Various *Trichogramma* species and strains are being used to target different pests in a wide range of crops. They are used for control of forestry pests (e.g. Canada) besides a wide range of field crops such as cotton, maize, tomatoes, capsicums, French bean, cut flowers, lettuce besides fruit crops like apples, beans, grapes, citrus and stone fruit.

The more common system is to rear them on the eggs of factitious lepidopteran hosts, which are easily cultured on stored grain media, such as *Corcyra cephalonica, Sitotroga cerealella* and *Ephestia kuehniella*. In China, collection of wild silk moths yields huge quantities of ready to use host eggs, for large-scale seasonal production of *Trichogramma* wasps. Research is also in progress for developing artificial eggs as an alternative means for mass production.

In Kenya, there is considerable potential for utilising *Trichogramma* on horticultural crops especially those grown for export. Scope also exists for their use in cotton, besides some legumes, cereals and oilseed crops. The paper discusses current promotional initiatives and future scenario for wide-scale utilisation of *Trichogramma* for biocontrol of important caterpillar pests in Kenya.

Key words: *Trichogramma*, Lepidoptera, biocontrol, cotton, legumes, cereals, oilseed crops, mass rearing, Kenya

Introduction

The concept of '*Trichogramma* farming' is only a century old (Enock, 1895). The wide scale mass production and utilisation of *Trichogramma* has mainly been popular in the USSR and China. Recent estimates by Hassan (1993) indicate that annually about 30 million hectares are covered globally by *Trichogramma* releases, which are targeted on both forestry and agricultural crop plots. An illustration of the global utilisation (target countries) of *Trichogramma* is provided in Table 12. The range of target pests on which *Trichogramma* has shown promise is listed

†*Deceased.*

Table 12. Various crops and trees on which *Trichogramma* spp. was used for controlling insect pests in different countries (data before 1991)

Crop/tree	Country
Corn	Former USSR, China (including Taiwan), Mexico, Philippines, Colombia, Bulgaria, France, Germany, Switzerland, USA, Italy, Austria, former Czechoslovakia, Romania
Sugarcane	China (including Taiwan), Philippines, Colombia, Iran, Egypt, Cuba, India, Uruguay, Mexico
Cotton	Former USSR, USA, Colombia, Mexico, China, Iran
Tomato	Former USSR, China, Mexico, Colombia, USA
Cabbage	Former USSR, China, Bulgaria, The Netherlands, former Czechoslovakia
Apple	Former USSR, Bulgaria, China, Germany, Poland
Beet	Former USSR, Bulgaria, China
Rice	China, Iran, India
Soyabean	Colombia, USA, China
Sorghum	Mexico, Colombia, China
Pine	China, Bulgaria
Pine	Former USSR, Bulgaria
Forage grass	Former USSR
Cayenne pepper	China
Tobacco	Bulgaria
Wheat	Former USSR
Citrus	China
Avocado	USA
Spruce	Canada
Olive	Tunisia
Plum	Bulgaria
Stored products	USA

Source: Li (1994).

in Table 13. Li (1994) has attributed the favorable cost: benefit scenario as an important factor for its wide scale adoption, especially in the developing world. It is important to recognise that the right choice of the *Trichogramma* species and/or strain is crucial for field impact; since these parasitoids are known to be relatively more habitat-specific than host-specific (Smith, 1996). Further, Bigler (1994) has pointed out the importance of quality control in ensuring consumer confidence in continuing to use *Trichogramma*.

Mass Production Systems

On Factitious Host Reared on Grains

Some of the lepidopterans that are known pests of stored grains, such as *Corcyra cephalonica* (Stainton), *Sitotroga cerealella* (Oliver) and *Ephestia kuhniella* (Zeller), are found to be useful as factitious hosts for the mass production of *Trichogramma* (Bigler *et al.*, 1987; Hassan, 1993; Singh *et al.*, 2001). The larval medium for rearing these hosts is mostly grains of cereals (wheat, maize, sorghum, millet). Supplementation of the medium with vitamins, fatty acids and proteins is also often attempted. Preventative and curative interventions are also available for managing unforeseen/occasional interference in host culture by storage beetles (e.g. *Tribolium*), storage mites, braconid parasitoids (e.g. *Bracon brevicornis)* and diseases (mainly by bacterial and fungal pathogens). An illustration of the steps in such mass production as adopted in most commercial insectaries currently

Table 13. Range of target pests where *Trichogramma* has shown promise (data before 1991)

Country	*Trichogramma* spp.	Target pest
China, Germany, former USSR	*T. dendrolimi*	*Adoxophyes* spp., *Agrotis* spp., *Cydia pomonella, Heliothis armigera, Pieris* spp., *Leguminivora glycinvorella, Ostrinia furnacalis, Pandemis heparana, Rhyacinonia buoliana*
India, China (including Taiwan), Philippines	*T. confusum* (= *T. chilonis*)	*Agrotis* spp., *Chilo* spp., *Argyroploce schistaceana, Cnaphalocrocis medinalis, Diatraea* spp., *Heliothis armigera, Leguminivora glycinvorella, Spodoptera exiguum*
Colombia, Mexico, USA, Nicaragua, Uruguay	*T. pretiosum*	*Alabama argillacea, Anticarsia* spp., *Cadra cautella, Diatraea* spp., *Heliothis* spp., *Trichoplusia ni, Kaiferrio lycopersicolla, Plodia interpunctella, Scrobipalpula absoluta*
Bulgaria, China, Germany, former Czechoslovakia, Egypt, Philippines, The Netherlands, former USSR	*T. evanescens*	*Agrotis* spp., *Clysia ambiguella, Lobesia* spp., *Loxostege sticticalis, Mamestra brassicae, Pieris* spp., *Ostrinia nubilalis*
Bulgaria, Poland, former USSR	*T. cacoeciae*	*Clysia ambiguella, Lobesia* spp., *Cydia pomonella, Lasperyresia* spp., *Orgyia antiqua*
Austria, France, Iran, Switzerland, The Netherlands, Romania, Italy	*T. maidis (T. brassicae)*	*Mamestra brassicae, Pieris* spp., *Ostrinia nubilalis*
Former USSR	*T. pintoi*	*Heliothis armigera*
Philippines, Thailand	*T. chilotraea*	*Chilo* spp., *Diatraea* spp.
Philippines	*T. nana*	*Chilo* spp., *Diatraea* spp.
China, India	*T. japonicum*	*Chilo suppressalis, Cnaphalocrocis medinalis*
India	*T. brasiliensis*	*Heliothis armigera*
Australia	*T. carverae*	*Heliothis armigera*
Bulgaria, former USSR	*T. embryophagum*	*Cydia pomonella*
Canada	*T. minutum*	*Choristoneura fumiferana*
USA	*T. nubilale*	*Ostrinia nubilalis*
Tunisia	*T. oleae*	*Prays oleae*
China (including Taiwan)	*T. ostriniae*	*Ostrinia furnacalis*
USA	*T. platineri*	*Amorbia cuneana*
Iran	*T. rhenana*	*Heliothis armigera*

From Li (1994).

in India is provided (Figure 2). An integrated system of quality control (Bigler, 1994) is also illustrated (Figure 3).

On Mass Collected Wild Silk Moths

Eggs of the Eri silkworm, *Philosamia cynthia ricini* Donovan and the oak silkworm, *Antherea perneyi* are used for mass production in China. The former is widely reared in state farms and people's communes in South China while the latter is reared in forests of North East China (Li, 1997). These are known as 'big eggs', since each egg can support several wasps, compared to 1–2 in the 'small eggs' of the factitious hosts mentioned in the previous section.

On 'Artificial' Eggs

Research on *'in vitro'* production of *Trichogramma* is currently in progress, especially in USA and China (Bigler, 1994; Li, 1997). Pilot production units are also being established in China (Fang Hao, Chinese Academy of Agricultural Sciences, pers. commun.)

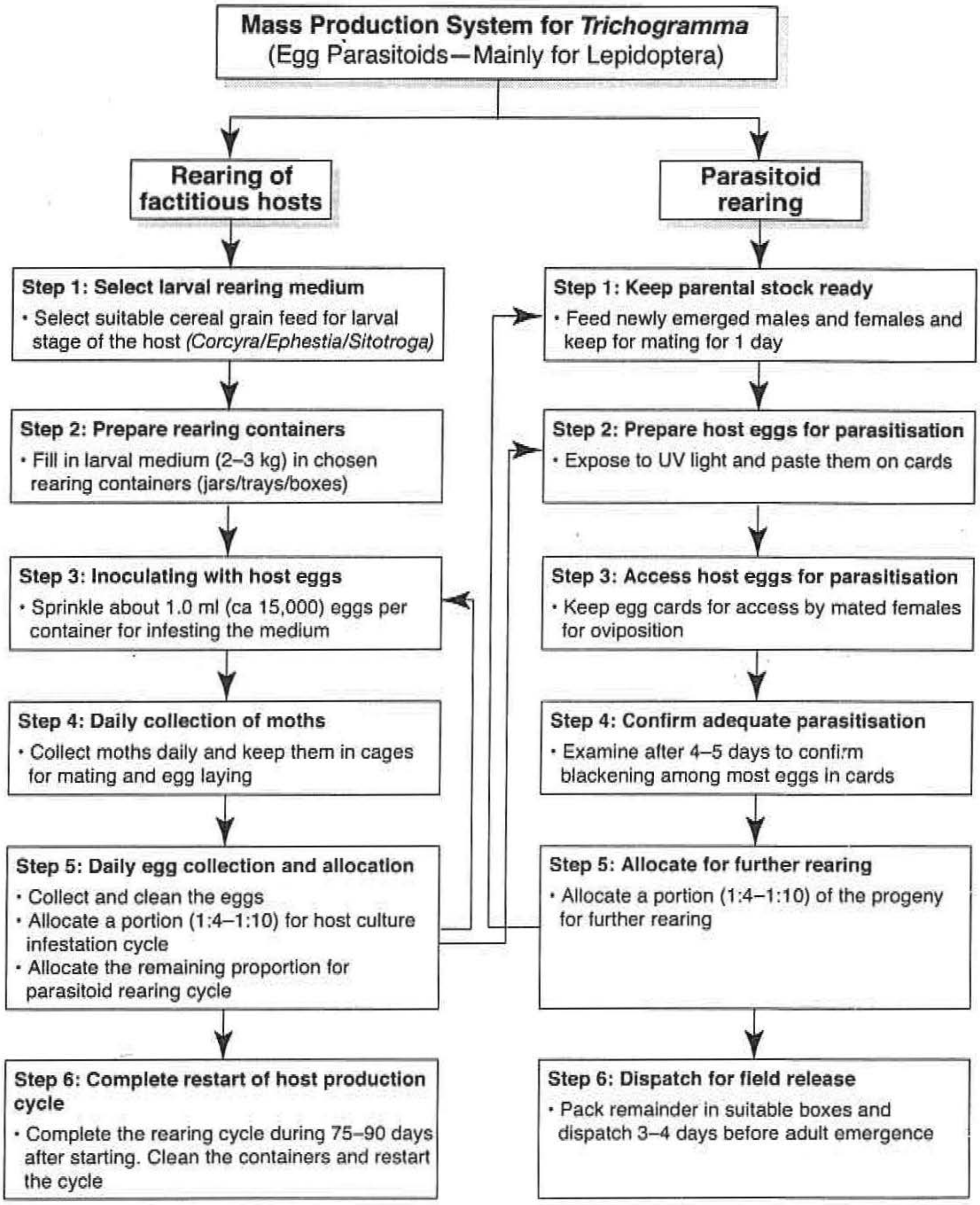
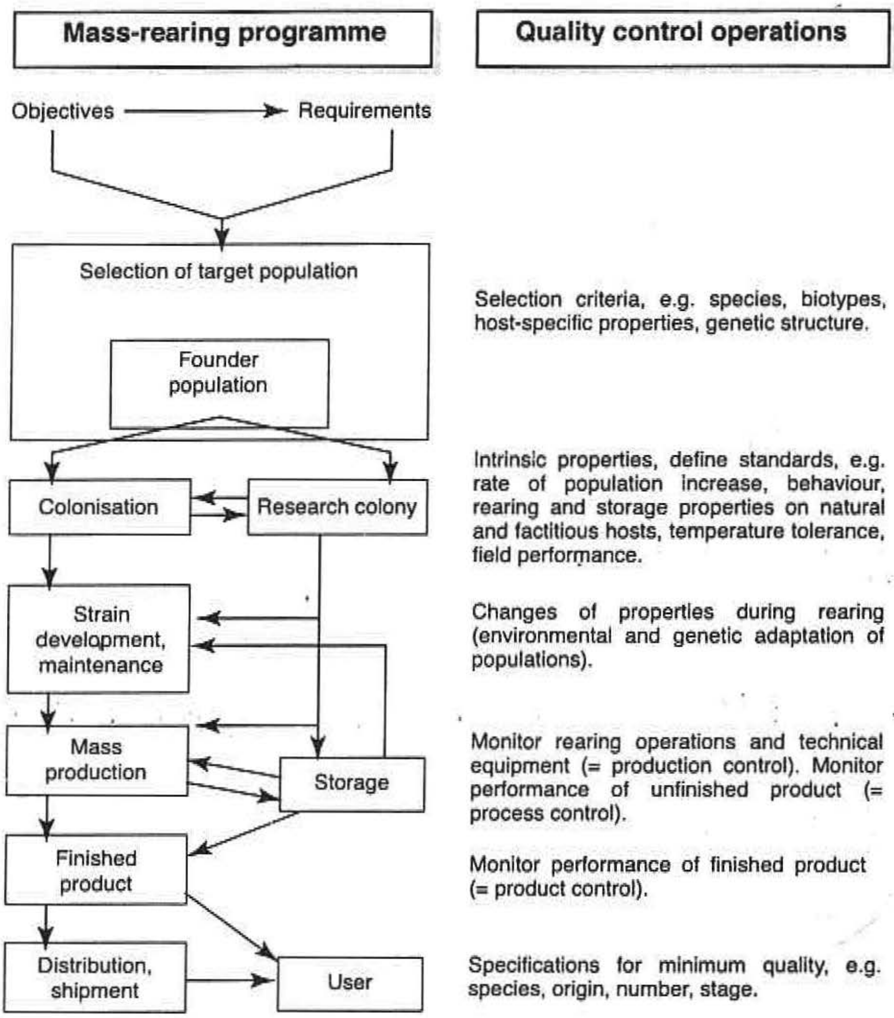


Figure 2.* Trichogramma *mass-rearing programme in commercial insectaries in India

Species/Strain Selection

Choice of Suitable Species/Strains for the Target Pest and Crop

This is a key factor in ensuring satisfactory impact in the target crop systems (Smith, 1996). Recent knowledge on the host specificity and preference of native *Trichogramma* to the target host is very limited. Ochiel (1989) observed some difference between *H. armigera* and cereal stemborers in preference and suitability for oviposition and development of *Trichogramma* sp. nr *exiguum*,



Source: Bigler (1994).

Figure 3.* Trichogramma *mass-rearing programme and routine quality control operations in developed countries

while Guang and Oloo (1990) observed that *Trichogramma* sp. nr *mwanzai* shows differential preference for oviposition between *Chilo partellus* and *H. armigera*. Muholo (2002) found that trichogrammatid species/strains originally recovered from *H. armigera* could differ in their preference and/or performance on other Lepidoptera such as *Plutella xylostella, Chilo partellus, Sesamia inferens* and *Busseola fusca*. Further, all these are laboratory studies and did not include the role of host plants in the selection of species/strains. Abera (2001) recovered five trichogrammatid species from *H. armigera* in his surveys in Kenya; among these, *T.* sp. nr *mwanzai* and *Trichogrammatoidea* sp. nr *lutea* were found to also occur on other hosts. Van den Berg and Cock (1993) had recorded five *Trichogrammatoidea* sp. on *H. armigera* in Kenya.

Currently, in Kenya, mass production of *Trichogramma* is being planned by Dudutech, a private enterprise in collaboration with ICIPE. It is visualised to cater to the needs for biocontrol of key lepidopteran pests of horticultural crops. ICIPE and KARI are also involved in evolving suitable guidelines for regulatory legislation that can harmonise their commercial production. Scope exists for expanding the coverage to industrial crops like cotton and sugarcane.

References

Abera T. H. (2001) Studies on native *Trichogramma* (Hymenoptera: Trichogrammatidae) for biocontrol of selected lepidopteran pests in Kenya. PhD thesis. Kenyatta University, Nairobi, Kenya. 190 pp.

Bigler F. (1994) Quality control in *Trichogramma* mass production, pp. 93–111. In *Biological Control With Egg Parasitoids* (Edited by E. Wajnberg and S. A. Hassan). International Organisation for Biological Control of Noxious Animals and Plants (IOBC). CAB International, UK.

Bigler F., Meyer A. and Bosshart S. (1987) Quality assessment in *Trichogramma maidis* Pintureau et Voegele reared from eggs of factitious hosts, *Ephestia kuehniella* Zell. and *Sitotroga cerealella* (Oliver). *Journal of Applied Entomology* 104, 304–353.

Enock F. (1895) Remarks on *Trichogramma evanescens* Westwood received by the Secretary of South London Entomology and Natural History Society. *Entomologist* 28, 282.

