Top: Because the LGB has invaded East Africa's cooler highlands, which is a grain basket area that supplies most of the region with the maize staple, the dual menace of stemborers and LGB has affected food security in East Africa. *icipe* started a biological control programme against LGB by introducing races of a native Central American predator, *Teretrius nigrescens* which is adapted to cooler temperatures.

Bottom: Mould-infected maize cobs pose a serious health threat to humans and animals. Since the moulds grow on grains damaged by stemborers and storage beetles, tackling maize pests also addresses the mould problem.

as *Telenomus isis*, which did not exist in ESA, was introduced and released in Kenya in 2005, and has been recovered in different release sites.

Stemborer IPM in western Africa

In contrast to eastern Africa, all stemborers in western Africa are indigenous. A comparison of natural enemies between the two regions showed that the indigenous larval parasitoid *Cotesia sesamiae*, which is parasitising the African maize stemborer in highland ESA, is rarely found in western and central Africa; thus, it was introduced into Cameroon for the first time by the end of 2006. The wasp got established; however, no post-release surveys have been carried out to evaluate the impact on the stemborer populations.

Biological control of the larger grain borer in ESA

A search for biological control agents of LGB in its areas of origin in Central America in the 1980s and 1990s, revealed the predator *Teretrius nigrescens* as the most promising candidate. The predator was released in several areas in Africa between 1991 and 1996. However, its effectiveness appears to depend on climatic conditions. Greatest successes were in hot-humid areas, and the predator was less efficient in hot-dry climates and constrained by cool temperatures more than its prey, the LGB. *icipe*, therefore, conducted studies from 2004 to

Text Box 1: Post-harvest losses in sub-Saharan Africa (SSA)

- There is paucity of evidence to support post-harvest losses (PHLs).
- PHLs are exaggerated.
- Research studies have focused on on-farm storage losses.
- Assessments of the entire value chain of losses, and post-harvest innovations, are incomplete.
- Assessments target physical losses, not weight loss of a commodity that becomes unfit for human consumption.
- Losses are often economic rather than physical product losses.
- There are few studies on adoption of strategies to mitigate losses.
- Information is missing on cost of losses, and the benefit of innovations.
- Improved technologies are impractical at the smallholder level, yet there are local methods that are user-friendly, effective, and cheaper to buy.

2007 on new races of *Teretrius nigrescens* from Central America that are adapted to different climates and has developed new molecular tools to differentiate these new races after releases in the field.

Triple bagging for maize weevil and LGB control

As an alternative to the use of chemical pesticides during storage, *icipe,* in partnership with Purdue University (USA), has tested the PICS triple bagging approach (hermetic sealing using plastic bags) against maize weevils and the LGB. Originally created for cowpea storage, PICS technology is a simple, low-cost, practical, and effective way to enable resource-poor farmers in Africa to preserve their grain after harvest with minimal losses to storage insects. It also eliminates the need for insecticide, enables farmers to store their grain instead of selling it at harvest when the price is lowest, and ensures a supply of nutritious grain for the table (or the market) for many months. The technology has been tested and proven effective for this and other legume crops, and is expected to allow long-term (multiple months) storage of maize without pest damage; in addition, it will enable farmers to store the maize grain until the commodity has a higher market value.

Analytical review of post-harvest losses in sub-Saharan Africa (SSA)

A review is underway that will provide evidence of current magnitude of post-harvest losses in SSA, identify the gaps, and give a future outlook to assist decision makers improve the strategies for post-harvest losses.

icipe – Working in Africa for Africa…

icipe – African Insect Science for Food and Health – was established in 1970 in direct response to the need for alternative and environmentally friendly pest and vector management strategies. Headquartered in Nairobi, Kenya, *icipe* is mandated to conduct research and develop methods that are effective, selective, non-polluting, non-resistance inducing, and which are affordable to resource-limited rural and urban communities. *icipe*'s mandate further extends to conserving and utilising the rich insect biodiversity found in Africa.

icipe contributes to sustained food security in Africa through developing integrated pest management systems for major agricultural and horticultural crops. Such strategies include biological control, and use of behaviour-modifying and arthropod-active botanicals. The Centre puts emphasis on control approaches that have no detrimental impact on the environment. These options are designed to fit the needs of the farmers, and are developed on-farm and with farmers' participation. Key areas of *icipe*'s plant health research include pests of tomatoes, brassicas, beans, fruits, and staple crops such as maize and sorghum.

