# "PUSH-PULL" ANNUAL REPORT FOR THE YEAR 1998-1999

## PLANT HEALTH MANAGEMENT

# Staple Food Crop Pests

Three projects centering on the management of insect pests, weeds and diseases affecting cereal crops are included in the Staple Food Crop Pests Sub-Division. A project on habitat management is examining novel approaches to controlling cereal stemborers and *Striga* in maize and sorghum. Push-pull' strategies have been developed which use certain plants to repel stemborers from cereal fields, and other plants to attract and trap them outside of the field. The plants used to repel or attract the stemborers are forages, which have a high value in farming systems where livestock are maintained. When planted between maize rows, the forage legume *Desmodium* has been shown to suppress *Striga hermonthica,* an extremely harmful parasitic weed found in many parts of Africa. Current research is focused on understanding the mechanism by which *Desmodium* controls *Striga.*

A second activity is a collaborative project between ICIPE and the Kenya Agricultural Research Institute, which has the objective of increasing the understanding of the epidemiology of maize streak virus (MSV). Within this larger project, ICIPE is focusing on the biology of MSV and its leafhopper vectors (*Cicadulina* spp.) with a view to understanding the uneven spread of MSV disease in nearly uniform susceptible maize types grown in different agroecological zones of Kenya. Results from this project clearly indicate that several species of *Cicadulina* are involved in MSV transmission, but that their vectorial capacity varies, even between populations of the same species collected from different locations. Another interesting finding, observed through successive adjacent plantings of maize, is that the progeny of *Cicadulina* breeding in a maize crop are not an important source of spread of the disease to later-planted maize.

The last activity in the Sub-Division is the programme on classical biological control of the exotic stemborer *Chilo partellus*. An exotic parasitic wasp introduced by the project in 1993 is now well established in southern Kenya, and its population has increased each year since the first releases. In 1998/99, average parasitism across more than 60 sites in the southern coastal zone was 9%, and at some sites was greater than 40%. The project is now working with governments in several countries in eastern and southern Africa to replicate the work done in Kenya. Parasitoids have been released in Uganda, Mozambique, Somalia, Malawi, Zambia, Zimbabwe and Zanzibar, and there is evidence of establishment in Mozambique, Uganda and Tanzania.

# New Integrated Stemborer and *Striga* Management Systems in Subsistence Maize Farming for Africa

***Background, approach and objectives***

Among the most important biotic constraints to maize production are lepidopteran stemborers, which feed inside plant stems, and the parasitic weeds belonging to the

genus *Striga*, which compete with the maize plant for water and nutrients. Reducing the losses caused by these pests through improved management strategies could significantly increase maize production, and result in better nutrition and purchasing power of maize growers. To put stemborer and striga weed control within the reach of African farmers, simple and inexpensive measures need to be developed that are tailored to the diversity of African cropping systems. A sustainable solution would be an integrated approach that simultaneously addresses both of these major problems.

The new approaches being developed as part of a habitat management programme for controlling stemborers and striga weed in maize-based cropping systems make use of a 'push-pull' strategy. This involves trapping stemborers on highly susceptible trap plants (the pull) and driving them away from the crop using repellent intercrops (the push). Plants which both repel stemborers and inhibit striga weed have also been identified. On-farm trials confirmed that these approaches, conducted separately and together, give significant yield increases and are acceptable to subsistence farmers.

The habitat management approach is suitable for small- to medium-scale farmers in Africa practising mixed agriculture. The strategy will also serve as a model for the management of other pests in Africa and beyond. The Project is being undertaken in different agroecologies in Kenya. Recommendations from this Project are demonstrated to farmers through on-farm trials conducted in collaboration with KARI and Ministry of Agriculture Livestock Development and Marketing (MOALDM).

The overall objective of the Project, now in Phase II (1998–2001), is to promote further the adoption by farmers of new stemborer and striga weed control technologies, including the integration of trap and repellent plants in a sustainable push-pull strategy, while continuing to assess their potential and limits.