Hassan S.A. (1993) The mass rearing and utilization of *Trichogramma* to control lepidopterous pests: Achievements and outlook. *Pesticide Science* 37, 387–391.

Li Li-Ying (1994) Worldwide use of *Trichogramma* for biological control on different crops: A survey, pp. 37–53. In *Biological Control With Egg Parasitoids* (Edited by E. Wajnberg and S. A. Hassan). CAB International, Oxon, UK.

Li Li-Ying (1997) Research and utilization of *Trichogramma* in China, pp. 149–166. In *Parasitoids and Arthropod Pests* (Edited by Li Ly). Guang Dong High Education Press, Guangzhou, China.

Muholo C. A. (2002) Studies on potential host range and non-target risk assessment of trichogrammatid egg parasitoids in Kenya. MSc Thesis. Addis Ababa University, Ethiopia. 122 pp.

Ochiel G. R. S. (1989) Biology of *Trichogramma* sp. nr *exiguum* Pinto & Platner (Hymenoptera-Trichogrammatidae) on some lepidopterous hosts in South Nyanza, Kenya. M. Phil. Thesis, Rivers State University of Science and Technology, Nkpolu, Port Harcourt, Nigeria. 140 pp.

Singh S., Paul A. V. N. and Singh A. K. (2001) Host effect on the quality of *Trichogramma brasiliensis* and *T. exiguum*. *Indian Journal of Entomology* 63, 350–355.

Smith S. N. (1996) Biological control with *Trichogramma*: Advances, successes and potential of their use. *Annual Review of Entomology* 15, 375–406.

van den Berg H. and Cock M. J. W. (1993) Stage-specific mortality of *Helicoverpa armigera* in three smallholder crops in Kenya. *Journal of Applied Ecology* 30, 640–653.

Research and Training in Promoting *Trichogramma* Utilisation for Biocontrol of the African Bollworm in Eastern Africa

S. Sithanantham, J. Baya, A. Kalyebi, C. Muholo, G. Momanyi, L. Migiro and C. M. Matoka
International Centre of Insect Physiology and Ecology (ICIPE), P. O. Box 30772-00100, Nairobi, Kenya

Abstract

The on-going regional initiative for promoting *Trichogramma* utilisation for biocontrol of *Helicoverpa armigera* in vegetable-based cropping systems in eastern Africa is focusing on building up local capacity for research and technology promotion. Human resource capacity building in relevant research speciality areas is integrated into postgraduate research projects hosted by the African Bollworm Biocontrol project. The following are the topics in which such specialised and 'hands on' training is being given on native trichogrammatid egg parasitoids for *H. armigera* biocontrol: (i) characterisation of inter- and intra-specific diversity of native *Trichogramma*; (ii) adaptation of chosen *Trichogramma* species and strains for climatic stresses and host plant attributes; (iii) host range and potential non-targets for selected *Trichogramma* species/strains; (iv) interaction of *Trichogramma* with other commonly used pest control products and (v) improvements in *Trichogramma* mass production technology.

In addition, short-term training is also being arranged at technical level for demonstration and promotional activities. The present project phase will build up a core group of trained research and extension personnel for supporting the expanded activities in a proposed follow-up phase.

Key words: *Trichogramma*, *Helicoverpa armigera*, capacity building, IPM, biological control, pesticides, egg parasitoids, mass production, eastern Africa

Introduction

Presently, a regional initiative to promote the utilisation of *Trichogramma* in biological control of the African bollworm (*Helicoverpa armigera*) in vegetable-based cropping systems in eastern Africa (Sithanantham *et al.*, 2002b) is ongoing. One of the important outputs of this initiative is to build national and regional capacity for sustaining relevant specialised research and for popularisation of *Trichogramma* use. This paper provides an overview of the theme areas and initiatives currently being undertaken towards capacity building under this project.

Characterisation of Inter- and Intra-specific Diversity of Native *Trichogramma*

The focus is on developing local capacity for utilising conventional and molecular taxonomic approaches in characterising the inter- and intra-specific diversity of the native egg parasitoids, especially trichogrammatids (Baya *et al.*, 2002). Training at doctoral level on the use of PCR of the internally transcribed spacer 2 region (ITS2) of the ribosomal DNA and amplified fragment length polymorphism (AFLP) methodologies for the study of molecular composition has been arranged. Two experts from the University of Hohenheim, Stuttgart, Germany, besides specialists from ICIPE and JKUAT provide supervision for this doctoral training.

Surveys conducted between June 2001 and October 2002 have yielded a total of 34 trichogrammatid accessions (6 in the genus *Trichogramma* and 28 in the genus *Trichogrammatoidea*) from on-farm surveys; while a total of 66 accessions (18 in the genus *Trichogramma* and 48 in the genus *Trichogrammatoidea*) were obtained from the on-station pesticide-free plots.

As a back up for this capacity, a reference collection of preserved specimens as well as a live repository of representative accessions is being established at ICIPE. It is expected that this will serve as a regional gene bank of native *Trichogramma* for eastern Africa.

Adaptation Potential of Native Trichogrammatid Species/Strains to the Habitat

There is need to provide expert back up for selecting well-adapted native trichogrammatid species so that they can perform satisfactorily when released in ecologies which have contrasting habitat attributes (Kalyebi *et al.*, 2002). Training at doctoral level is being provided for selecting for adaptation to temperature and humidity regimes, through life table and functional response studies. Net-house evaluations are being planned to identify species and strains, which are compatible with the target host plants of *Helicoverpa armigera*. An expert from Germany (BBA, Darmstadt) and specialists from ICIPE and Kenyatta University are supervising this doctoral training.

Interaction of *Trichogramma* with the Other Pest Control Products/Practices

In promoting the adoption of *Trichogramma* use as a component of integrated pest management (IPM), local expertise and knowledge is required to assess compatibility of different pest control products and practices being adopted in the target crop systems. A training project at Masters level jointly supervised by an expert from the Project Directorate for Biological Control, Bangalore, India and experts from JKUAT (Kenya) and ICIPE, is focused on categorising the compatibility and safety of the commonly used pest control products through adoption of standardised bioassay methodologies, supported by net house evaluations.

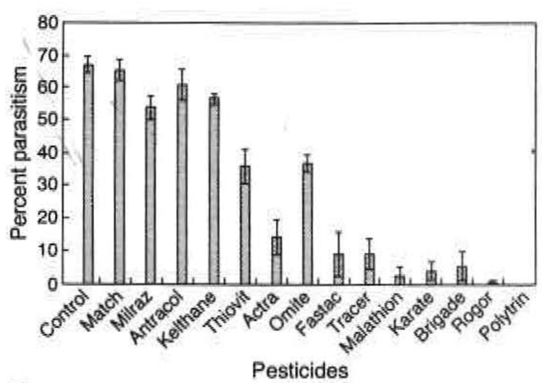


Figure 4. Relative safety of some commonly used pesticides to* Trichogramma *adults

This training project is also providing baseline information on the relative safety of several chemical pesticides that are currently used in horticultural crops in Kenya. Figure 4 illustrates the relative mortality caused to adult *Trichogramma* by some of the commonly used pesticides, when the parasitoids are exposed to fresh spray deposits. Figure 5 provides information on the relative duration (days after spraying) up to when 50% mortality is found, caused by the different pesticides evaluated. Tests with botanicals such as neem have been carried out (Sithanantham *et al.*, 2002a).

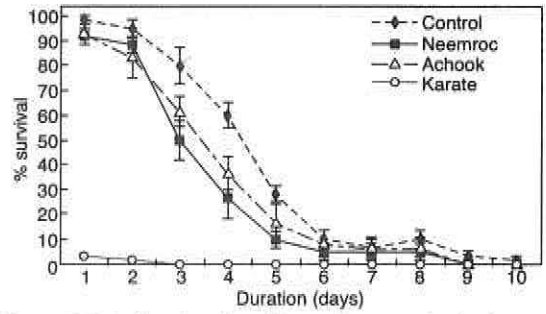


Figure 5. Relative duration (days after spraying) when 50% mortality is caused by different pesticides

Host Range and Non-target Methodology Studies

The potential impact of *Trichogramma* release on *H. armigera* in the target crop may be substantially affected by the extent to which the parasitoids actively seek for and attack the target host, in the likely presence of other hosts on the same crop or in neighbouring crops in or around the farms. There is need for local expertise to characterise the promising native species / strains for their potential specificity and / or preference for the target pest. Sithanantham (2002) has indicated the importance of appropriate non-target studies and methodologies so as to address the concerns of stakeholders in relation to environmental and biodiversity conservation, with focus on the developing country scenario. An MSc training project is addressing the development or refinement of appropriate methodologies (lab and field) for assessing the non-target effects of *Trichogramma* release in model target agroecosystems (Muholo *et al.*, 2002). An expert from Switzerland (FIAA, Zurich) is providing the supervision for this speciality theme, besides specialists from the University of Addis Ababa (Ethiopia), a butterfly farming project (Kipepeo Self Help Project, Kenya) and ICIPE.

In Kenya, there is considerable potential for promoting biological control of the African bollworm *Helicoverpa armigera*, especially by using native egg parasitoids. For enabling the selection of the most efficient species/strain of native egg parasitoids, the potential host range and relative host preference studies were undertaken during 2001–2002. Eight representative species/strains of native egg parasitoids from Kenya were tested including *Trichogramma* sp. nr *mwanzai* (1), *Trichogrammatoidea* sp. nr *lutea* (3) and *Trichogrammatoidea* sp. (4). Laboratory 'no choice' tests on the host suitability of five lepidopteran pests—*Chilo partellus* Swinhoe, *Busseola fusca* Fuller, *Sesamia calamistis* Hampson, *Plutella xylostella* L. and *Helicoverpa armigera* Hübner, besides the factitious laboratory host *Corcyra cephalonica* Stainton and the wax moth, *Galleria melonella* L.—showed that the overall progeny production per adult female parasitoid on these hosts was 1.9, 12.9, 7.5, 2.4, 4.0, 7.3 and 0.1 respectively.

Among the parasitoids tested on *H. armigera*, *Trichogramma* sp. nr *mwanzai* resulted in a relatively high progeny production (7.2), among all the hosts studied. This species also produced more progenies on *B. fusca* (32.5) and nearly the same level of progenies on *C. partellus* (8.5), *S. calamistis* (7.2) and *C. cephalonica* (6.2). However, it was less successful on *P. xylostella* (0.6) and did not produce any progeny on *G. melonella*. Among the parasitoids tested, while *Trichogramma* sp. nr *mwanzai* produced the greatest number of progeny on *H. armigera*, *C. partellus*, *B. fusca* and *S. calamistis*, *Trichogrammatoidea* sp. nr *lutea* recorded the highest progeny on *C. cephalonica* and *G. melonella*, and *Trichogrammatoidea* sp. recorded maximum progeny on *P. xylostella*. Paired choice tests for comparing each host with *H. armigera* showed that *B. fusca*, *S. calamistis* and *C. cephalonica* were more preferred for parasitisation than *H. armigera*. *Plutella xylostella* and *C. partellus* appeared to be less preferred, whereas *G. melonella* was not preferred at all.

Sampling of the eggs of the butterfly, *Papilio demodocus* Esper. from natural stands of its common host plants (*Citrus* spp.) in coastal Kenya indicated that while trichogrammatids did not naturally attack them, some scelionid egg parasitoids were recovered from them. Follow-up studies to determine any potential risks to the local butterfly (*P. demodocus*) farming on native egg parasitoids are being planned. Dr J. C. Monje and Prof. Zebitz of the University of Hohenheim, Germany gave specialised advice in the identification of the trichogrammatids used in this study.

Improving Mass Production Technologies

While the basic techniques in mass production of *Trichogramma* are known and readily available for undertaking commercial mass production, there is also scope to refining them further so to enhance the efficiency and economics of production. This should also help in upgrading the competitiveness of the *Trichogramma* technology with alternative options for the end user. Sex ratio studies on native trichogrammatid strains have been carried out (Osiemo et al., 2002). A training project (MSc level) is focused on evaluating options that can cut down on production cost for the factitious host (e.g. *Corycra, Ephestia*) and the parasitoid. Useful information is also emerging from these studies. Between the two factitious hosts, *Ephestia kuhniella* and *Corcyra cephalonica*, *Corcyra cephalonica* is found to result in greater progeny production, both for *Trichogramma* and *Trichogrammatoidea* species. The effect of age of host eggs on the extent of female progeny production, for parasitoid adults of differing age, is illustrated in Figure 6. The influence of different ratios of host eggs on female progeny production is summarised in Figure 7. External experts from China (CAAS, Beijing) and India (PCI-BCRL, Bangalore), besides specialists from Jomo Kenyatta University of Agriculture and Technology (Kenya) and ICIPE provide the supervision for this training. In addition, a technician from a private enterprise in Kenya (Dudutech) has also been trained in mass production of *Trichogramma*.

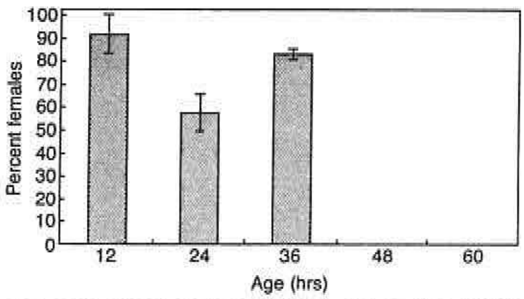


Figure 6. Effect of age of host egg on the extent of female progeny production, for* Trichogramma *adults of differing age

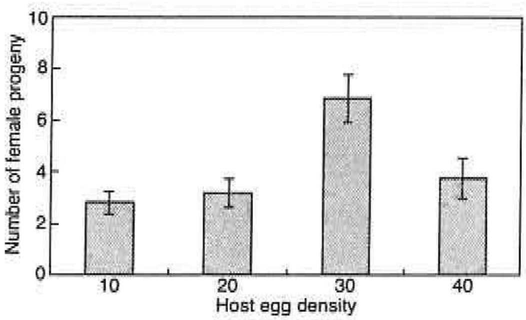


***Figure 7. Influence of different ratios of* Corcyra cephalonica *eggs on female progeny production in* Trichogramma *sp. nr* mwanzai**

Popularisation and Impact Assessment Training

There is equally a need for providing short-term training at technician level as 'master trainers' for further training to be given for extension and demonstration activities. At project level, such short-term training has been arranged for technicians from the national biocontrol teams from Ethiopia (1), Kenya (1), Tanzania (2) and Uganda (1).

Conclusion

The ongoing project has visualised relevant theme areas for local capacity building and involved suitable experts and specialists to provide the supervision for training young researchers in *Trichogramma* utilisation. Complementary training for extension and demonstration activities is also being organised.

References

Baya J. M., Monje J. C., Osir E. O., Kimani S., Sithanantham S., Gitonga L. and Zebitz C. P. W. (2002) Characterisation of the inter- and intra-specific diversity and habitat association of native trichogrammatid species occurring on *H. armigera* in eastern Africa, pp. 21–22. In *Egg Parasitoids for Biological Control of Crop Pests (Abstracts)*. Proceedings of the 6th International Egg Parasitoid Symposium, 15–18 September 2002, Perugia, Italy. University of Perugia, Italy.

Kalyebi A., Sithanantham S., Overholt W. A., Mueke J. M. and Hassan S. A. (2002) Studies on species and strain adaptation among native trichogrammatid collections in eastern Africa, p. 37. In *Egg Parasitoids for Biological Control of Crop Pests (Abstracts)*. Proceedings of the 6th International Egg Parasitoid Symposium, 15–18 September 2002, Perugia, Italy. University of Perugia, Italy.

Muholo C., Seyoum A., Ngi-Song A., Romeis J., Sithanantham S., Matoka C. M., Baya J. and Ayiemba W. (2002) Study of the potential host range and host preference of some native trichogrammatid egg parasitoids in Kenya, pp. 46–47. In *Egg Parasitoids for Biological Control of Crop Pests (Abstracts)*. Proceedings of the 6th International Egg Parasitoid Symposium, 15–18 September 2002, Perugia, Italy. University of Perugia, Italy.

Osiemo Z., Ngi-Song A., Stouthamer R., Sithanantham S. and Gitonga L. (2002) Study on the offspring sex ratio of a native trichogrammatid species, *Trichogrammatoidea* sp. nr *lutea* Girault (Hymenoptera: Trichogrammatidae) in Kenya in relation to rearing conditions, pp. 47–48. In *Egg Parasitoids for Biological Control of Crop Pests (Abstracts)*. Proceedings of the 6th International Egg Parasitoid Symposium, 15–18 September 2002, Perugia, Italy. University of Perugia, Italy.

Sithanantham S. (2002) Research approaches for non-target risk assessment in biological control of lepidopteran pests and needs in developing countries, pp. 225–240. In *Proceedings of the Symposium on Biological Control of Lepidopteran Pests*, 17–19 July, 2002, PDBC, Bangalore, India (Edited by P. I. Tandon, C. R. Ballal, S. K. Jalali and R. J. Rabindra). Society for Biocontrol Advancement, Karnataka, India.

Sithanantham S., Baya J. and Matoka C. M. (2002a) Laboratory study of effect of two neem products as sprays on the survival of adults of *Trichogramma* sp. nr *mwanzai*, pp. 42–43. In *Egg Parasitoids for Biological Control of Crop Pests (Abstracts)*. Proceedings of the 6th International Egg Parasitoid Symposium, 15–18 September 2002, Perugia, Italy. University of Perugia, Italy.