COVER PHOTOS

Top left: Maize leaves that young larvae of the spotted stemborer have damaged. The adult stemborer moth lays her eggs on the leaves of young maize plants where they hatch into larvae, which then feed on the leaves before boring into the stem.

Top right: An *icipe* ARPPIS PhD researcher rearing stemborers in a laboratory at the Eduardo Mondlane University in Mozambique. Training of graduate students, extension agents, and farmers, is an integral part of *icipe*'s R&D effort.

Bottom left: A stemborer larva feeding inside a maize stem. Stem damage reduces the nutrient flow to the grain, and often results in lodging of stems.

Bottom right: The ultimate sign of success – a happy farmer in front of his healthy maize crop.

Donors: DGIS, The Netherlands; BMZ, Germany: Kirkhouse Trust, UK; IDRC, Canada;
Bill & Melinda Gates Foundation, USA.

Collaborators: NARES and universities from 11 countries in East and southern Africa; IITA; CIMMYT.

Photos: icipe

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Pre- and Post-harvest Management

of Maize Pests in Sub-Saharan Africa

icipe
African Insect Science for Food and Health

The larger grain borer (LGB) *Prostephanus truncatus*, is a post-harvest pest of maize and dried cassava. It was accidentally introduced from Central America into Africa over 30 years ago, and is now present in the majority of the sub-Saharan African countries. In Kenya, locals refer to it as the 'Osama' beetle because of its devastating nature of bringing down their maize stores (Photo courtesy of Georg Goergen, IITA).

Background

Maize is exotic to Africa, having been introduced from Central America approximately 500 years ago. In Africa, maize encountered a plethora of indigenous pest species that attack the crop in the field and in store.

Two exotic invasive pests were accidentally introduced to Africa, worsening the situation. The first was the spotted stemborer *Chilo partellus* from Asia, which arrived about 80 years ago and spread over the lowlands and mid-altitudes of East and southern Africa (ESA). Climatic modelling shows that it is a matter of time before it spreads to Central and West Africa.

The complex of indigenous African and invasive borer species that attack cereals, together, causes yield losses of 20–40% in sub-Saharan Africa, which could feed 27 million people. Aside from losses to maize, stemborer feeding in cobs renders the grain susceptible to infections by storage moulds, which produce toxic by-products (such as aflatoxins) that are responsible for the high liver cancer rates in Africa. Chronic exposure to aflatoxins also causes immunosuppression, rendering people more susceptible to infectious diseases, such as malaria.

The second invasive pest is a beetle known as *Prostephanus truncatus*, or the larger grain borer (LGB). It is native to Central America and arrived in Africa in the early 1980s. Since then, it has

Top: Maasai pastoralists have started growing maize in East Africa. These two farmers have intercropped their maize with a legume for control of stemborers.

Bottom left: A maize cob showing symptoms of stemborer feeding damage and storage mould (*Aspergillus flavus*) infection. Once pests such as stemborers and LGB damage grains, they become susceptible to mould fungi infections that produce toxic by-products (aflatoxins) that are poisonous to people and animals, and can lead to liver cancer.

Bottom right: A cocoon of the parasitoid *Cotesia flavipes* spun out of a larva of the spotted stemborer. This natural enemy that *icipe* scientists introduced from Asia to Africa is now keeping the populations of the invasive borer species under control in many East and southern African countries.

spread over most of sub-Saharan Africa, causing 30–90% of losses in stored grain, depending on the storage structure. In Kenya alone, LGB inflicts damage amounting to an estimated US$ 116 million annually. The beetle is causing increased concern as it continues to spread throughout Africa.