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***Work in progress***

***1. MANAGEMENT OF STRIGA WEED USING FODDER LEGUMES***

Field trials were conducted in Suba District of Kenya, where *Striga hermonthica* is a serious limitation to the cultivation of cereals. Maize was intercropped with five species of legumes: cowpea (*Vigna unguiculata*), soybean (*Glycine max*), sun hemp (*Crotolaria juncea*), greenleaf (*Desmodium intortum*) and silverleaf (*Desmodium uncinatum*) in alternate rows. A control plot of maize mono was also included. The six treatments were completely randomised and planted in 6 replications in a six by six quasi-complete Latin Square Design. Each treatment plot was 6 x 6 m. The maize variety used was the susceptible, medium maturity, commercial hybrid 511, recommended for mid-altitude regions with moderate rainfall. The trials were planted during the long and short rainy seasons (March to July and September to December) of 1998 and long rains of 1999.

Intercropping maize with the fodder legumes, *D. uncinatum* and *D. intortum* significantly reduced striga infestation when compared to maize monocrop (Figure 1). Reduction in striga infestation by intercropping maize with the two species of

*Desmodium* was significantly greater than by intercropping the maize with soybean, *s*un hemp and cowpea, and gave an associated significantly higher growth of maize.

We are also examining other species of *Desmodium* for their striga-inhibitory and stemborer-repellent effects and their adaptability under various agroecosystems. Efforts are now underway at ICIPE and IACR-Rothamsted to identify the allelochemicals produced by the root systems of *D. uncinatum* and *D. intortum* which inhibit *Striga* in the soil.

### *2. PUSH-PULL STRATEGIES FOR CONTROL OF STEMBORERS*

Napier grass and Sudan grass, two widely used commercial fodder grasses, can provide natural control to stemborers by acting as trap plants for the pests and as reservoirs for their natural enemies. Although the stemborers oviposit heavily on the attractive napier grass, only very few larvae are able to complete their life cycles. Napier grass has its own defence mechanism against crop borers. When the larvae enter the stem, the plant produces a gummy substance, which causes the death of the pest. Napier grass or Sudan grass, when planted around maize fields, can decrease stemborer infestation on maize and thus increase crop yield (See *ICIPE 1995–1997 Annual Scientific Report*). Planting Sudan grass around maize fields also increases the efficiency of natural enemies.

Previous work has also shown that intercropping maize with non-traditional hosts and non-host companion plants produces a marked impact in reducing stemborer infestation on maize. Planting maize into an already-established crop of molasses grass (*Melinis minutiflora*) and silverleaf (*D. uncinatum*) significantly reduces stemborer incidence (See *ICIPE 1995–1997 Annual Scientific Report*).

The Project has now developed fully integrated 'push-pull' or stimulo-deterrent diversionary strategies. In this habitat management system, which involves combined use of trap and repellent plants, insects are repelled from the main crop, and are simultaneously attracted to a discard or trap crop. The integrated push-pull strategies also incorporate increased parasitism of stemborers caused by one of the intercrops, molasses grass. The leguminous intercrop silver leaf also reduced damage to maize by striga very considerably and this aspect has been developed for integration with stemborer control in the areas where both pests are found to pose serious constraints to maize production.

In a push-pull field trial at ICIPE, Sudan grass was planted as a border around a maize field, and maize was intercropped with silverleaf, *D. uncinatum.* Sudan grass was used as a trap plant for stemborers. Stemborer and striga weed infestations and maize yields were compared with a control plot where maize monocrop was grown. The push-pull strategy significantly reduced stemborer and striga infestation on maize and significantly increased maize yield (Table 2).

### *3. SEMIOCHEMICALS FROM* MELINIS MINUTIFLORA

Significant progress has been made in the analysis of airborne volatiles of host and non-host plants to discover the compounds responsible for attractancy or repellency to stemborers, especially from the molasses grass, *M. minutiflora*. The volatile oil obtained by hydrodistillation of the molasses grass deterred oviposition of *Chilo partellus*, demonstrating that the volatile semiochemicals play a major role in oviposition deterrence of stemborers on the grass (See *ICIPE 1995–1997 Annual Scientific Report*).

In this review period, a similar study was conducted with *Busseola fusca*. *Melinis minutiflora* oil extract was tested for *B. fusca* ovipositional deterrence in various concentrations (1250, 2500, 5000, 7500 and 10,000 ppm) dissolved in hexane. The test chemical was applied to a surrogate stem ovipositor at the rate of 100 ml per surrogate stem (see *ICIPE 1994 Annual Scientific Report*), aiming where the insect places its ovipositor. After the solvent evaporated (30 min after application), treated

and control (treated with hexane only) surrogate stems were placed in a wire mesh cage. Three gravid *B. fusca* females were then released in each cage, and oviposition on the extract-treated and the control surrogate stems was recorded after a period of 12 hours. The results presented in Figure 3 demonstrate a strong ovipositional deterrence with increasing concentration of the oil. On *B. fusca*, (*E*)-? -ocimene and ? -terpenolene were found to be the major electrophysiologically active compounds in *M. minutiflora* airborne volatiles. Ovipositional bioassays against *B. fusca* are in progress.