Sithanantham S., Monje C., Zebitz C. P. W., Hassan S., Baumgärtner J., Overholt W., Löhr B., Osir E., Nangayo F., Mulugeta N., Ogwang J., Mgoo V. and Matoka C. M. (2002b) Collaborative research initiative towards improved understanding and utilization of the native egg parasitoids for bio-control of *Helicoverpa armigera* in eastern Africa, p. 61. In *Egg Parasitoids for Biological Control of Crop Pests (Abstracts)*. Proceedings of the 6th International Egg Parasitoid Symposium, 15–18 September 2002, Perugia, Italy. University of Perugia, Italy.

Current Collaborative Research and Linkage Activities on the African Bollworm, *Helicoverpa armigera* (Hb.) Biocontrol with *Trichogramma* in Kenya

C. Kariuki[1], S. Njihia[1], S. Sithanantham[2], J. Baya[2] and C. M. Matoka[2]

[1]*Kenya Agricultural Research Institute (KARI), National Agricultural Research Centre (NARC)-Muguga, P. O. Box 30148, Nairobi, Kenya;*
[2]*International Centre of Insect Physiology and Ecology (ICIPE), Box 30772-00100, Nairobi, Kenya*

Abstract

The African bollworm (ABW), *Helicoverpa armigera* (Hb.), is a key pest of a wide range of crops including vegetables (e.g. tomato, okra, French bean), legumes (e.g. pigeonpea, beans), oilseeds (e.g. sunflower, sesame) and fibres (e.g. cotton) in Kenya. Currently, the need to develop biocontrol based integrated pest management (IPM) towards sustainably managing this pest is being increasingly recognised.

The current collaborative activities jointly undertaken by KARI-Muguga and ICIPE are part of an on-going regional initiative for promoting the utilisation of trichogrammatid egg parasitoids in biocontrol of this pest in eastern Africa. Joint on-farm surveys were undertaken in vegetable-based cropping systems during 2001–2002 that yielded 37 recoveries of native egg parasitoids from ABW in tomato crops, out of which seven belong to the genus *Trichogramma* and 30 to the genus *Trichogrammatoidea*. The seasonal load of ABW eggs on tomato at Muguga has been estimated as 11, 16 and 60 per 10 plants per week (season 1—short rains 2001, season 2—long rains 2002 and season 3—short rains 2002, respectively). Pheromone trap catches of adult males of ABW at Muguga commenced from October 2001 and peaks in adult catches were observed during January, May and June 2002. Linkages are being established with a group of tomato farmers growing the crop near Muguga for initiating farmer-participatory awareness building activities on biocontrol and IPM of ABW in the tomato crop. It is visualised that the on-going KARI–ICIPE collaboration during the current phase (2001–2004) will be extended to a follow up phase for wide-scale popularisation of trichogrammatid egg parasitoid use for ABW management through the deployment of the wasps as biocontrol agents in the country.

Key words: *Helicoverpa armigera*, *Trichogramma*, biocontrol, tomato, IPM, collaboration, Kenya

Introduction

In Kenya, the African bollworm (ABW), *Helicoverpa armigera* (Hb.) is recognised as an important pest on cotton, vegetables, legumes and oilseeds (Farrel *et al.*, 1995). Past research on *H. armigera* management in Kenya has mainly focused on chemical control, yield loss assessment and recording of natural enemies. The only limited research focus in the region on natural enemies of ABW was by van den Berg and Cock (1993), who listed the locally occurring enemies (parasitoids, predators, pathogens). The contribution of major mortality factors in the egg and larval stages of ABW was also quantified and the important role played by the host crop in the impact of biocontrol agents pointed out. The study gives a basis on which further biological control initiatives for the region could be built.

The Current Collaborative Initiatives

As part of an on-going regional initiative for popularising *Trichogramma* for biocontrol of ABW in eastern Africa (2001–2004) (Sithanantham *et al.*, 2002), the KARI biocontrol team at Muguga is currently undertaking collaborative activities with ICIPE, which are summarised below.

Table 14. Trichogrammatid collections in Kenya: On-farm survey, 2001–2002

	Trichogramma	*Trichogrammatoidea*	Other species
Crop			
Tomato	5	28	10
Okra	0	2	4
Maize	2	0	0
Total collections	**7**	**30**	**14**
Altitude			
Low	0	12	0
Medium	4	3	1
High	3	15	13
Total for each group	**7**	**30**	**14**

On-farm Surveys for Collection of Native Trichogramma

During 2001–2002, KARI and ICIPE jointly undertook on-farm surveys in different vegetable production areas in the country. A summary of the surveys and the recoveries of native trichogrammatid egg parasitoids from ABW hosts during these surveys are provided in Table 14. So far, seven *Trichogramma* and 30 *Trichogrammatoidea* collections have been identified.

Supplementary Recovery of Native Trichogramma *from Pesticide-free On-station Plots*

During 2001–2002, ABW eggs were sampled from pesticide-free target crops of ABW (tomato, okra, capsicum, cotton, pigeon pea and sunflower) grown on-station at Muguga. These provided a recovery of three collections of trichogrammatids. The trials had multiple *Helicoverpa* host crops (tomato, capsicum, okra, sunflower, pigeon pea and cotton) and two non-ABW host crops (sorghum and kale) from which other lepidopterans could oviposit.

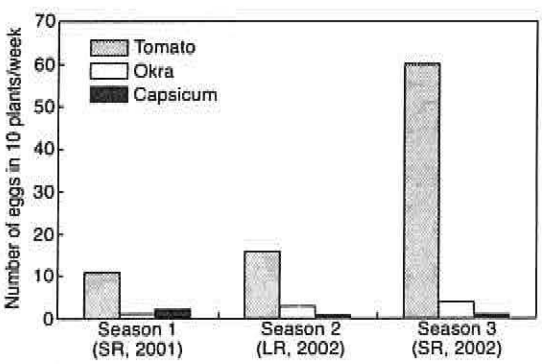


Figure 8. On-station egg load on tomato/okra/capsicum, NARC, Muguga, Kenya 2001–2002

On-station Monitoring of Egg Load of ABW on Tomato

In the above plots, grown for three seasons during 2001–2002 at Muguga, it was possible to estimate the ABW egg load on tomato, the main target crop. On an average, each tomato plant had 11, 16 and 60 eggs of ABW per week in the three seasons studied. Estimates for egg loads on okra were 1, 3 and 4 in the three seasons. The summary data on ABW egg load in the chosen host crops are furnished in Figure 8.

On-station Monitoring of ABW Adults in Pheromone Traps

Standard pheromone traps (plastic funnel, hood, sleeve and septa) obtained from India (PCI-BCRL, Bangalore) were installed from October 2001 at Muguga. Daily trap moth catches of adult males of ABW were recorded. The data collected until October 2002 showed peaks in adult catches

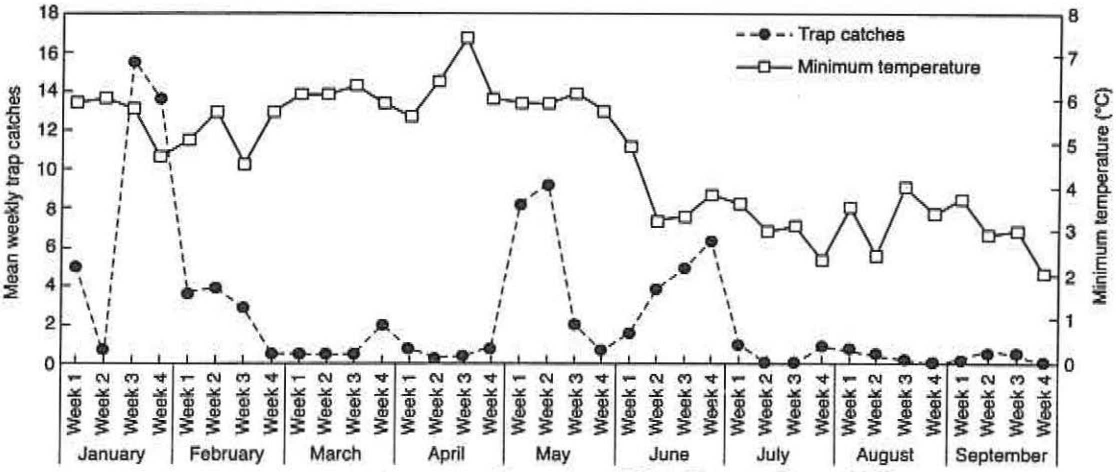


Figure 9. On-station pheromone trap data — weekly catches, NARC Muguga, Kenya 2002

during the months of January, May and June 2002, with mean weekly catches of 15.4, 9.1 and 6.2 respectively. The trend in ABW adult trap catches at Muguga in relation to minimum temperature is illustrated in Figure 9.

Establishing a Culture of the Factitious Host

The establishment of a culture of the factitious host was also undertaken as an important and integral back up initiative for the research and demonstration activities at Muguga. The ICIPE team provided the initial training and nucleus culture of the host, *Corcyra cephalonica* (Stainton). The culture has been built up on maize flour as the host larval medium. Presently, the culture produces a reasonable number of moths that can sustain an initial egg parasitoid culture for demonstration purposes.

Initiating Linkages with Tomato Farmers' Group Near Muguga

In preparation for a follow-up phase for popularising the use of trichogrammatid egg parasitoids for biocontrol of ABW in vegetable-based cropping systems in the country, KARI-Muguga and ICIPE have jointly identified a small group of tomato growers near Muguga. In about 2–3 seasons, they will be made aware of the IPM options for ABW, including validation of the benefits of using *Trichogramma* as a biocontrol component.

Looking Ahead

It is hoped that the present collaboration activities will lead to adequate baseline information as well as preparatory experience, to be able to support wide-scale popularisation of *Trichogramma* use in ABW biocontrol during a follow-up phase. We also expect to link up with additional scientists from KARI and the universities, besides Ministry of Agriculture extensionists, private enterprise and NGOs during that phase. Initiatives are also being made to link the farmers with other specialists in important crop production constraints such as disease, other pests like mites and so boost the farmers' crop productivity and economic base.

References

Farrel G., Kibata G. N. and Sutherland J. A. (1995) A Review of Crop Protection Research in Kenya. KARI/ODA Crop Protection Project, National Agricultural Research Laboratories, KARI, Nairobi, Kenya. 165 pp.

Sithananatham S., Zebitz C. P. W., Monje J. C., Hassan S., Kariuki C. M., Njihia S., Ogwang J., Sekematte B., Mohammed D., Mulugeta N., Mugoo V., Pallangyo B. and Matoka C. M. (2002) Collaborative research initiative towards improved understanding and utilisation of the native egg parasitoids for biocontrol of *Helicoverpa armigera* in eastern Africa, p. 61. In *Egg Parasitoids for Biocontrol (Abstracts)*. 6th International Symposium, 15–18 September 2002, Perugia, Italy. University of Perugia, Italy.

van den Berg H. and Gock M. J. W. (1993) *African Bollworm and Its Natural Enemies in Kenya*. International Institute of Biological Control (Kenya Station) and Natural Resources Institute (Overseas Development Administration), UK. CAB International, UK. 81 pp.

Overview of African Bollworm Biocontrol Elsewhere and KARI Collaboration Activities

Current Status of the African Bollworm, *Helicoverpa armigera*, Its Management and Future Research Needs in Western Kenya

M. A. Mulaa
National Agricultural Research Centre, P. O. Box 450, Kitale, Kenya

Abstract

The African bollworm (ABW), *Helicoverpa armigera* (Hb.), is an important pest on tomato and *Desmodium*, besides cotton, maize, sunflower, sorghum and beans. While there is some information on biology and ecology of ABW, there is need and scope to characterise its population dynamics in benchmark sites across the country. Progress has been made in the KARI research centre at Kitale in identifying tomato varieties tolerant to ABW (Cal J, Fortune, Caltana, Kenton). Sprays of botanicals (e.g. pepper, Mexican marigold) have been found promising for ABW control on tomato. Intercropping maize and *Desmodium* has been found to reduce the incidence of ABW in the latter. Need-based timing of pesticide application based on thresholds has been shown to reduce the number of applications by half. Natural enemies that show potential for ABW biocontrol include *Trichogramma* sp., besides larval parasitoids, predators and pathogens. Areas for future research, as well as training and extension needs are indicated. Themes for future KARI–ICIPE collaboration are also suggested.

Key words: *Trichogramma* sp., biocontrol, botanicals, training and extension, western Kenya

Importance of African Bollworm on Target Crops

The African bollworm (ABW), *Helicoverpa armigera* (Hb.), is an important pest in many parts of the world mainly in Africa, Asia, Europe, the Middle East and Australia. It is a highly polyphagous and mobile insect pest that attacks various crops in Kenya (Table 15). In western Kenya the pest is becoming very important especially on cotton, tomatoes, *Desmodium*, maize, sunflower, sorghum and beans. The highest yield losses have been observed mainly on cotton, tomatoes and pigeon peas. The damage caused by the pest varies on different crops; generally, the parts attacked include fruits/pods, developing seeds, flowers, bracts and young leaves. On tomato, yield loss may reach more than 50%, making the fruits unmarketable (Mulaa *et al.*, 1999 a, b). Attacks by *H. armigera* on growing terminal parts, before flowering, may cause loss of plant uniformity and poor seed production, e.g. in tomatoes and *Desmodium* (Mulaa and Muyekho, 2000). *Helicoverpa armigera* is found in all parts of Kenya where the host crops are grown, i.e. in the lower midlands and upper midland agroecological zones (Table 16).

Pest Biology and Ecology

The biology and ecology of *H. armigera* is mainly dependent on the host plant and the prevailing weather conditions. Life cycle studies of *H. armigera* have

Table 15. Extent of importance of the African bollworm on important target crops in Kenya

Target crop	Importance	Extent of yield loss
Cotton, *Gossypium hirsutum*	Very important	< 50
Tomato, *Lycopersicum esculentum*	Very important	< 50
Pigeon pea, *Cajanus cajan*	Very important	< 50
Dolichos, *Dolichos lablab*	Very important	< 50
Desmodium, *Desmodium uncinatum*	Very important	< 50
Maize, *Zea mays*	Important	> 20
Sunflower, *Helianthus annuus*	Important	< 20
Okra, *Hibiscus esculentus*	Important	> 20
Soybean, *Glycine max*	Important	> 20
Sorghum, *Sorghum vulgare*	Important	20–30
Chickpea, *Cicer arietinum*	Important	> 20
Cowpea, *Vigna unguiculata*	Important	> 20
Greengram, *Vigna aureus*	Important	> 20
Beans, *Phaseolus*	Just important	< 20
Safflower, *Carthamus tinctorius*	Just important	> 10
Tobacco, *Nicotiana tabacum*	Just important	> 10
Groundnut, *Arachis hypogaea*	Just important	> 10

been conducted mainly on cotton, sorghum and sunflower (van den Berg *et al.*, 1993) and *Desmodium* (Mulaa and Muyekho, 2000). In East Africa, there are 6–8 generations a year, and one life cycle takes between 35–56 days. Adults of *H. armigera* are night flying moths, which lay spherical yellow eggs, singly on young leaf bracts or flower buds. Egg laying starts about 4 days after emergence and may continue for 10 days. One female may lay up to 1000 eggs. Eggs hatch within 3–4 days. There are 5–6 larval instars, which take 25–38 days. Pupation takes place in the soil and takes between 10–14 days (Mulaa and Muyekho, 2000). The peaks of *H. armigera* eggs and larvae usually coincide with the flowering period of the crops they attack, e.g. for cotton between the 9th and 13th week after germination (Nyambo, 1986). The same observations were made on *Desmodium* (Mulaa and Muyekho, 2000). However, there is need and scope to characterise the population dynamics of the pest in benchmark sites representing the major crop production ecologies in different parts of Kenya including Western Province.