Control

Stemborers, moulds, and storage pests are interlinked; thus, solving the stemborer problem in the field will also reduce problems in store. Because both the spotted stemborer and LGB are invasive pests, they were considered suitable candidates for classical biological control. Invasive species become devastating in their new areas of introduction because they lack their specific natural enemies that keep them in check in their aboriginal home. Classical biological control involves going back to the areas of origin of the pest to search for effective and specific natural enemies, which are then brought to the regions the pest has invaded. The reuniting of the pest and its natural enemy often results in keeping pest populations in control, making it a sustainable and environmentally-friendly approach for pest control.

Biological control in East and southern Africa

In the early 1990s, *icipe* initiated efforts to bring the exotic spotted stemborer under natural control. Since the small wasp *Cotesia flavipes* was brought from India and Pakistan, there has

Top: Entomologist, Rose Ndemah and colleagues inspecting maize fields in the forest zones of Cameroon. Here, they are monitoring these fields for stemborer damage, and the presence of newly introduced natural enemies.

Bottom: A maize cob that the LGB has destroyed. When this devastating beetle gets into stored maize it reduces the maize grain to powder. The pest is destructive when the maize is stored on the cob, and not as shelled grain.

been a 57% decrease in populations of the spotted stemborer, and the populations are still falling. *Xanthopimpla stemmator*, a natural enemy of the pest, was released at the same time as *Cotesia flavipes*; and *Cotesia sesamiae* and *Telenomus isis* were redistributed to other locations.

We conducted an economic impact study in Kenya, Zambia, and Mozambique on maize and sorghum 20 years following the first release in 1993. Findings show that biological control has contributed to an aggregate monetary surplus of US$ 1.4 billion to the economy of the three countries with 84% (US$ 1.4 billion) to produce maize, and the remaining 16% (US$ 214 million) to produce sorghum. The net present value from the programme over the period 1993–2013 is estimated to be US$ 272 million for both crops, and ranges from US$ 142 million for Kenya to US$ 39 million for Zambia. Estimates of the internal rate of return (IRR) of the *icipe* BC programme are 67% for the aggregate of the three countries, and are attractive, as the returns are above the considered actual discount rate of 10%. The estimated benefit–cost ratio (BBR) is 33:1, implying that each dollar of funds invested in *icipe*'s Biological Control research and releases, results in another additional 33 dollars of net benefit. The estimated number of people lifted out of poverty through this BC programme is on average 57,400 persons (consumer and producers) per year in Kenya, 44,120 persons in Mozambique, and 36,170 persons in Zambia, representing an annual average of 0.35, 0.25 and 0.20% towards reducing total poverty in each of the three countries.

icipe scientists introduced *Cotesia flavipes*, a natural enemy of the invasive spotted stemborer, from Asia into Africa (Photo courtesy of Georg Goergen, IITA).

Other potential benefits include increase in caloric intake of households (as a result of producing more maize), decrease in cases of food poisoning (as a result of reduced aflatoxin contamination of cobs that stemborers have damaged), and ability to conserve biodiversity (as a result of increased land use efficiency).

After these successes in Kenya, the wasp was released and got established between 1998 and 2005 in Ethiopia, Somalia, Malawi, Mozambique, Uganda, Tanzania, Zambia, Zanzibar, and Zimbabwe.

While the wasp imported from Asia is keeping the exotic spotted stemborer under control, the indigenous African stemborers remain a major problem for the farmers. One of the most important is *Busseola fusca*, the African maize stemborer, which is a serious pest in the cooler areas of ESA. In West Africa it is common in the dry savannas, where it attacks sorghum. In Central Africa, it is the main maize pest across all altitudes, from the humid forests to the mountain areas. The existence of different geographic races of the pest that vary in their climatic requirements explains these differences, and also the differences in natural enemy species occurring in the different regions. The latter opens up avenues for the 'redistribution' biological control approach. Redistribution implies the expansion of the geographic range of a natural enemy to areas where it did not exist. For example, a tiny egg parasitoid from West Africa known