## *4. ON-FARM TRIALS OF STEMBORER AND STRIGA WEED MANAGEMENT IN KENYA*

Farmer-participatory trials on the management of stemborers and striga weed were initiated during January 1997 in Trans Nzoia and Suba Districts of Kenya, supported by a special funding from the Gatsby Charitable Foundation. These trials were undertaken in collaboration with small- and medium-scale farmers who are expected to benefit from ICIPE's IPM technologies. The on-farm approach is a highly interactive process, characterised by interdisciplinary, participatory and collaborative approaches. Scientists from KARI and extension staff from MOALDM also work very closely with ICIPE scientists in implementing on-farm trials. During 1998 and 1999, the on-farm trials continued. In 1999, the on-farm trials consisted of 150 farmers in Trans Nzoia district and 60 in Suba District. In both years, the farmers were selected by nomination by the farming community.

Community mobilisation was undertaken with the help of KARI staff, agricultural extension agents and local administrative leaders. Meetings were convened at four villages. The primary objectives of these meetings were to create awareness on the use of fodder plants for management of stemborers and to select farmers for participation in the on-farm trials. In Trans Nzoia, the farmers who used Napier grass as trap plant for stemborers in 1998 participated in fully-integrated 'push-pull' trials during 1999. The farmers had a choice of using *D. uncinatum* or *M. minutiflora* as repellent plants with napier grass. New farmers selected in 1998 used napier grass as a trap plant. Increase in maize yield was recorded in most of the on-farm trials where farmers used napier grass or a combination of napier grass with a repellent plant (Figure 4).

In Suba District, the farmers who used *D. uncinatum* as a method of stemborer and striga control and napier grass for stemborer control in 1998, participated in fully-integrated 'push-pull' trials during 1999. Similar selection procedures were used to select trial farmers from three divisions of the district. Five farmers participated in the use of *D. uncinatum,* and two in the use of napier grass. The results of on-farm trials in Suba District are summarised in Figure 4.

### *4.1 FARMERS' PERCEPTIONS ON HABITAT MANAGEMENT*

Habitat management strategies can confer various benefits to farmers who practise them. The most important contributions are increased grain yield, higher milk production and reduction in levels of pest and weed infestation from participating farms. These benefits translate into improved food security, higher farm incomes and contribute to the sustainability of low-input agriculture. Fifty farmers in Trans Nzoia District and 24 farmers in Suba District who participated in on-farm trials in 1998 were interviewed for their perceptions towards the habitat management strategies and the effectiveness of using this innovation as a stemborer and/ or striga control method. Results from both the districts are presented in Table 4.1.

### *4.2 BENEFIT-COST RATIO*

Evaluating returns to investments in habitat management strategies is key in the ex-ante assessment of the feasibility of these technologies in contributing to farm income and improved welfare. As a preliminary step towards the economic feasibility of the various habitat management strategies, data on various components of

income (benefits) and costs was gathered from Trans Nzoia District in 1998 and analysed for options in different agroecological and socioeconomic settings. Comparisons were made with farmers who used pesticides for stemborer control. Results showed the highest benefit-cost ratio for the farmers who used both napier grass and *Desmodium* in a 'push-pull' strategy (Figure 4.2). Similar data need to be collected from different places and different types of farmers, including women farmers, in order to assess yield or income stability or variability over time. This is to assist in generating estimates of economic returns under different weather regimes (i.e. good vs. bad seasons) in various agroecologies for different types of farmers.

## *5. WOMEN'S PARTICIPATION IN HABITAT MANAGEMENT*

Women's contribution to agricultural production in eastern African countries is significant. Despite variations across cultural and socio-political backgrounds, women contribute enormously towards agricultural resource allocation decisions. During 1999, women farmers and members of women groups were invited to ICIPE's Mbita Point Field Station for a one-day workshop on the role of women in habitat management strategies for controlling stemborers and striga weed. The aim of the workshop was to provide information about the technology to women farmers, to get first-hand information from them about their contributions to the habitat management strategies and to help develop their potential in sustaining and diffusing the technology. A pre-coded focused questionnaire was administered to capture information on various activity profiles for cultivation of maize, napier grass and *Desmodium* and for animal production undertaken by men, women and children. The information related to napier and *Desmodium* cultivation is summarised in Figures 5a and 5b. The information will be valuable in future training to identify a target group for a specific activity in habitat management.