Table 16. Extent of the African bollworm on important crops in different provinces in Kenya

Important African bollworm crops	Region/Province	District(s)
Cotton, Sorghum	Nyanza (lower midlands)	Kisumu, Siaya, Kisii
	Western (upper midlands)	Busia, Bungoma, Teso, Kakamega, Vihiga
	Eastern (lower midlands)	Kirinyaga (Mwea), Kitui, Machakos, Lower parts of Embu
Tomato	Western (upper midlands)	Kakamega, Bungoma (Kimilili), Vihiga
	Eastern (lower midlands)	Kirinyaga (Mwea), Embu, Machakos
	Rift Valley (upper midlands)	Trans Nzoia, Nakuru (Subukia, Bahati), Uasin Gishu (Moiben)
	Coast (lower lands)	Kilifi (Chonyi, Mtwapa, Malindi), Kwale (Msambweni)
Maize, Beans, *Desmodium*	Western (upper midlands)	Busia, Bungoma, Kakamega, Vihiga
	Rift Valley (upper midlands)	Trans Nzoia, Uasin Gishu, Nakuru

On-going Research on African Bollworm Management in Western Province

Control Strategies for African Bollworm Management

Experiments on control of *H. armigera* have been on-going at the National Agricultural Research Centre, Kitale since 1997 on tomatoes and desmodium. Tomato varieties tolerant to *H. armigera*, aphids and diseases have been identified. Varieties such as Cal J, Fortune, Caltana and Kenton were found to be tolerant to

Table 17. Known/recommended control methods for African bollworm on target crops in western Kenya

Target crop	Type of control	Practice/ recommended product	Extent of adoption*	Remarks
Cotton	Chemical	Use of pesticide mixtures, e.g. Thiodan (endosulfan)/Sevin (carbaryl)	2	Cotton has several pests, which cannot all be controlled by one pesticide type.
		Sevin (carbaryl)/ Sumicidin (fenvalerate)	2	Cotton has several pests which cannot all be controlled by one pesticide type.
		Rotation of pesticides with different modes of action	3	Most farmers have limited knowledge of the pesticide groups and about resistance management.
	Cultural	Adopting a 'closed' season	1	Not very effective against *Helicoverpa armigera* because the ABW has several alternative hosts and sometimes undergoes diapause.
		Burning all crop residues after harvest	1	This may result in soil erosion, depletion of the soil nutrients and destruction of natural enemies.
		Early planting	2	Most farmers prefer planting food crops first due to low cotton prices.
		Crop rotation	2	This is not very effective because it is a polyphagous pest that can migrate.
		Using trap crops, e.g. maize, whose tassels are more attractive to the egg-laying moth than cotton	3	Farmers are not sensitised of the logic behind this technology and need to be trained.
Beans, pigeon pea, sorghum	Cultural	Early planting, crop rotation, burning crop residues, intercropping	2	Most farmers practice intercropping for food security and because of small acreage. Therefore this is an easy technology to adopt.
Tomatoes	Cultural	Crop rotation	2	–
		Intercropping	3	–
	Chemical	Spraying several insecticides especially pyrethroids such as fenitrothion, permethrin, cypermethrin	1	Most farmers do not follow the pre-harvest intervals and spray on calendar basis.
	Biological	Spraying with *Bacillus thuringiensis* (e.g. Dipel)	3	Not available in some areas.
	Indigenous knowledge	Spraying with pepper extracts or ash	2	This technology is currently being scaled up.
Desmodium, maize	Cultural	Intercropping maize/*Desmodium*/Napier	2	The technology also controls stemborers in a 'push-pull' strategy.
	Chemical	Spraying with systemic insecticides, e.g. dimethoate	3	This may not be a very economical method and may even be toxic to livestock if pre-harvest intervals are not followed.

*1, good, 2, moderate, 3, low.

H. armigera compared to Moneymaker, a variety grown by most farmers in Trans Nzoia district. Experiments for screening effective botanicals for controlling pests of tomatoes indicated that pepper and Mexican marigold were effective against pests of tomatoes including *H. armigera* (Mulaa *et al.*, 1999 a, b). These treatments gave higher cost: benefit ratios compared to the synthetic pyrethroid, Karate. Timing of pesticide application based on economic thresholds was tried and the number of pesticide applications reduced by half. Screening of effective pesticides for control of *Desmodium* pests was done during 1999–2000 and dimethoate was found to be effective against *H. armigera*. Intercropping maize and *Desmodium* was found to reduce the incidence of the African bollworm in *Desmodium* (Mulaa and Muyekho, 2000).

Current recommended control strategies for *H. armigera* management include use of pesticides mainly synthetic pyrethroids (e.g. Karate) and organophosphates (e.g. endosulfan and diazinon) and use of cultural practices such as early planting and destruction of crop residues (Table 17). Most farmers have adopted use of pesticides on commercial crops such as cotton and tomatoes with the majority spraying on calendar basis rather than on economic thresholds supported by pest population monitoring. Very few farmers use indigenous practices such as botanicals because the technology is still under experimentation to determine the effective concentrations, formulations and frequency of applications (Mulaa *et al.*, 1999 c). However, a few farmers are using liquid pepper to control vegetable pests.

Status of Knowledge on Natural Enemies and their Potential for Biocontrol in Kenya

There are several natural enemies, which have been reported to occur on *H. armigera*; the most common ones in Kenya are reported in Table 18. The natural enemies that seem to have potential in the East African region include the egg parasitoid *Trichogramma* sp., larval parasitoids, mainly *Linnaemya longirostris* and *Cardiochiles* sp. and predators such as *Orius* sp. and *Cheilomenes* sp. (Nyambo, 1990; van den Berg *et al.*, 1993). However, the rates of parasitism and the types of natural enemies have been found to vary in different crops (Nyambo, 1990). Pathogens such as *Bacillus thuringiensis* have been used as sprays (e.g. Dipel) in vegetables. The potential for different biocontrol agents in ABW management and the priorities for research gaps to be filled are indicated in Table 19.

Future Needs for Improved African Bollworm Management

Priority Research Areas

1. Survey to investigate the distribution of *H. armigera* and natural enemies in different regions of Kenya besides gathering information on farmers' perception on the yield loss they cause and the farmers' control practices for *H. armigera* on different crops.
2. On-farm trials to assess yield loss due to *H. armigera* management on major crops in different agroecological zones.
3. Studies on seasonal fluctuation of *H. armigera* in the field in different agroecological zones using light and pheromone traps and field sampling/monitoring.
4. Using cage experiments to assess the efficacy of potential native natural enemies in different agroecological zones.
5. Evaluate the need for introducing exotic natural enemies, which are found to be promising elsewhere.

Table 18. Natural enemies of African bollworm known to occur in Kenya

Group	Common name	Scientific name	Insect stage attacked	Crops where commonly known
Braconid parasitoids	Parasitic wasps	*Charops* sp.	Larvae	Sorghum, cotton, maize, chickpea, tomato
		Cardiochiles sp.	Larvae	Sorghum, cotton, maize, chickpea, tomato
		Chelonus curvimaculatus	Larvae	Sorghum, cotton, maize, chickpea, tomato
		Apanteles diparopsidis	Larvae	Sorghum, maize
		Disophyrys sp.	Larvae	Sorghum, maize
Ichneumonid parasitoids	Parasitic wasps	*Campoletis chloridae*	Larvae	Maize
		Temelucha sp.	Larvae	Maize
		Natalia sp.	Larvae	Sorghum, tomato
		Pristomerus sp.	Larvae	Sorghum, tomato, cotton
		Meteorus sp.	Larvae	Maize, cotton
Trichogrammatid parasitoids	Parasitic wasps	*Trichogrammatoidea* spp.	Eggs	Maize, sorghum, tomato, cotton
Tachinid parasitoids	Parasitic wasps	*Linnaemya longirostris*	Larvae	Maize, cotton, sorghum
		Paradrino halli	Larvae	Maize, sorghum, cotton, chickpea, tomato
		Palexorista laxa	Larvae	Maize, sorghum, cotton, chickpea, tomato
		Sturmiopsis sp.	Larvae	
Predators	Coccinellidae	*Cheilomenes lunata*	Larvae/ pupae	Maize, cotton, sorghum
		Cheilomenes propingua	Larvae/ pupae	Maize, sorghum, cotton, chickpea, tomato
		Cheilomenes sulphurea	Larvae/ pupae	Maize, sorghum, cotton, chickpea, tomato
	Neuroptera	*Anisochrysa boninensis*	Larvae/ pupae	Maize, cotton, sorghum
	Chrysopidae (syrphids)	*Chrysoperla congrua*	Larvae/ pupae	Maize, sorghum, cotton, chickpea, tomato
	Birds	*Quelea quelea*	Larvae/ pupae	Maize, sorghum, cotton, chickpea, tomato
	Ants	*Componotus* sp.	Larvae	Maize, sorghum, cotton
	Praying mantis	*Pheidole* spp.	Larvae	Maize, sorghum, cotton
	Anthocorids	*Myrmicaria* sp.	Larvae	Maize, sorghum, cotton
Pathogens	*B.t.*	*Bacillus thuringiensis* var. *kurstaki*	Larvae	Maize, sorghum, cotton
	Baculovirus	Nuclear polyhedrosis virus (NPV)	Larvae	Pigeon pea, maize

Table 19. Future scope for improved use of natural enemies for biocontrol of African bollworm in Kenya

Biocontrol agent or method	Score for future potential*	Score for need for further research*
Biocontrol agent		
Egg parasitoids	2	1
Larval parasitoids	1	1
Pupal parasitoids	2	1
Predators	3	3
Pathogens	1	1
Biocontrol method		
Introductions (of exotic species/strains)	1	1
Augmentation (repeated mass production and releases)	2	1
Conservation (encouragement of *in situ* practices)	3	2

*1, Good; 2, moderate; 3, Low/poor.

Training and Extension Needs

There is need to sensitise farmers and extension officers on the importance of scouting for *H. armigera* and how to scout and identify *H. armigera* eggs and larvae. Training of researchers and extension officers in identification of potential natural enemies of *H. armigera* is also critical. Collaborative research and convening of periodical workshops to share experiences and lessons learnt so as to help design future experiments/research activities need to be explored.

Suggested Themes for Future KARI/ICIPE Collaboration

1. Surveys to identify 'hot spots' of *H. armigera* and natural enemies. Find out farmers' perception of damage caused by *H. armigera* and farmers' current control practices.
2. Conduct on-farm trials to assess actual yield losses caused by *H. armigera* and determine the economic thresholds for spraying.
3. Develop integrated pest management packages for *H. armigera* on different crops.

References

Mulaa M. A. and Muyekho F. (2000) A survey of pests of economic importance on *Desmodium* spp. in terms of forage and seed yield in Bungoma and Trans Nzoia districts, Kenya. *NARC-Kitale, Annual Report, 2000.* Kenya Agricultural Research Institute, Kenya.

Mulaa M. A., Chesoli C. and Wanyama J. (1999a) Survey of farming practices and farmers constraints of tomato production in Nyakinyua village, Trans Nzoia district, pp. 1–3. In *Proceedings of the KARI/DFID NARP II End of Project Conference,* KARI, Nairobi, Kenya (Edited by J. A. Sutherland). Kenya Agricultural Research Institute, Kenya.

Mulaa M. A., Chesoli C. and Wanyama J. (1999b) Participatory evaluation of tomato varieties for increased production and cash generation, pp. 312–314. In *Proceedings of the KARI/DFID NARP II End of Project Conference,* KARI, Nairobi, Kenya (Edited by J. A. Sutherland). Kenya Agricultural Research Institute, Kenya.

Mulaa M. A., Chesoli C., Wanyama J. and Powon M. (1999c) Sustainable pest and disease control in tomatoes through use of indigenous technical knowledge and pesticides based on economic thresholds, pp. 340–342. In *Proceedings of the KARI/DFID NARP II End of Project Conference,* KARI, Nairobi, Kenya (Edited by J. A. Sutherland). Kenya Agricultural Research Institute, Kenya.

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

Nyambo B. T. (1990) Effect of natural enemies on the cotton bollworm, *Heliothis armigera* Hübner (Lepidoptera: Noctuidae), in Western Tanzania. *Tropical Pest Management* 36, 50–58.

van den Berg H., Cock M. J., Oduor G. I. and Onsongo E. K. (1993) Incidence of *Helicoverpa armigera* (Lepidoptera: Noctuidae) and its natural enemies on smallholder crops in Kenya. *Bulletin of Entomological Research* 83, 321–328.

Present Knowledge and Potential Options for Control of the African Bollworm in Southwestern Kenya

O. E. V. Magenya
Kenya Agricultural Research Institute,
Kisii Regional Research Centre, P. O. Box 523, Kisii, Kenya

Abstract

The African bollworm (ABW), *Helicoverpa armigera* (Hübner), is a pest of major importance, damaging a wide variety of food, fibre, oilseed, fodder and horticultural crops in southwestern Kenya. Two to three ABW larvae on a plant can destroy all the bolls on cotton within 15 days. The African bollworm consumes the grains on maize cobs and damages tomato fruits, often preventing fruit development, and so causing premature fruit drop. The main control method available to farmers has been the use of chemical pesticides. However, this has proved unsustainable. The escalation in cost of insecticide-based control and the replacement of the cheaper pyrethroids, coupled with the reduced effectiveness of other insecticide groups against the bollworm and the increasing environmental concerns, have all given new impetus to the development of safer alternatives like microbial and other biocontrol agents and products.

Among the potential natural enemies of ABW, the egg parasitoids of the family Trichogrammatidae seem to be the most feasible biocontrol agent. This paper reviews the potential demand and adoption of *Trichogramma* in southwestern Kenya, as estimated across crops, and postulates the likely scenario of the involvement of investors, suppliers, and production stakeholders in the use of 'trichos'. The future needs for the improvement of the African bollworm management, priority research themes, training and extension needs, and the scope for research/extension activities are also discussed.

Key words: *Trichogramma* sp., biocontrol, 'trichos', training and extension, southwestern Kenya

Introduction

The Kisii Regional Research Centre of the Kenya Agricultural Research Institute (KARI) has a mandate to conduct adaptive and applied research in 14 districts of southwestern Kenya, namely Kisii, Nyamira, Migori, Kuria, Homa Bay, Suba, Gucha, Rachuonyo, Trans Mara, Kisumu, Nyando, Kericho, Bomet and Buret. The mandated area is composed of 1.0 million hectares of arable land, out of a total of 1.1 million hectares. It supports a population of 3.0 million people with 588,915 small-scale farm households from several groups (KARI, 2002). It covers a wide range of agroecological zones, 20 soil types and ethnic groups. The area has the potential of producing a wide range of crops that include food, fibre, oilseed, fodder and horticultural crops.

This diversity, coupled with the high population increase, has resulted in the evolution of a wide range of farming systems. Consequently, the decrease in land-holdings has contributed to the increase in poverty levels that has rendered most households unable to produce sufficient food. It is therefore necessary to intensify agricultural research, for these changing socioeconomic circumstances, to enhance food production in these small land holdings (Makini *et al.*, 1993; Mbugua *et al.*, 1996).

The Special Features of the African Bollworm

The African bollworm, *Helicoverpa armigera* (Hübner), is a pest of major importance, damaging a wide variety of food, fibre, oilseed, fodder and horticultural crops in southwestern Kenya. The importance and apparent success of *H. armigera* as a pest is in large measure due to its well-developed survival strategies, in terms of mobility, polyphagy, rapid and high reproductive rate and diapause and dispersal, which enable it to exploit food sources separated both by unfavourable times and distance, and thereby escaping its natural enemies. It is an effective migrant, not displaying typical migratory behaviour, but responding largely to local environmental cues and undertaking either short or long distance flights in directions largely governed by prevailing weather systems (Fitt, 1989). Adults can migrate over long distances borne by wind (Pedgley, 1985).

Economic Importance of the ABW in the Region

Table 20. Extent of importance of the African bollworm in target provinces/districts in southwestern Kenya

Crops in which ABW is known to be important	Province	District(s) where ABW is important
Cotton, maize, tomato, sunflower, capsicum, pigeon pea, sorghum, chickpea, pepper, beans, tobacco, cabbage	Nyanza	Nyando, Homa Bay, Migori, Suba, Rachuonyo, Kuria, Nyamira, Kisii and Gucha
Maize, tomato, capsicum, cabbage, chickpea, pigeon pea, pepper, beans	Rift Valley	Trans Mara, Kericho, Bomet and Bureti

Source: Anonymous (2001a, b; 2002).

Table 21. Extent of importance of the African bollworm on important target crops in southwestern Kenya

Target crop	Extent of importance*	Extent of yield loss (%)
Cotton	1	70
Maize	3	35
Tomato	1	60
Sunflower	1	60
Cabbage	2	50
Capsicum	2	60
Pigeon pea	1	65
Sorghum	3	40
Pepper (sweet + chillies)	2	60
Beans (dry + soybean)	2	40
Tobacco	3	45
Chickpea	2	65

*1, Very important; 2, important; 3, just important.
Source: Anonymous (2001a, b; 2002).

The peculiarities above make the ABW particularly well adapted to exploit transient habitats such as man-made agroecosystems. Its preference for damaging harvestable flowering parts of high value crops such as cotton, tomato, maize and pulses confers a high socioeconomic cost to subsistence agriculture of southwestern Kenya. The districts and estimated overall area grown to the target crops are listed in Tables 20 and 21.

Monetary losses result from either the direct reduction of yields or the cost of monitoring and control, i.e. the cost of insecticides. *Helicoverpa armigera* has been reported causing serious losses throughout its range, in particular to cotton, tomatoes, and maize. For example, on cotton, two to three larvae on a plant can destroy all the bolls within 15 days; on maize, they consume grains and on tomatoes, they invade fruits, preventing development and causing falling.

Current Control Methods of ABW in Southwestern Kenya

The main control method available to farmers has been the use of chemical pesticides (Table 22). However, this has proved unsustainable. The escalation

Table 22. Known/recommended control methods for the African bollworm on target crops in southwestern Kenya

Target crop	Type of control method	Recommended practice/product	Extent of adoption by farmers*	Remarks
Cotton	Chemical	Pyrethrins: Karate, Ambush	1	Production of cotton was decreasing but is now picking up. Farmers have to use chemicals.
Tomato	Chemical	Pyrethrins: Karate, Ambush and Diazinon	2	Damage is still high despite spraying of these pesticides.
Maize	Cultural	Timely planting	2	Damage is not very severe in maize.
Sunflower	None	None	None	Farmers do not adopt any control.
Pepper	Chemical	Pyrethrins: Karate, Ambush and Diazinon	2	Farmers still experience damage after spraying these pesticides.
Beans (dry) and soybeans	Use of resistant varieties	Farmers plant insect- and disease-tolerant varieties	2	Use of chemicals is uneconomical in beans.
Chickpea	Use of resistant varieties	Farmers plant insect- and disease-tolerant varieties	3	Use of chemicals is uneconomical in chickpea.
Capsicum	Chemical	Pyrethrins: Karate, Ambush and Diazinon	2	Farmers still experience damage even after spraying these pesticides.
Cabbage	Chemical	Pyrethrins: Karate, Ambush and Diazinon	2	Farmers still experience damage even after spraying these pesticides.

*1, Good; 2, moderate; 3, low/poor.
Source: Anonymous (2001 a, b; 2002).

in cost of insecticide-based control and the replacement of the cheaper pyrethrins by combination products, coupled with the reduced effectiveness of other insecticide groups against the bollworm and the increasing awareness of environmental concerns have given new impetus to the development of safer alternatives. There is, therefore, both need and potential of utilising non-chemical alternatives such as biocontrol in managing ABW in southwestern Kenya.

Status and Potential of Natural Enemies

The important natural enemy species tend to vary from crop to crop and from region to region. Levels of parasitism are in many cases host related, particularly in the Trichogrammatidae. The impact of parasitoids on the seasonal abundance of *H. armigera* is still poorly understood. For example in Kenya, van den Berg (1993) found that predators, chiefly Anthocoridae and Formicidae, suppressed *H. armigera* on sunflower, maize, sorghum and cotton in fields in southwestern Kenya, while parasitism was apparently low. In contrast, in northern Tanzania, parasitism was the major cause of mortality on sorghum, cotton and a weed (*Cleome* sp.), but the importance of the different species of parasitoid varied with host plant (van den Berg *et al*., 1990).

Potential Demand Scenario for *Trichogramma* in Southwestern Kenya

The potential demand scenario for utilising trichogrammatid egg parasitoids as augmentative biocontrol agents, including scope for local mass production and delivery systems, is illustrated in Appendix 1.

Future Needs for Improved African Bollworm Management

Priority Research Themes

1. Determination of the impact of parasitoids on the seasonal abundance of *H. armigera* on various host plants.
2. Comparative biological studies of the African and exotic *H. armigera* parasitoids for identifying promising species/strains for classical biocontrol programme.
3. Crop host variety trials in varied agro eco-zones.

Training/Extension Needs

1. Training workshops on biological control for frontline extension staff and farmer groups.
2. Training workshops on handling of biological control agents for extension staff and farmers groups.
3. Training on *H. armigera* identification and pest scouting on various crops.

Scope for Research/Extension Activities

1. Provision of expertise from research and mobilisation of extension staff and farmers for training purposes.
2. Cost sharing of resources for training purposes.
3. Follow-up activities by extension staff.

Themes That Require KARI–ICIPE Collaboration

1. Comparative biological studies of the African and exotic parasitoids, construction of life tables, and identification of promising strains.
2. Implementation of a pilot biological control programme for *H. armigera*.

Conclusion

The prevalence of insecticide resistance and awareness of environmental concerns has necessitated the development of alternative strategies to be included in ABW management. Nongovernmental organisations that are actively involved in agricultural development at grassroots level in the region provide greatest potential as investors in mass production of *Trichogramma*, followed by cooperatives/unions managed by farmers, Horticultural Crops Development Authority/Fresh Produce Exporters Association of Kenya and private enterprises. Factors that may influence adoption of *Trichogramma* will include awareness, availability and ease of use. These obstacles can be overcome through training for stakeholders, e.g. suppliers, producers, farmers and extension agents. There is need to develop collaborative activities amongst research institutes in order to address the gaps in the currently available options for use in ABW management. Priority research themes and training/extension needs have to be addressed urgently as a means of contributing to the improvement of the management of the ABW.

References

Anonymous (2001a) Ministry of Agriculture and Rural Development, Homa Bay District. Horticultural Crops Annual Report 2001. Government of Kenya.

Anonymous (2001b) Ministry of Agriculture and Rural Development (MOARD). Kisii District Annual Report 2002. Government of Kenya.

Anonymous (2002) Ministry of Agriculture and Rural Development (MOARD), Homa Bay District. Horticultural Crops Annual Report 2002. Government of Kenya.

Fitt G. P. (1989) The ecology of *Heliothis* species in relation to the agroecosystem. *Annual Review of Entomology* 34, 17–48.

KARI [Kenya Agricultural Research Institute] (2002) Kenya Agricultural Research Institute Medium Term Plan, July 2003–June 2008 (MTP III) Nairobi, Kenya.

Makini F. W., Njue E. K. and Mulamula H. H. A. (1993) Varietal preference, adoption and performance of improved seed and fertilizer technologies among maize farmers: Implications for planning maize research. KARI/CIMMYT Maize Database Project Seminar on Farmers Evaluation of Priority Problems, State of Adoption and the Role of Extension and Women in the Transfer of Maize Production Technologies in Kenya, 23rd–24th September, 1993, Nairobi, Kenya. Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT) and Kenya Agricultural Research Institute (KARI), Kenya.

Mbugua D. M., Makini F. W., Makelo M., Onyango C., Maisiba G., Kwach J. K., Korir P. K. and Dyck E. (1996) Developing low-cost sustainable options for improved soil management: Methodological approaches to on-farm soil productivity research in KARI-Kisii and Kitale research mandate regions. Paper presented in the 15th Conference of the Soil Science Society of East Africa 19th–23rd August 1996, Nanyuki, Kenya. Soil Science Society of East Africa, Kampala, Uganda.

Pedgley D. E. (1985) Windborne migration of *Heliothis armigera* Hübner (Lepidoptera: Noctuidae) to the British Isles. *Entomologists' Gazette* 36, 15–20.

van den Berg H., Nyambo B. T. and Waage J. K. (1990) Parasitism of *Helicoverpa armigera* (Lepidoptera: Noctuidae) in Tanzania: Analysis of parasitoid–crop associations. *Environmental Entomology* 19, 1141–1145.

van den Berg H. (1993) Natural control of *Helicoverpa armigera* in smallholder crops in East Africa. PhD thesis. Wageningen Agricultural University, the Netherlands. 233 pp.

Appendix I

Potential Demand and Adoption of *Trichogramma* in Biocontrol of *Helicoverpa armigera* in Southwestern Kenya

(i) Important target crops include: (a) cotton, (b) tomato, (c) sunflower, (d) capsicum, (e) pigeon pea, (f) sorghum and (g) chickpea.

(ii) Estimated area and important districts where African bollworm target crops are commonly grown:

Target crop	District	Estimated area (ha)
Cotton	Nyando, Homa Bay, Migori, Suba, Kuria and Rachuonyo	15,861
Tomato	Homa Bay, Kisii, Nyamira, Kericho, Bureti	8786
Sunflower	Rachuonyo, Homa Bay, Suba	1380
Capsicum	Kisii, Rachuonyo, Bomet, Bureti, Homa Bay	890
Pigeon pea	Rachuonyo, Homa Bay, Suba	3124
Chickpea	Rachuonyo, Homa Bay, Suba	2159

Source: KARI – Five-Year Strategic Medium Term Plan, 2002.

(iii) Estimated maximum annual demand of parasitoid wasps per crop for southwestern Kenya:

Crop	Area (ha)	Number of releases (on crop per season)	Potential demand per crop season (millions)*
Cotton	15,861	6	9517
Tomato	8786	5	4393
Pigeon pea	3124	4	1250
Chickpea	2159	4	1079
Sunflower	1380	6	828
Capsicum	890	4	356
Total			**17,423**

* Potential demand per crop season (millions) is on the basis of 100,000 wasps/ha/release.

(iv) Projected demand of *Trichogramma* per month per crop (millions):

	Month				
Crop	May	June	July	August	September
Cotton	–	–	3172	3172	3172
Tomato	1464	1464	1464	–	–
Sunflower	-	276	276	276	–
Capsicum	119	119	–	–	–
Pigeon pea	4165	4165	4165	–	–
Chickpea	360	360	360	–	–
Total	**6108**	**6384**	**9437**	**3448**	**3172**

(v) Factors that may influence adoption are:
  (a) Lack of awareness of the mechanism of biological control by farmers makes them wary/cautious of any introduced organisms.
  (b) Availability and cost of *Trichogramma* to farmers will be important factors. Where the crop is presently not highly paying, e.g. cereal and/or cotton, farmers might find it difficult to invest in expensive inputs. However, with follow-up training workshops with emphasis on the inherent benefits of biological control, it is expected that farmer perceptions will change.
  (c) Ease of use might be a factor among some illiterate farmers, however, it is expected that with follow-up training workshops, this obstacle will be overcome.
  (d) Availability of *Trichogramma* is influenced by the profit margins of the suppliers and in turn by the demand made by the farmers.

(vi) Expected adoption rate of farmers over a 10-year period are:

  (a) Awareness, availability and establishment of *Trichogramma* across the ecological zones and effectiveness of the releases in suppressing bollworm incidences will influence the level of adoption.
  (b) After the first 3 years, 30% of farmers will adopt *Trichogramma* use across southwestern Kenya, 60% after 6 years, 85% after 9 years and 90% after 10 years.

(vii) Potential investors in mass production would be ranked as follows:

Cooperatives/Unions	1
NGOs	2
FPEAK/HCDA	3
Private enterprises	4

(viii) Evaluation of scope of local delivery systems for *Trichogramma:*

Agro-input retailers	1
Farmers' cooperatives	2
Private enterprise	3
CBOs	4
NGOs	5

Research Status and Future Needs for Sustainable Management of the African Bollworm in Kilifi Region, Coastal Kenya

T. M. Pole and A. I. Kimani
Kilifi Institute of Agriculture, P.O. Box 195, Kilifi, Kenya

Abstract

In coastal Kenya, *Helicoverpa armigera* is of high economic importance, as it attacks many vegetable crops like tomato, brinjals, okra and capsicum besides cowpea, pigeon pea, cotton and sunflower. The current dependence on chemical pesticides is not sustainable, as it is uneconomical and is not catering to consumer concerns as well as ecosystem safety.

There is need for evolving more sustainable methods, especially biocontrol, botanical and cultural practices. The need for training of trainers and farmers' groups for popularising these practices is also indicated.

Key words: *Trichogramma* sp., *Helicoverpa armigera*, biocontrol, extracts, Trichogrammatidae, Kilifi, coastal Kenya

Importance of the African Bollworm on Target Crops

The African bollworm (*Helicoverpa amigera*) is a polyphagous insect pest and is of great economic importance in Kilifi District and Coast region as a whole due to: (i) low crop yields; (ii) low quality produce; (iii) a lot of money and energy spent to put in place chemical control measures and (iv) adverse environmental effects due to indiscriminate use of pesticides.

Helicoverpa armigera constitutes part of the pest complex on several target crops on which observations have been carried out at the Kilifi Institute of Agriculture. Losses on these crops are attributed to cost of protection and yield loss. It therefore has been difficult to apportion the losses by *H. armigera* even when the total loss may be known. Substantial losses at the Institute farm have been observed on vegetable crops including tomato, brinjals, okra and capsicum. *Helicoverpa armigera* was, however, noted to be a major pest of tomatoes where losses of between 30–56% were recorded (Table 23).

Table 23. Extent of importance of the African bollworm on target crops in Kilifi District, coastal Kenya

Target crop	Extent of importance*	Extent of yield loss (%)
Tomato	1	30–56
Brinjals	3	10
Garden peas	2	15
Capsicum	2	30
French bean	2	Not certain
Sunflower	3	10
Cowpea	2	20
Okra	2	40
Cotton	1	30–40
Maize	3	10
Pigeon pea	1	50

*1, High; 2, moderate; 3, low.

The African Bollworm Biology and Ecology

The African bollworm undergoes a complete metamorphosis. The larvae are the damaging life stage (Hill, 1983). After hatching, the larva crawls on the surface of the leaf and goes towards the flower or fruit where it starts feeding.

Eventually it enters the fruit where it feeds and develops before pupating in the soil (Hill, 1983).

African bollworm studies at Kilifi Institute of Agriculture experimental farm have not focused on ABW generations due to adoption of the 'closed' season during which pests are expected to shift to uncultivated plants for the continuation of their life cycle. The African bollworm has, however, generally shown a preference for hosts ranging from cultivated vegetables that are mostly annuals to wild plants. Among the cultivated plants preferred were tomatoes > brinjals > sunflower > okra. Observations have been limited to the above crops due to the current interest in them.

Current Control Strategies for African Bollworm Management

The current management of the African bollworm at the Kilifi Institute of Agriculture farm is based mainly on cultural practices combined with the use of chemical pesticides (Table 24). Cultural practices in use include early planting, destruction of residues and use of trap crops. Uncultivated marginal areas have also been used for survival and buildup of predators and parasites especially during the closed seasons. The efficacies of chemical pesticides (including Bulldock®, Brigade® and Karate®) on the natural enemy population and the degree of control of pests have not been adequately evaluated at Kilifi Institute of Agriculture.

Common Practices Adopted by Farmers

The most common practices of farmers around Kilifi Institute of Agriculture involve the use of neem extracts from leaves and seeds and also extracts of hot pepper sprayed onto the vegetables. Cultural methods have not been practised successfully due to lack of knowhow. Chemicals have also not been widely used because of their prohibitive prices and lack of skills and equipment (Table 24).

Table 24. Known/recommended control methods for African bollworm management at the Kilifi Institute of Agriculture farm and extent of farmers' adoption

Target crop	Type of control	Recommended practice/ product	Extent of farmers' adoption*	Remarks
Tomato	Chemical	Bulldock Karate Brigade	2	Lack of skills, equipment and the high cost.
	Cultural	Closed season, field sanitation and uncultivated marginal areas	3	Land pressure limits closed season.
	Biological	Spiders, wasps and birds	3	Knowledge not widely shared or practised.
Brinjals	Chemical	Brigade Karate	3	Knowledge not widely shared or practised.
Cotton	Chemical	Bulldock	3	–
	Cultural	Field sanitation and crop rotation	3	–
Capsicum	Chemical	Karate Marshall	3 3	– –
	Cultural	Closed season and crop rotation	2	–

*1, Very common; 2, common; 3, less common.

Knowledge on Natural Enemies and Potential for Biocontrol

The current knowledge is limited to listing the known parasitoids and predators in target crops of the African bollworm (Greathead and Girling, 1989; Cock *et al.*, 1991) (Table 25).

Table 25. Known natural enemies of the African bollworm in coastal Kenya

Group	Natural enemy	Crop
Parasitoids	Chalcid wasp (*Trichogramma minutum*)	Tomato, capsicum
Predators	Black widow spider (*Latrodectus mactans*, robber fly (*Efferia interrupta*), birds, e.g. thrush (*Turdus viscivorous* and *Gallus domestica*)	Tomato, brinjals and capsicum

Future Potential for Different Types of Biological Control Agents and Methods for *Helicoverpa armigera* Management

While research on conservation or augmentation biocontrol has not been undertaken so far on ABW in Kilifi, the potential for them appears promising (Table 26).

Table 26. Future scope for improved use of natural enemies for biocontrol of the African bollworm in Kilifi District, coastal Kenya

Biological agent/method	Score for future potential[1]	Score for need for further research[2]
Biocontrol agent		
Egg parasitoids	2	1
Larval parasitoids	1	2
Pupal parasitoids	3	4
Predators	2	1
Pathogens	2	1
Biocontrol method		
Introduction (of exotic species/strains)	2	1
Augmentation (repeated mass production and releases)	2	1
Conservation (encouragement of *in situ* practices)	1	2

[1]1, Good; 2, moderate; 3, limited.
[2]1, Very high; 2, high; 3, moderate; 4, limited.

Future Need for Improved African Bollworm Management in Kilifi District

Priority Research Areas/Themes

1. Research on the effect of improved farming/cropping systems on natural enemies and pest status.
2. An assessment of the use of chemical controls on the pest status and natural enemies among regions and crops.
3. Augmentation and conservation of key natural enemies among regions and crops for use in *H. armigera* management.
4. Combine biocontrol with botanicals and cultural practices.

Training Needs

Researchers and trainers in the management of the African bollworm require training on mass rearing techniques of natural enemies, use of genetic markers in population studies and integrated pest management techniques. The gap between research findings and farmers' knowledge is too wide, particularly along the coast. This is due to the existing organisation of the extension services and the adapted approach. The farmers, who are the ultimate users of the research findings, have not been adequately reached because they are in the remote rural areas. They have not changed their attitude and behaviour and are generally unaware of these issues. There is an urgent need for training these farmers using the Farmers' Field Schools (FFS) approach for involvement of these farmers in research through a participatory approach.

Scope for Linkages

Research/extension and training activities need to be expanded to involve a multi-stakeholder network. These activities should seek the involvement of local, regional and international research institutions such as Kenya Agricultural Research Institute, International Centre of Insect Physiology and Ecology (ICIPE), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Centro International de Agricultura Tropical (CIAT), World Agroforestry Centre (ICRAF) and International Institute of Tropical Agriculture (IITA). Other stakeholders include the agricultural extension services, training institutes, outreach farmers and development authorities such as the Horticultural Crops Development Authority.