### *Output*

*Publications*

Khan Z. R. (1998) Habitat management strategies for control of insect pests in Africa: A novel approach to IPM for the twenty-first century, pp. 53–64. In *Ecological Agriculture and Sustainable Development,* Vol. 2 (Edited by G. S. Dhaliwal, N. S. Randhawa, R. Arora and A. K. Dhawan). Indian Ecological Society and Centre for Research in Rural and Industrial Development, Ludhiana, India.

Khan Z. R. and Saxena R. C. (1998) Host plant resistance to insects, pp. 118–154. In *Critical Issues in Insect Pest Management* (Edited by G. S. Dhaliwal and E. A. Heinrichs). Commonwealth Publishers, New Delhi.

Pathak M. D. and Khan Z. R. (1998) Management of rice stemborers in Asia, pp. 227–238. In *Tropical Entomology: Proceedings of the 3rd International Conference on Tropical Entomology* (Edited by R. K. Saini ). ICIPE Science Press, Nairobi.

Polaszek A. and Khan Z. R. (1998) Host plants, pp. 3–10. In *African Cereal Stem Borers: Economic Importance, Taxonomy, Natural Enemies and Control* (Edited by A. Polaszek). CAB International, UK.

*Conferences organised*

Habitat Management Strategies for Suppression of Cereal Stemborers and Striga Weed, 19 September 1998, Institute of Agricultural Research, Addis Ababa, Ethiopia (Funded by BBSRC and Gatsby Charitable Foundation).

Conservation of Gramineae and Associated Arthropods for Sustainable Agricultural

Development in Africa, ICIPE, Nairobi 23–25 November 1998, funded as a PDF-Block A by the Global Environment Facility through UNEP (To develop a project proposal for funding).

International Workshop on Habitat Management Strategies for Control of Stemborers and Striga Weed in Maize-Based Farming Systems in Africa, 27–30 June 1999, ICIPE's Mbita Point Field Station, Mbita Point.

*Conferences attended*

Khan Z. R. (1998) International Workshop on the Management of Cereal Stemborers in Africa, Nairobi, Kenya, 12–13 October, 1998. Paper presented, 'Use of wild host plants in cereal stemborer and striga management'.

Khan Z. R. (1998) The 6th Eastern and Southern Africa Regional Conference, 21–25 September 1998, Institute of Agricultural Research, Addis Ababa, Ethiopia. Paper presented, 'Maize production technology for the future: Challenges and opportunities'.

Khan Z. R. (1998) Annual Meeting of the Entomological Society of America, 8–12 November, 1998, Las Vegas, USA.

Khan Z. R. (1999) Annual Meeting of the Entomological Society of America, 12–16 December, 1999, Atlanta, GA, USA.

*Proposals written*

Implementation of habitat management strategies for stemborer and striga suppression in maize-based farming systems in eastern Africa. To be submitted for funding through ASARECA jointly with national programmes.

Mechanism of *Striga* suppression in maize-*Desmodium* intercrop. Submitted to Rockefeller Foundation.

'Push-pull' strategies for management of stemborers and striga weed in Lake Victoria Basin of East Africa. Submitted to USAID.

Conservation of gramineae and associated arthropods for sustainable agricultural development in Africa submitted to UNEP for funding by the Global Environment Facility

*Project proposals funded in 1998 and 1999*

'New integrated stemborer and *Striga* management systems in subsistence maize farming for Africa' (1998–2001)—Funded by Gatsby Charitable Foundation

'Conservation of gramineae and associated arthropods for sustainable agricultural development in Africa'— PDF-Block A funded by Global Environment Facility.

'Mechanism of striga suppression in maize–*Desmodium* intercrop'— funded by Rockefeller Foundation.

***Capacity building***

Training has been a very strong component of the Gatsby-funded Project. Several MSc and PhD students from different countries are working under the project (Table

A).