Suggested Themes for ICIPE Collaboration

1. Identification of predators, pathogens and parasites.
2. Possibilities of multiplication and dissemination of natural enemies for the control of the African bollworm.
3. A study of the possibility of using traps.
4. Improvement of *H. armigera* management through multi-stakeholder research activities across regions and crops.
5. Strengthening linkages between research and extension for management of *H. armigera*.
6. Farmers' training on simplified problem-solving research skills.

References

Cock M. J. W., van den Berg H., Oduor G. I. and Onsongo E. K. (1991) The population ecology of *Helicoverpa armigera* in smallholder crops in Kenya with emphasis on its natural enemies. Final Report, Phase II: April 1988–March 1991. International Institute of Biological Control, Ascot, UK. 179 pp.

Greathead D. J. and Girling D. J. (1989) Distribution and economic importance of *Heliothis* and their natural enemies and host plants in southern and eastern Africa, pp. 329–345. In *Proceedings of the Workshop on Biological Control of* Heliothis*: Increasing the Effectiveness of Natural Enemies* 11–15 November 1985, New Delhi, India (Edited by E. G. King and R. D. Jackson). Far Eastern Regional Research Office of International Cooperation and Development, US Department of Agriculture, New Delhi, India.

Hill D. S. (1983) *Agricultural Insect Pests of the Tropics and Their Control*. 2nd Edition. Cambridge University Press, London, UK. 746 pp.

Research Status and Future Needs for Sustainable Management of the African Bollworm in Kwale District of Coastal Kenya

V. M. Kega

Kenya Agricultural Research Institute-Matuga,
P. O. Box 4, Matuga, Kenya

Abstract

The African bollworm *Helicoverpa armigera* (Hb.) is a fruit borer on tomato, brinjals, okra, capsicum and eggplant, besides being a pod borer on cowpeas and green grams in coastal Kenya. Farmers use a variety of methods to control this pest. These include cultural and ecological control methods. There is little published information on these methods. Natural enemies also control the pest but very little work has been done on their potential and utility in the region. Most of the farmers use some kind of spray solution in water, which may be from plant derivatives (especially from neem) or commercial pesticides.

Trichogrammatid egg parasitoids constitute an important group of natural enemies of the African bollworm. There has been preliminary collection of native trichogrammatid species in the region and these are to be evaluated and integrated with other suitable methods so as to come up with an integrated pest control strategy for this pest.

Key words: *Trichogramma* sp., neem, cotton, vegetables, insecticides, Kwale, coastal Kenya

Introduction

Vegetable production is emerging as an important income-generating activity of the smallholder farmer in coastal Kenya mainly as a result of the attractive prices being offered in the two main towns of Mombasa and Malindi and other urban centres in the region.

Local production does not meet the demand and the shortfall is met by imports from central Kenya and Tanzania especially from areas around Tanga, Moshi and Tarekia. Vegetable growing in Kwale is mainly carried out at Shimba hills and the main crops grown in order of importance are tomato, capsicum, eggplant, kale, brinjal, okra and amaranthus. There is little irrigation and most of this cultivation is rain fed.

The most important lepidopteran pest in the region is the African bollworm *Helicoverpa armigera* (Hübner). It attacks a wide range of crops and is particularly important in limiting production in tomato, brinjals, capsicum and tungunja (Anon, 2000). In addition to vegetables, it also attacks other crops like cotton, sorghum, sesame, sunflower, maize and cowpea.

The pest has wild hosts in the families Euphorbiaceae, Amaranthaceae, Malvaceae, Solanaceae, Compositae, Portulacaceae and Convolvulaceae. In some countries, for example in the United Kingdom, it is listed among the quarantine pests.

The Biology of the African Bollworm

The ABW moths become sexually mature and mate about four days after emergence having fed from nectar in plants. This may continue for a further 10 days. The moth is only active at night and lays its eggs singly on the plant. The preferred sites are the underside of leaves or the reproductive parts of the plant, besides the softer vegetative parts.

The incubation period varies from 2–8 days depending on temperature. On hatching, the larva eats some or its entire eggshell, before feeding on the plant. It will bore through the fruit or buds. Scouting for larvae is important to enable correct timing of spray applications. The larvae pass through six instars and the larval period may vary from 15–35 days.

Pupation normally occurs in the soil at a depth of 2.5–17.5 cm, but on maize, pupation may occur in the cob top. The pupa is enclosed within a layer of silk. Both diapause and non-diapause pupae are produced, the latter towards the end of the season. The pupal period of the non-diapause pupae varies between 15–52 days while that of the diapause pupae is highly variable (Anon, 1998).

Major infestations of ABW correspond to the flowering and fruiting periods of the crop and during these seasons there may be a succession of infestations on various crops as they come into the flowering phase/stage.

Importance of the African Bollworm in Coast Province

Table 27. The importance of the African bollworm on target crops in Coast Province, Kenya

Crop	District (s)
Cotton	Lamu, Tana River, Malindi
Tomato	Taita, Mombasa, Kwale, Lamu
Okra	Mombasa, Kwale
Brinjal (egg plant)	Kilifi, Malindi
Tungunja (wild egg plant)	Kwale

Table 28. Importance of the African bollworm on important target crops in Kwale District, Kenya

Target Crop	Extent of importance[1]	Extent of yield loss (%)[2]
Cotton	1	80 (if not sprayed)
Tomato	1	80
Okra	2	40
Brinjal (egg plant)	2	60

[1]1, Very important; 2, important; 3, just important.
[2]Estimate.

In Coast Province, the pest attacks most of the crops grown, but is more important on cotton and vegetables (Table 27). There are slight attacks on maize but the main pests of maize are the cereal stemborers.

The African bollworm is a very important pest in Shimba hills and other vegetable growing areas of Kwale. There are reports of up to 80% loss in tomato fields especially when the attacks exacerbate blossom end rot infection (Table 28).

Control Methods for African Bollworm on Target Crops

Ecological Control

Ecological control entails bringing about a radical change in the environment of the crop and pest so as to favour the survival of the crop. Farmers in Tana River and Taveta practice this when flooding their cotton or tomato fields before planting.

Resistance Breeding

Pest problems can be overcome by breeding for a variety of a crop that is resistant to pest attack. At present this has not happened for the African bollworm and the main reason may be due to the polyphagous nature of the pest.

Cultural Measures

This demands modification of the system of culture, e.g. early planting, deep ploughing or short intervals between the sowing dates of successive crops to avoid ABW build up (Table 29). Farmers in Shimba Hills and the coastal belt of Kwale also burn their fields as a form of land preparation and this kills any diapausing larvae of the African bollworm.

In Shimba Hills, high ABW infestations have been reported, where brinjals or tungunja have been left too long in the field. This shows that there is need for a closed season. The planting of less desirable crops like chillies (hot pepper) has been reported to bring down infestation levels of the African bollworm.

Use of diversionary (trap) crops, for example soybean, has been suggested but its efficacy is not proven.

Chemical Control

Most farmers in the region use synthetic chemicals when the pest infestations are high. Because of the high temperatures and relative humidity in the area, pest build up is very high and thus, there is reliance on use of pesticides by the commercial vegetable growers. They use commercial products or mixtures of plant extracts. These include neem, *Lantana*, chillies and *Tephrosia* (Table 30).

Biological Control

This entails the use of natural enemies to control the pests on the crops. Use of pathogens like viruses (nuclear polyhedrosis virus) and antagonistic fungi like *Metarhizium anisopliae* have been tried with limited success most probably because the pest is an internal feeder (borer) (Table 31).

Egg parasitoids of the genus *Trichogramma* are the best biological control alternatives as they parasitise and kill the pest at the egg stage before the crop is damaged (Table 32).

Table 29. Known/recommended control practices for the African bollworm on target crops and extent of farmer adoption in Kwale District, Kenya

Target crop	Type of control	Practice being recommended	Extent of farmer adoption*	Remarks
Cotton	Ecological	Flooding	1	–
	Cultural	Burning of crop debris	2	
Vegetables	Cultural	Burning of crop debris	1	–
		Relay crop with pepper	3	
		Deep ploughing	2	

*1, Very important; 2, important; 3, just important.

Table 30. Known/recommended control products for the African bollworm on target crops and extent of farmer adoption in Kwale District, Kenya

Target crop	Product being recommended	Extent of farmer adoption*	Remarks (if any)
Cotton	Polytrin	1	–
	Neem/pepper/ *Vernonia*/*Tephrosia*	2	
Vegetables	Decis, Karate	2	–
	Chillies, neem	1	

1, Very important; 2, important; 3, just important

Table 31. Natural enemies of the African bollworm known to occur in Kwale district, coastal Kenya

Group	Common name	Scientific name	Crops where commonly found
Parasite	Trichogrammatid egg parasitoid	*Trichogramma* sp.	Tomato, okra, brinjal, egg plant, capsicum
Predator	Birds, praying mantis	–	–
Pathogen	Baculoviruses, antagonistic fungi	Nuclear polyhedrosis virus, *Metarhizium anisopliae*	–

Table 32. Future scope for biocontrol agents/methods of the African bollworm in cotton and vegetables in coastal Kenya

Biocontrol agent/ method	Score for Future potential*	Score for need for further research*
Biocontrol agent		
Egg parasitoids	1	1
Larval parasitoids	1	1
Pupal parasitoids	1	1
Predators	2	1
Pathogens	1	1
Biocontrol method		
Introductions (bring in exotic species/strains)	1	1
Augmentation (mass produce and release repeatedly)	1	1
Conservation (encourage *in situ* practices)	2	2

*1, Good; 2, moderate, 3, low/limited; 4, not certain.

Discussion

Control of the African bollworm in the region is by use of chemicals especially in the districts of Mombasa, Kilifi and Kwale. Use of botanicals is prevalent in Lamu. Most farmers in the region use cultural control methods against the pest. There is little reported work on the use of biocontrol agents. In general there has been very little attention directed to this pest thus there is need to inventorise practices being used by the farmers in the control of ABW, screening for efficacy of the botanicals and development of active ingredients and dose rates of these products.

The survey and identification of the biocontrol agents, formulation of the candidate biopesticides and finally the development of an integrated pest management strategy against the pest need to be enhanced.

References

Anonymous (1998) Minutes of the Regional Research and Advisory Committee Meeting of 18th November 1998. Regional Research Centre, Mtwapa, Kenya.

Anonymous (2000) *Local and Export Vegetables Growing Manual.* Agriculture Inputs Cooperation (AIC)/Japanese International Cooperation Agency (JICA).

African Bollworm: Pest Status, Present Knowledge and Options for Control in the Cotton Growing Regions in Kenya

B. M. Ngari
Kenya Agricultural Research Institute,
National Fibre Research Centre, Mwea Tebere,
P. O. Box 298, Kerugoya

Abstract

Many arthropod pests attack cotton, with infestation starting at germination. The African bollworm is a very serious pest of cotton in all parts of Kenya and heavy attack occurs during the flowering period. It causes yield losses of 40–70%. There are two generations of bollworm in the cotton growing regions of Kenya. A single larva can destroy 14 or more squares of the cotton plant during the entire larval period. The population of *Helicoverpa armigera* varies with the seasons and sites. Several predators and parasites attack the African bollworm. The control practices are chemical, host plant resistance, cultural and sanitary methods. Integrated pest management (IPM) remains the most promising approach to cotton insect pest control in general and to this pest in particular.

Key words: *Helicoverpa armigera*, *Gossypium hirsutum*, cotton, biocontrol, insecticides, IPM, Kenya

The Importance of the African Bollworm on Cotton

Cotton is a fibre crop grown as a strategic cash crop in low rainfall areas and in much of the arid and semi-arid lands (ASAL), which cover about 87% of the landmass in Kenya and are inhabited by about 27% of the population (Table 33). This is because the crop tolerates drought than most annual crops. It is therefore a poverty eradication crop, with great potential in the creation of employment at the household level, and the local spinning and textile industries (Mugo and Masake, 2002). The seed is an important source of oil for humans and food for livestock (Luttrel *et al.*, 1994). The crop has a great potential for export, and thereby helps earn foreign exchange.

Table 33. Extent of importance of the African bollworm in cotton in Kenya

Target crop	Extent of importance	Extent of yield losses
Cotton	Very important	40–70%

Kenya has a potential of 350,000 hectares suitable for rain-fed cotton production with a farm labour value of Kshs 2.3 billion per year. It has an irrigation potential of 34,000 hectares, which has farm labour value of Kshs 0.5 billion. The potential lint production from rainfed cotton is 260,000 bales and irrigated cotton 108,000 bales. The local demand for lint is estimated at 120,000 bales while the current production is only 50,000 bales per annum (36%) (Opondo, 2001; Mugo and Masake, 2002).

The traditional cotton (*Gossypium hirsutum* L.) growing areas in Kenya are the coastal strip, the shores of Lake Victoria, and the lower altitude areas of Central and Eastern provinces especially Kirinyaga, Mbeere, Meru, Machakos, Mwingi and Kitui districts (Table 34). These areas lie between 0–1400 masl (Acland,

Table 34. Extent of importance of the African bollworm in cotton in six regions/provinces in Kenya

Crop	Region/ Province	Districts where African bollworm is important
Cotton	Central	Kirinyaga
	Eastern	Mbeere, Meru Central, Meru South, Meru North, Machakos, Kitui, Makueni, Mwingi
	Nyanza	Busia, Nyando, Bondo, Rachuonyo, Migori, Siaya, Kisumu, Homa Bay
	Coast	Malindi, Kilifi, Kwale, Tana River, Lamu, Taita/Taveta
	Western	Bungoma, Busia and Teso
	Rift Valley	Baringo, Marakwet, Keiyo and Pokot

1971). The crop is sown in October in Central and Eastern provinces. The cotton crop experiences two months of drought in January and February. The cotton variety HART 89M compensates for early yield loss caused by either moisture stress or by insect attack by putting extra growth at the top of the plant, when there is adequate soil moisture (Acland, 1971; Munro, 1987).

Small-scale farmers on holdings of less than 1 hectare mainly grow cotton; and there are over 140,000 farmers in Kenya growing cotton on about 40,000 hectares, with 20,000 bales of lint produced. Production rose to a peak of 70,000 bales in 1984/1985. Poor loan repayments and liberalisation of the sub sector by 1994/1995 led to a production drop to 20,000 bales, where it has remained until 2000 (Opondo, 2001; Mugo and Masake, 2002). Lack of capital and credit facilities has forced the farmers not to follow the recommended agronomic practices (Waturu *et al.*, 2002). Poor weather conditions have led to low yields of between 300–500 kg of seed cotton per hectare as opposed to the world average of 589 kg/ha (Opondo, 2001).

Cotton used to be grown under irrigation in Hola and Bura irrigation schemes in Tana River district in the 1970s and 1980s. The lint production derived from the scheme rose steadily by 12% in 1980/1981 to a record maximum in 1987/1988. However, these schemes collapsed in the late 1980s due to a change of the river course.

The recorded yields in Kenya of up to 4345 kg/ha and 900 kg/ha have been recorded in research stations and farmers fields respectively (Ikitoo *et al.*, 1988). These wide yield differences are probably due to poor agronomic practices, low soil fertility, rainfall patterns, diseases and arthropod pests (Munro, 1987; Ikitoo *et al.*, 1988). A cotton field is a dynamic community with a physical environment, a crop phenology and unrestricted animal population that is much influenced by the presence of infield weeds and even by an array of surrounding crops and native populations. The pests and natural enemies are influenced by the sequence of weather and their interactions.

Cotton is attacked by a myriad of arthropod pests with infestation starting at germination. Some of the early season pests include aphids (*Aphis gossypii*), cotton red spider mites (*Tetranychus telaerous*), thrips *Frankinella* sp., leaf miners (*Liriomyza* sp.), and whiteflies (*Bemisia tabaci*). The cotton aphid occurs on young plants in dry weather spells and disappears rapidly with the onset of rains. The red spider mite is the second most important seedling pest, often being severe during the dry spells and clearing on the onset of rains. Thrips are an important sucking pest during seedling emergence through early squaring. Severe thrips infestation may damage the growing parts of seedlings. Whiteflies attack cotton during the dry season and disappear rapidly on onset of rains (Munro, 1987). The African bollworm (*Helicoverpa armigera*) is a very serious pest of cotton in all parts of Kenya and heavy attack occurs during the flowering period (Muthamia, 1971). A single larva on a plant can destroy all bolls in 15 days (CAB, 2000). The ABW causes yield losses of 40–70% depending on infestation (Waturu and Njoka, 1988). The cost of *H. armigera* control is equivalent to 29% of the total income per hectare.

Pest Biology and Ecology

Helicoverpa armigera moths are attracted to cotton fields when flowering begins. They lay their eggs and develop into small larvae, which are attracted to squares, flowers and very young bolls. Occasionally, the larvae eat leaves, but only when no other food is available. Early damage to squares and bolls causes shedding of these plant parts. As the larvae grow older, they are attracted to mature bolls destroying them completely. Their characteristic feeding position is with the front half of the body inside the bolls with the other half protruding outside. There is usually an accumulation of frass nearby, normally in the epicalyx. The larvae of the African bollworm pupate in the soil (Acland, 1971). The African bollworm eggs take 2–4 days to hatch to first instars. There are six instars. A single larva can destroy 14 or more squares of the cotton plant during the entire larval period. Moulting normally takes place on the upper side of cotton leaves during the daylight hours. The total larval period takes 14–24 days. When the larva is fully mature, it burrows into the soil where it pupates. The pupal period lasts 10–14 days depending on the temperature. The adult moth starts to lay eggs four days after emergence and continues to lay eggs for 10 days. A single female moth can lay a total of 1000 eggs (Muthamia, 1971).

There are two generations of bollworms in the cotton growing regions of Kenya, which take 35 to 58 days. In general, application of pesticide sprays only reduces the second-generation population (Pearson, 1958; La Croix, 1964). Oduor and co-workers (1991) described the population of *H. armigera* at two sites in Central and Eastern Provinces. During the short rains, populations of *H. armigera* remained substantial throughout the season at Mwea Tebere. Most of the eggs and young larvae occurred during the late vegetative early squaring stages. The population of older larvae increased marginally after this period. *Pheidole* sp. was the most common predator at the vegetative stage but its population dropped as that of *Orius* spp. increased later in the season. *Helicoverpa armigera* occurred in relatively lower numbers during the long rains. Eggs and larvae were only occasionally observed after the squaring stages. *Pheidole* sp. ants were common especially at the flowering stage. No pathogens were found and parasitism was extremely rare. Only two cases of parasitism by *Trichogammatoidea* sp. and two larval *Charops* sp. parasitoids were recorded over the two rainy seasons.

At Makueni, similar observations were recorded during the short rains. The older larvae were initially scarce and started to increase in number at the onset of boll formation. Only coleopteran predators were recorded during the vegetative phase of cotton. After this phase, the population of coleopteran predators, together with that of *Orius* sp. increased appreciably during the short rains. During the long rains, the pest occurred in very low numbers with an egg count peak of 0.6 eggs/plant. No young larvae were recorded and at squaring phase they were very few *Orius* sp. The population increased steadily up to the bolling stage. *Pheidole* sp. ants were also present but decreased as the bolling stage began. Incidence of parasitism was estimated from laboratory-reared field-collected eggs and larvae. There was very low parasitism by *Trichogrammatoidea* sp. and *Apanteles* sp. No diseased larvae were recovered.

Helicoverpa armigera can breed on a wide range of plant species, including many cultivated crops like maize, sorghum, tobacco, groundnuts, cowpea, *Dolichus* beans, pigeon pea and chickpea. These hosts are more attractive to the bollworm than cotton itself. These alternative host plants allow the bollworm to maintain or increase in numbers prior to attacking cotton or may divert the attack from cotton, depending on the relative acreage, timing and attraction to cotton and the host plants (Munro, 1987).

Current On-going Research on Management of the African Bollworm at Mwea Tebere

1. The use of entomopathogenic nematodes (EPNs) in control of the African bollworm.
2. On-farm trials on rational use of pesticides.
3. The efficacy of new and old pesticides in regulation of the African bollworm.
4. The efficacy of *Bt* cotton in the management of the African bollworm.
5. Characterisation and quantification of arthropods in cotton ecosystems in Kenya.

Current Control Strategies for African Bollworm on Cotton IPM Programmes

Helicoverpa armigera is a pest of major importance. Its major pest status is rooted in its mobility, high reproductive rate and diapause. The high level of control under these circumstances and absence of adequate natural control means that chemical or at best integrated control methods usually need to be adopted. In view of the need to make use of and exploit the existing spectra of natural enemies to reduce excessive dependence on chemical control, particularly where there is resistance to insecticides, various IPM programmes have been developed in which different control tactics are combined to suppress pest numbers below threshold levels. These vary from judicious use of insecticides, based on economic thresholds, and regular scouting to ascertain pest levels (Table 35). The major constraint to development of IPM for *H. armigera*, particularly in cotton, has been the need to deal with a complex of pests. Also the characteristics of the cotton plant (hairiness) can be unfavourable to *H. armigera* or to jassid pests. The withholding of early season application of synthetic pesticides to encourage build-up of natural enemies against the sucking pests is recommended. The need to control sucking pests that can be severe on young plants also kills the natural enemies. The major control practices include chemical, host plant resistance, cultural and sanitary methods.

Regulatory Control

Cultural practices such as enforced 'closed' season may be regarded as regulatory, but to be effective, these will depend on strict compliance, geographical isolation and the absence of significant alternative hosts in the area.

Regulation on the use of insecticides against which *H. armigera* has severe incipient resistance, and of 'hard' insecticides that are particularly damaging to natural enemies is recommended. This is not practised, but Kenya Pest Control Products Board (KPCPB) has released a list of chemical pesticides that can be

Table 35. Known/recommended methods for African bollworm control in the cotton growing regions in Kenya

Crop	Type of chemical/ cultural/biological control method	Percentage of farmers adopting	Remarks
Cotton	Chemical (cypermethrin)	100	Lower dose used due to high prices.
	Cultural	80	Early land preparation and burning of previous season crop are the preferred methods.
	Biological	–	Not introduced to farmers.

used to control cotton pests (Waturu *et al.*, 2002). Currently the collaboration between Kenya Agricultural Research Institute (KARI) and the Cotton Ginners' Association may help improve pesticide resistance management.

Cultural Control and Sanitary Methods

Cultural manipulations of crop or cropping systems and land management have been tried as tactics to manage *H. armigera* populations. In the case of cotton, the farmers are told to cut and burn the previous season's crop to destroy the bollworms and to minimise pest carry-over. The land is also ploughed immediately after removing the previous crop and is left fallow for at least one month. Ploughing-in of cotton stubble and burning is important in destroying the bollworm pupae (Acland, 1971). Most small-scale farmers in the cotton growing zones follow these cultural practices: burning the cotton stubble after harvest, ploughing the land early, and dry planting at the recommended spacing (Waturu *et al.*, 2002).

Host Plant Resistance

The planting of crop varieties that are resistant or tolerant to *H. armigera* has received major attention particularly for cotton, pigeon peas and chickpea. Few eggs are laid on cotton plants having glabrous leaves. However, both larval survival and susceptibility to jassid attack are higher (CAB, 2000). In recent years, genetic engineering has enabled genes carrying the toxic protein of *Bacillus thuringiensis* to be introduced in cotton. Transgenic cotton gives better control of bollworms and offers considerable promise for use in IPM. As with the use of all resistant crop varieties, care is needed to avoid excessive selection pressure against the resistant factor, and in such a system, a mixture of both resistant and susceptible varieties is often recommended to lessen this risk (CAB, 2000). If the transgenic cotton works well, there will be a tendency to grow Bt cotton. But if the resistance breaks for whatever reason, then all our cotton will be wiped out. This is possible because selective pressure inserted on pests can spark some pest evolution to overcome this through resistance.

Chemical Control

The main management measure used to control the African bollworm is by the application of synthetic chemical insecticides at 8–9 weeks after plant emergence at an interval of 14 days. Two sprays are applied during the bottom crop (before tasselling) and another two during the top crop (after tasselling and silking) giving a total of four sprays in a season. A number of synthetic insecticides have been tested and found effective against these pests and are currently in use (Waturu *et al.*, 2002).

Chemical insecticides are currently essential for the control of *H. armigera* on cotton and are likely to remain an important component of the control strategies. However, reliance on biological pesticides and use of more specific, less disruptive compounds will increase with time (Fitt, 1994). Integrated pest management (IPM) remains the most promising approach to cotton insect pest control, although insecticides are still the primary control method used in worldwide production systems (Fitt, 1994).

The major pesticides used to control bollworms are mainly synthetic pyrethroids (e.g. cypermethrin, alpha and betacypermethrin). Biological pesticides have been evaluated and found effective, especially *Bacillus thuringiensis* and are being incorporated in improved pest control regimes (Ngari *et al.*, 2001). These products are supplied to the farmers by the ginneries on credit. The collaboration between the researchers and the ginneries owners will assist in management of insecticide resistance on cotton.

Knowledge on Natural Enemies and Potential for Biological Control

In Kenya, the following natural enemies of the African bollworm have been recorded on cotton. The predators include the ants *Pheidole* sp., the anthocorid bug, *Orius* sp. and the coccinellids *Cheilomenes* spp., *Chilocorus* spp. and *Scymus* sp. The known parasitoids are *Trichogramma* sp. and *Apanteles* sp. (van den Berg *et al.*, 1988; Odour *et al.*, 1991). Several predators and parasitoids have been observed in cotton growing regions in Eastern, Central and coastal provinces on cotton (Table 36). Several predators of the families Anthocoridae, Lygaeidae, Nabidae, Reduviidae, Chrysopidae, Hemerobidae, Staphylinidae, Syrphidae, Sphecidae, Vespidae and Formicidae have been collected in the cotton ecosystem using water, sticky and pit fall traps. Some parasitoids of the families Tachinidae, Ichneumonidae and Braconidae were collected (Ngari, 2001 unpublished).

Table 36. Natural enemies of the African bollworm known to occur in Kenya in cotton

Group	Common name	Scientific name	Province
Predators	Staphylinids Anthocorids Ants	*Paederus* sp. *Orius* sp. *Pheidole* sp.	Eastern and Central
Parasitoids	Braconids	*Charops* sp., *Apanteles* sp.	Eastern and Central
	Trichogrammatids	*Trichogramma* sp.	
Pathogens	Virus	Nuclear polyhedrosis virus	Eastern and Central

Potential of Different Types of Biological Control Agents

Entomophagous arthropods can be of great value in suppressing insect pest populations, especially of *H. armigera*, because of the importance of naturally occurring predators and parasites populations. The efficacy of these predators may be affected by (i) the density of predators and prey, (ii) the distribution of predators and prey, (iii) the area of habitat searched, (iv) the prey preference and available alternative foods plus (v) the influence of broad-spectrum insecticides, as well as other factors. Scope for augmentative biocontrol with trichogrammatid egg parasitoids has shown promise elsewhere and should receive research attention for optimisation and benefit validation. Introduction of exotic natural enemies may be considered where appropriate, as well. However, there are many potential problems involved in establishment of introduced natural enemies for an annual crop like cotton; although they may be effective suppressants. In the case of cotton, which is a host of many arthropods, the most immediate opportunity for substantial use of natural enemies is related to mass production and conservation of the native species of the dominant predators and parasitoids. This is justified based on the amount of money that goes in using insecticides. However, further work needs to be done on the role of natural enemies on cotton.

Future Needs for Improved Bollworm Management

Research Priority Areas/Themes

1. Biology and ecology of the African bollworm in cotton ecosystems.
2. Identification of natural enemies and their role in management of African bollworm (Table 37).

3. Integration of entomopathogenic nematodes in management of the African bollworm.
4. Use of transgenic cotton and search for resistance against bollworm.

Table 37. Future scope for improved use of natural enemies for biological control of the African bollworm in cotton in Kenya

Biological control agent/method	Score for future potential*	Need for further research*
Biological control agent		
Egg parasitoids	1	1
Larval parasitoids	2	1
Pupal parasitoids	3	3
Predators	1	1
Pathogens	1	2
Biological control method		
Introduction (bring exotic species/strains)	2	1
Augmentation (mass produce and release species)	1	1
Conservation (encourage *in situ* practices)	1	1

*1, Good; 2, moderate; 3, low/limited; 4, not certain.

Training Needs

1. Identification and the role of naturally occurring populations of predators and parasites of *Helicoverpa armigera* in cotton ecosystem.
2. Rearing and mass production techniques for predators (e.g. *Chrysopa*) and egg parasitoids (e.g. *Trichogramma*) for augmentative biocontrol of the African bollworm.
3. Training of farmers on the importance of natural enemies in management of the African bollworm
4. Training of front-line extension staff in the biological control of the African bollworm.
5. Training on host plant resistance against the African bollworm.

Scope for Research/Extension/Training Activities

1. Scouting for pests and natural enemies to determine the threshold levels and role of natural enemies of the African bollworm.
2. Assessing the effectiveness of the integrated pest management packages.
3. Determining the insecticide resistance against synthetic pyrethroids already in use against the African bollworm

Themes in KARI–ICIPE Collaboration

1. Assessing insect resistance to synthetic pyrethroids and pesticide residues.
2. Identification and rearing of natural enemies of the African bollworm to be used in introduction or augmentation biocontrol.

References

Acland J. D. (1971) *East African Crops: An Introduction to Production of Field and Plantation Crops in Kenya, Tanzania and Uganda*. Longman, London (for the Food and Agriculture Organistation of the United Nations). 252 pp.

CAB (2000) *Crop Protection Compendium*. Global module. 2nd module. CAB International, Wallington, UK. 609 pp.

Fitt G. P. (1994) Cotton pest management. Part 3. An Australian Perspective. *Annual Review of Entomology* 39, 543–562.

Ikitoo E. C., Onzere B. B. and Karani E. W. (1988) Fertilizer use and soil fertility studies. *KARI NERCO Annual Report*, pp. 23–25.

La Criox E. A. S. (1964) Insecticide dusts on cotton in Coast Province, Kenya. *The Empire Cotton Growing Review* 41, 137–143.

Luttrel R. A. G., Fitt G. P., Ramaldho F. S. and Sugonyaer E. G. (1994) Cotton pest management. Part 1. World perspective. *Annual Review of Entomology* 39, 517–526.

Muthamia J. (1971) *Cotton Pests and Their Control*. Entomology Section, Department of Agriculture, Ministry of Agriculure, Kenya. 32 pp.

Mugo F. and Masake D. (2002) (Eds) Christian Agricultural and Related Professionals' Association (CARPA). Proceedings of a Consultative Meeting on Marketing and Financing the Cotton Industry held at Ufungamano House 12 July 2002. 37 pp. Report by CARPA.

Munro J. H. (1987) *Cotton*. Tropical Agricultural Series. Longman Group (UK) Limited. 436 pp.

Ngari B. M., Waturu C. N., Onzere B. B., Kagito S. K., Nzeve D. N. and Njiju S. M. (2001) Rationalised use of pesticides in cotton. *KARI NFRC Mwea Annual Report*.

Oduor G. I., Cock M. J. W., Waturu C. and Songa J. M. (1991) The population ecology of the African bollworm *Helicoverpa armigera* and its natural enemies in smallholder crops at two sites in Eastern and Central provinces of Kenya, pp. 145–157. In *Recent Advances in KARI's Research Programmes*. Proceedings of the second KARI Annual Scientific Conference Held at Panafric Hotel Nairobi, Kenya on 5–7 September 1990.

Opondo R. M. (2001) KARI spearheads revitalisation of the cotton industry in Kenya. *KARI Highlighter* No. 6, pp. 1–3.

Pearson E. O. (1958) *The Insect Pests of Cotton in Tropical Africa*. Commonwealth Institute of Entomology, London. 355 pp.

van den Berg H., Waage J. K. and Cook M. J. W. (1988) *Natural Enemies of* Helicoverpa *in Africa—A Review*. CAB International, UK. 81 pp.

Waturu C. and Njoka S. W. (1988) Cotton entomology in Central and Eastern Kenya in 1987/88. *KARI NFRC Annual Report*, pp. 35–36.

Waturu C. N., Opondo R. M., Macharia J. M. K., Onzere B. B. and Wasike V. W. (2002) Recommendation for growing cotton in Kenya. KARI. 10 pages. Unpublished. Mimeograph.

Three middle rows were harvested and weights for damaged and healthy fruits recorded.

Results and Discussion

The results on the efficacy of Avaunt 150 SC at three rates in the control of the African bollworm in snowpeas are summarised in Table 38. These results indicate a significantly higher yield from plots treated with the standard insecticide Decis at 0.10 g per litre (3330.0 g per 9.0 m row). The yields from the three rates tested for Avaunt 150 SC namely 0.20, 0.25 and 0.30 ml in 1 litre of water were not significant at P = 0.05 but were significantly higher from the untreated control.

The mean yields from the four insecticidal treatments (3 rates of Avaunt 150 SC and the standard Decis) were, however, not significantly different from one another.

In Table 39, the results of the efficacy of Keshet 2.5 EC in the control of African bollworm, *H. armigera*, in tomatoes are summarised. The yield data indicated no significant difference between the four insecticidal treatments (three rates of Keshet and one rate of the standard Decis) and the control.

The mean damage transformed percentages again showed no significant difference between the four insecticidal treatments but all four differed significantly from the untreated control.

Table 39. Efficacy of Keshet 2.5% EC at three rates in the control of the African bollworm, *Helicoverpa armigera* in tomato

Treatment	Rate of application per litre of water	Transformed % damage/harvesting*						% Damage	Total weight/3 m row plot (g)
		1st	2nd	3rd	4th	5th	Mean		
Keshet 2.5% EC	1.5 ml	18.9 ab	13.3 ab	17.6 a	11.8 ab	8.96	14.1 b	5.9	1733.3 a
Keshet 2.5% EC	2.0 ml	7.3 b	8.2 ab	13.1 a	9.3 ab	12.8 ab	10.1 b	3.1	1733.3 a
Keshet 2.5% EC	2.5 ml	21.2 a	8.6 ab	14.5 a	3.4 b	4.9 b	10.5 b	3.3	1700.0 a
Decis (tablet) 25% w/w	0.10 g	19.4 ab	6.9 b	11.9 a	8.1 ab	4.7 b	10.2 b	3.2	1500.0 a
Control	–	14.5 ab	24.9 a	18.4 a	22.4 a	20.3 a	20.1 a	11.8	1530.0 a
F value P=0.05		2.2	2.0	0.7	2.5	5.0	5.0	–	0.7
LSD P=0.05		12.2	17.0	11.4	14.5	9.5	5.5	–	717.6
CV (%)		39.8	72.8	40.1	70.2	48.7	57.5	–	56.1

Means in the same column followed by the same letter are not significantly different by T-test (LSD) at P=0.05.
*Transformed % damage = angular transformation (arcsin $\sqrt{P}$%, where P = percentage tomato fruits damaged by the African bollworm, *Helicoverpa armigera*).