During the trials, the project also organised several training activities for farmers and extension staff in Trans Nzoia and Suba Districts (Table B). The main objective was capacity building in terms of knowledge, skills and ability to apply the technology. The training also involved visits to on-station and on-farm technology trials. The views expressed by the farmers during the training session were taken into account and variations incorporated where appropriate. In some of the training workshops, an exchange of MOA staff and farmers from the two districts was facilitated to allow exchange of experiences. In addition to the training sessions, field days were also held in each on-farm trial site of Trans Nzoia and Suba Districts to give an opportunity to a large cross-section of farmers in the project areas, to observe and assess the technology under evaluation. Several hundred farmers from the project sites took part in field days.

***Impact***

The integrated strategy of stemborer and striga weed control developed under this project is potentially attractive to farmers, because it manifests the following important features which render it distinctively more advantageous than some other methods:

- **Food security.** Intercropping or mixed cropping of maize, grasses and fodder legumes has enabled farmers/users to increase crop yield to improve food security. This feature of the technology is suitable to mixed farming conditions, which are prevalent in eastern Africa.
- **Livestock production.** Habitat management strategies have contributed to increased livestock production (milk and meat) by availing more fodder and crop residues, especially on small farms where competition for land is quite high. It has been demonstrated by the Project that intercropping of forage legumes with cereal crops can improve the quantity and quality of livestock feeds on smallholder farms in various sub-Saharan African countries. The Project has assisted farmers in the semi-arid Suba District of Kenya to acquire 'grade' cattle in a bid to help them meet the district milk shortfall of 40%.
- **User-friendly technology.** The proposed technology introduces practices which are already familiar to farmers in Africa. The approach has affinity to the common agricultural practice of multiple cropping (a system that is based on the diversity of crops, rather than a monocrop) and is based on the use of economically valuable plants. The cultivation of napier grass for livestock fodder and soil conservation is being encouraged in eastern Africa and is already widely practised.
- **Exploiting biodiversity.** This habitat management approach embodies maintenance of species diversity, i.e. by intercropping different plants to avoid the pest problems associated with monoculture. The beneficial effects of field margin habitats in supporting greater arthropod biodiversity and in enhancing natural enemy populations within adjacent cereal fields is well known.
- **Sustainability.** In this approach, the full integration of several crop protection approaches creates a sustainable system by obviating rapid development of resistance/adaptation by pests, which is a feature common to single control measure, e. g. pesticides or genetically-based resistance.
- **Protecting fragile environments.** Higher crop yields and improved livestock production, resulting from habitat management strategies, are helping support rural households under the existing stressful socioeconomic and agroecological conditions. Thus, there will be less motivation for human migration to fragile environments in search of cultivable land.
- **Income generation and gender empowerment.** These habitat management strategies can contribute considerably towards enhancing farm incomes and

gender empowerment through sale of farm grain surpluses, fodder and *Desmodium* seed, especially for women farmers/groups and rural youth groups. The cultivation of napier grass and *Desmodium* for livestock fodder and for soil conservation is being encouraged in Trans Nzoia and is already widely applied.

- **Technology transfer.** Farmers (80%) participating in on-farm trials want to extend the technology to larger areas of their farms. The Project intends to reach about 500 more Kenyan farmers in farm trials up to the year 2001.

  Over the next five years, ICIPE plans to test the habitat management technology in three other African countries—Ethiopia, Uganda and Tanzania—in collaboration with national agricultural research systems. Recognising the important role of women in subsistence farming, ICIPE is ensuring that women benefit from on-farm trials and training opportunities. The Project organised an international workshop at ICIPE's Mbita Point Field Station. The workshop helped in stimulating interest among researchers and extension staff that would lead to a regional project to test the results of habitat management strategies in different agroecologies and eventually to be adopted by small scale farmers.
- **Media attention and publicity.** The interest created by this project has earned it a recent mention in international reputable publications—*New Scientist* (24 October, 1998, page 25) and *National Geographic* (February 1999, pages 82–83). During 1998 and 1999, field trials were visited by several donors, notable among them are Rockefeller Foundation, USAID and United Nations Development Programme. Maize scientists from Ethiopia, Kenya, Tanzania, Sudan, South Africa and Uganda also visited the trials. The Project's recommendations are reaching 5 million Kenyan farmers through one of the most popular Kiswahili soap opera radio programmes entitled 'Tembea na Majira' on which ICIPE works closely with Media Trust based in Nairobi.

(*See also reports on Biodiversity and Conservation, Biosystematics Unit, Behavioural and Chemical Ecology Department.*)