Conclusions

In this paper the status of African bollworm as a key pest on vegetable crops has been documented. Among chemical pesticides recently tested at this Centre for the control of *Helicoverpa armigera* in snowpea, Avaunt 150 SC was found to be effective, at any of the three rates tested, without any significant losses in yield. The control of *H. armigera* in tomatoes was effectively achieved by using any of three rates of Keshet tested.

The results indicated that the standard pesticide Decis is still effective in the control of *H. armigera* in tomatoes and compares favourably with the two higher rates of Keshet (2.0 and 2.5 ml per litre of water) in terms of percentage damage.

While the paper has mainly illustrated the results of recent on-station testing of two new pesticide products, it is important to point out that there is need and scope to develop non-pesticidal alternatives for ABW management. Although recent research has not been done on these options at our Centre, it is evident from experience elsewhere that botanicals (e.g., neem), microbials (e.g. NPV, *B.t.*) and macrobials (e.g. *Trichogramma*, *Chrysopa*) offer good potential as candidates for further testing and demonstration as components of integrated pest management (IPM) for this pest on most target vegetable crops.

Acknowledgements: The contributions of both Farmchem Ltd and Amiran (K) Ltd in providing the test products as well as financial support are gratefully acknowledged.

References

Anonymous (1999) *1999 Annual Report*. Ministry of Agriculture and Rural Development (MOARD), Kenya.

Anonymous (2000) *2000 Annual Report*. Horticultural Crops Division, Ministry of Agriculture and Rural Development (MOARD), Kenya.

Anonymous (2001) *Horticultural Crops Production Manual* Vol. 3 (Revised) Kenya Agricultural Research Institute (KARI).

Bohlen E. (1973) *Crop Pests in Tanzania and Their Control*. Verlag Paul Parey, Berlin. 142 pp.

Hill D. S. (1983) *Agricultural Insect Pests of the Tropics and Their Control*. 2nd Edition. Cambridge University Press, London, UK. 746 pp.

Kambo C. M. (2002a) Efficacy of Avaunt 150 SC against African bollworm, *Helicoverpa armigera* on snow peas (unpublished paper).

Kambo C. M. (2002b) Efficacy of Keshet 2.5 EC (deltamethrin) against African bollworm, *H. armigera* on tomato (unpublished paper).

Highlights and Recommendations

Annex A

HIGHLIGHTS OF TECHNICAL SESSION 1:

Overview of ABW Research and Management in Kenya

Chair: Dr C. Kariuki (KARI),
Co-chair: Mr I. Kimani (MoA),
Rapporteur: Mr J. Baya (ICIPE)

1. General observations

(i) The African bollworm is a serious pest on major food crops and vegetables, e.g. tomatoes and cut flowers.
(ii) It is also widely distributed from low to high altitude and also attacks a wide range of crops, e.g. fodder crops (*Desmodium*), tomatoes, cotton and tobacco.
(iii) Therefore, it is important for stakeholders to collaborate in order to enhance control measures, namely biological and cultural methods and pesticide use.
(iv) Training of farmers and extension agents would enhance increased results of control measures.

2. Brief discussions on individual papers

2.1. Paper by Kibata entitled *'National Research Status and Future Needs for Biocontrol Based African Bollworm Management in Kenya'*

Q: Do we see the scope for integrating *Trichogramma* and NPV use with pesticide use in target crops?
R: *There is that possibility but appropriate compatible pesticides may be limited; nevertheless, this should be explored.*
Q: Do you see any future for biocontrol in the flower industry, bearing in mind the many chemical pesticides being sprayed?
R: *There has to be dialogue between flower growers and end users, so as to make them agree to tolerate the slow action of the biocontrol agents.*
Q: Do we have an initiative to sensitise the farmers on alternative approaches of African bollworm management, since they are so fixed on conventional chemicals?
R: *I am afraid not at present; but this could best be done through farmer field schools or CBO, and participatory approaches given the declining role of the government extension services.*

2.2. Paper by Kambo entitled *'Pest Status, Present Knowledge and Options for Control of the African Bollworm in Thika Region'*

Q: Do you feel that pesticide use is not a very sustainable option, due to the limitations created by resistance, resurgence and residues?
R: *Pesticides as specific pest management strategies are not sustainable and have to be judiciously used and in conjunction with other management strategies such as natural enemies, cultural practices etc.*

2.3. Paper by Mutinda entitled *'Pest Status, Present Knowledge and Options for Control of the African Bollworm in Embu Region'*

Q: Considering the polyphagous nature of the African bollworm, would it be preferable to depend on tolerance than antibiosis or preference?

R: *In the short term, that may be the way forward. The control of the African bollworm will depend on tolerance across the many crops under cultivation. It will be difficult to put in place a resistance-breeding programme for ABW on most of the target crops.*

2.4. Paper by Tunje Pole entitled *'Pest Status, Present Knowledge and Options for Control of the African Bollworm in Kilifi Region'*

Q: Could you expound on the term 'genetic markers'?

R: *Genetic markers refer to known short strand DNA sequences, which can be used to assess the diversity/relation among groups of organisms, through techniques such as RAPD/RFLP PCR.*

Q: Please indicate whether model farmers' groups could be trained on IPM technologies for African bollworm on tomato in your (Kilifi) region?

R: *It is possible especially among the outreach farmers' groups around the Kilifi Institute of Agriculture, who work closely with the student trainees and agricultural staff.*

Q: In view of the predators and parasites identified in Kilifi, what is the impact of the pesticides used for management of the African bollworm on the natural enemies?

R: *Chemical pesticides have been suspected to also destroy the natural enemies of the pest, but the degree of impact on the pest has not been established. Also some degree of pesticide tolerance has been noticed in the target pest.*

2.5. Paper by Oscar Magenya entitled *'Pest Status, Present Knowledge and Options for Control of the African Bollworm in Kisii Region'*

Q: Please clarify about how common the occurrence of the African bollworm is on cabbage?

R: *We find some occasional occurrence of the African bollworm on kales in many places. We encounter up to 20% of heads attacked by African bollworm during certain seasons as reported by cabbage farmers; on the other hand, very few African bollworm larvae have been reported on kales in South Nyanza, Kenya.*

Q: Should we evaluate promising exotic egg and larval parasitoids for African bollworm biocontrol so as to achieve a wider impact?

R: *Yes, it would be important to include larval parasitoids in evaluation of promising biocontrol agents.*

Q: In farmers' management strategies you mentioned the use of pyrethroids to control the African bollworm or did you mean synthetic pyrethroids?

R: *Yes, synthetic pyrethroids. It would be better to talk about optimal population of parasitoids to be released in the other technical session on potential for* Trichogramma *in biocontrol.*

2.6. Paper by Mulaa et al., entitled *'Pest Status, Present Knowledge and Options for Control of the African Bollworm in Kitale Region'*

Q: There is less infestation on *Desmodium* when intercropped with maize. Where do the bollworms go? Could we be inviting trouble by introducing the intercrop in Central Kenya where there are two seasons of maize?

R: *I think the intercropping situation lowered* H. armigera *on* Desmodium, *probably because maize is much taller and could have interfered with the movement of moths under the maize canopy. In the study area (Kitale), Helicoverpa is not a very serious pest on maize. Further observations may be necessary in other agroecological zones.*

Q: Please comment on whether you would like to test *Trichogramma, B.t* and NPV for African bollworm control on *Desmodium* to avoid synthetic pesticides?

R: *It will definitely be adopted by many farmers, because the natural enemies and* B.t., *NPV are safer alternatives. Experiments could be designed on-station and on-farm in Bungoma and Trans Nzoia districts.*

Q: Do you think trap crops like short duration pigeon peas and *Tagetes* should be tested for diverting African bollworm from *Desmodium* and tomato in your region?

R: *I think it is a very good idea, apart from pigeon peas; we could also look at other crops that may be preferred by farmers as trap crops in different agroecological zones.*

2.7. Paper by Ngari entitled *'Pest Status, Present Knowledge and Options for Control of the African Bollworm in Mwea Region'*

Q: The African bollworm is a major pest of cotton. It also has numerous wild hosts that are more preferred. Is there any habitat management initiative in place to enact the push-pull concept?

R: *Studies have shown that intercropping cotton with maize reduces the population of bollworms on cotton. However, the yield of cotton may be reduced. We need to confirm the farmers' claim, collect samples and rear the insects to determine whether what they are previewing is correct.*

Q: Please comment on the field efficacy, duration and likely agencies for mass production and local delivery of entomopathogenic fungi (EPN) in cotton growing areas.

R: *Yes, ICIPE could assist in tricho/NPV and Bt* trials.

2.8. Paper by Sithanantham entitled *'Biocontrol Based IPM of* Helicoverpa armigera—*Global and African Scenario and Trichogrammatid Egg Parasitoids Utilisation in ABW Biocontrol Elsewhere and in Africa'*

Q: Why do you think you had low parasitoid recoveries from the on-farm surveys?

R: *Low recoveries were due to insecticide use interference on the on-farm target crops.*

Q: Have you explored the possibility of using 'bait' eggs?

R: *Bait eggs have also been occasionally tried; however, natural egg recoveries are preferable for such habitat focus collections.*

Q: Have you tried rearing *Trichogramma* spp. on African bollworm itself? If so, how were the results?

R: *Trichogrammatid collections naturally recovered from African bollworm eggs and studied in the laboratory showed variability in preference to original host versus other non-target Lepidoptera.*

Q: Was *Corcyra* chosen by design?

R: *It was chosen as it is found to be more productive and was also easier to handle without much troubleshooting. It is also easy and cheap to rear and mass-produce.*

Q: On the basis of collected information, how confident are we to continue augmenting indigenous natural enemies?

R: *It is well known that native species/strains tend to be suitable for inundative release systems since they are well adapted to the local environmental conditions.*

2.9. Paper by Kega entitled *'Pest Status, Present Knowledge and Options for Control of the African Bollworm in Kwale Region'*

There were no comments but he added that there is a family of eggplant highly preferred by the bollworms.

2.10. Paper by Ochiel et al., entitled *'Pest Research Status and Future Potential for Trichogramma Use in Kenya'*

He explored the need to continue *Trichogramma* research.

HIGHLIGHTS OF TECHNICAL SESSION 2:

Overview of ABW Biocontrol Elsewhere and KARI Collaboration Activities

Chair: *Mr Kibata (KARI),*
Co-chair: *Mr Tunje (MoA),*
Rapporteur: *Mr Kega (KARI)*

Main observations

(i) Globally, biocontrol is emerging as a key component of *Helicoverpa armigera* IPM.

(ii) There are substantial field test results from elsewhere, showing the potential for *Trichogramma* to control the African bollworm infestations on tomato and cotton.

(iii) The overall African scenario and the Kenyan situation of emphasis in horticultural crops, justify biocontrol of the African bollworm in *Trichogramma*.

(iv) Current KARI–ICIPE initiatives seek to build up a collection of native trichogrammatids to help in biodiversity utilisation.

(v) Complementary activities to build baseline data on the African bollworm population dynamics as well as to link up with model vegetable farmers' group (at Muguga) are in progress.

HIGHLIGHTS OF TECHNICAL SESSION 3:

Potential for *Trichogramma* in Biocontrol in Kenya and Elsewhere

Chair: *Dr G. Ochiel (KARI),*
Co-chair: *Mr S. Muinde,*
Rapporteur: *Mr C. M. Matoka (ICIPE)*

Main observations

(i) The global trend of utilisation of *Trichogramma*, during the last five decades, shows that this method is adoptable in Africa, especially in Kenya.

(ii) The choice of suitable species/strains and appropriate local mass production cum delivery systems as well as awareness building among stakeholders in Kenya should receive priority attention.

(iii) The laboratory and field visits during this session provided the participants with an orientation of the relevant methodologies and techniques currently available for *Trichogramma* evaluation and utilisation.

(iv) The questionnaire response sheets filled in by participants and the discussions on the guidelines would provide adequate basis for visualing the future utilisation (demand) scenario for *Trichogramma* in Kenya.

HIGHLIGHTS OF TECHNICAL SESSION 4:

Vision for Future Research—Training and Networking

Chair: Dr Mulaa (KARI),
Co-chair: Mr Ngari (KARI),
Rapporteur: Mr Magenya (KARI)

Recommendations on the following needs relating to *Trichogramma* use and related biocontrol/IPM for ABW management in Kenya were presented by the workshop participants and were discussed and adopted:

- *Future research needs:* Mr Kibata
- *Future training needs:* Mr Kimani
- *Future policy support needs:* Mr Kimani
- *Future networking needs:* Dr Ochiel
- *Current collaboration needs:* Dr Ochiel

Future research needs:

- We need short-term research to help *forecast 'peaks' as well as 'good' or 'bad' ABW seasons* for the major target crops in Kenya.
- We should develop a *crop-wise and region-wise database on the commonly found natural enemies of ABW,* to help evolve suitable strategies to conserve or augment them.
- It is important to identify *'crop-specific'* and *'habitat-specific'* **Trichogramma** *species/strains,* for enabling appropriate impact validation.
- It is important to participatorily *quantify the economic and ecological benefits due to* **Trichogramma** *use,* as an IPM component in selected target crops of ABW.
- We recommend that a *combination of* **Trichogramma** *with biocontrol products directed at the larval stage (e.g.* **B.t.** *and NPV)* should be given priority.
- We should undertake priority research to enhance/assess the *compatibility of* **Trichogramma** *with commonly used pest control products* (pesticides) in chosen target crops.

Future training needs:

- We need to initially *train extensionists as 'master trainers',* so as to be able to organise awareness building on *Trichogramma* use among end users.
- We should *also train a wider group of stakeholders*—extensionists, private enterprise, NGOs, CBOs and model farmers' groups in ABW biocontrol-based IPM.

Future policy support needs:

- Since ABW attacks a wide range of crops and is also important in export agriculture, we should strongly recommend that ***'ABW should be declared as a national priority pest'*** for purposes of future research–extension support.
- The concerned national institutions (Pest Control Products Board-PCPB, Kenya Plant Health Inspectorate Services-KEPHIS, Kenya Standing Committee on Imports and Exports-KSTCIE) should be requested to ***develop policy guidelines that encourage private enterprise and other producers to invest in* Trichogramma *production.***
- There is need for ***encouraging* Trichogramma *utilisation as a key component of IPM and organic agriculture*** initiatives in Kenya.

Future networking needs:

- ICIPE should lead and involve interested KARI/University/MoA experts and private enterprises in an ***ABW management-working group*** to facilitate exchange of information and experience.
- It would be useful for KARI, MoA and ICIPE to establish a national ***ABW IPM task team*** to link up in different research and training activities.
- ICIPE, KARI and MoA should jointly ***formulate a complementary·ABW project on biocontrol-based IPM*** for Kenya and approach donors for funding.

Current collaboration needs:

- ICIPE is requested to extend the ABW adult monitoring ***to additional KARI/MoA benchmark sites,*** even in the present phase of the ongoing ABW project (2003–2004).
- ICIPE is also requested to assist in the ***identification of samples of ABW egg parasitoids collected from other KARI centres,*** even during the present phase of the project (2003–2004).

Workshop Programme

Annex B

List of Workshop Participants

Annex C

List of Workshop Participants

Kenya Agricultural Research Institute (KARI)

Dr Margaret Mulaa, Kitale
Dr Gerald Ochiel, Kibos
Dr Vincent Kega, Matuga
Mr Oscar Magenya, Kisii
Mr Benard Ngari, Mwea
Dr Charles Mutinda, Embu
Mr Gilbert Kibata, Nairobi
Mr Charles Kambo, Thika
Dr Charles Kariuki, Muguga
Mr Samuel Njihia, Muguga

Ministry of Agriculture (MoA)

Mr D. K. Njeru, Nairobi
Mr Tunje Pole, Kilifi
Mr Kimani Ironjo, Kilifi

Farmers' Representatives

Mr Samuel Muinde (Farmers' representative), Kilifi
Mr Samuel Karanja (Farmers' representative), Muguga

ICIPE Scientific/Research Staff

Dr S. Sithanantham
Mr C. M. Matoka

ICIPE Postgraduate (PhD/MSc) Scholars

Mr Joseph Baya
Mr Andrew Kalyebi
Ms Constance Muholo
Ms Lorna Migiro
Mr George Keere
Ms Jackline Makatiani

These proceedings review the current research status of the African bollworm, *Helicoverpa armigera*, in Kenya on a regional and crop-wise basis and outline the future research and training needs for sustainably managing this pervasive pest using *Trichogramma* as a biocontrol agent.

Kenya Agricultural Research Institute

ISBN: 92 9064 169 X

icipe
International Centre
Insect Physiology ar
Ecology