Project Title: **Extending the "Push-Pull" technology for East African smallholder agriculture**

FINAL TECHNICAL REPORT

DATE: July 2011

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International Centre of Insect Physiology & Ecology (*ICIPE*)

Collaborators:

Farmer Organisations: Heifer Project International- Kenya, INSPIRE CONSORTIUM – Integrated Soil Productivity Initiative through Research and Education (Uganda), and Africa2000 Network

National Agricultural Research Systems: Kenya Agricultural Research Institute (KARI, Kenya); Lake Zone Agricultural Research & Development Institute (LZARDI, Tanzania), National Research Organizations (NARO, Uganda).

International: Rothamsted Research, UK

Private sector: Western Seed Company

Policy makers: Ministry of Agriculture, Animal Industry and Fisheries, Uganda; National Agricultural Advisory Services (NAADS), Uganda; National Agriculture and Livestock Extension Programme (NALEP), Kenya; Ministry of Agriculture Food and Co-operatives, Tanzania; and National Agricultural Research Systems.

Project Supported by Kilimo Trust East Africa

Start date: August 2009

End date: June 2011

Address of Lead institution: The International Centre of Insect Physiology and Ecology
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Nairobi, Kenya.

Project Completion Summary

Project Title:	Extending the "Push-Pull" technology for East African smallholder agriculture	
Grant Number	KT0609	
Lead Organization:	International Centre of Insect Physiology & Ecology (*ICIPE*)	
Project Leader:	Prof. Zeyaur R. Khan	
Partner Organizations & names of key staff from each	Organization	Name
	Kenya Agricultural Research Institute	Dr. E. Mukisira, Director Dr. J. Mureithi, Deputy Director, Research
	Lake Zone Agricultural Research and Development Institute(LZARDI)- Tanzania	Dr. January Mafuru, Senior Scientist / Economist
	National Agricultural Research Organization (NARO)-Uganda	Dr. G. Asea, Head Cereal Crops Research; Dr. M. Otim, Scientist
	National Agricultural and Livestock Extension Programme (NALEP)	Mr. Tom Bonyo, National Coordinator
	INSPIRE	Mr. F. M. Kabuye, Executive Director
Project Purpose	Improved cereal crop production through development and implementation of robust science-based integrated technologies for management of *Striga,* soil fertility and insect pests.	
Location	Country & Districts	Sub-Counties/Division
	Kenya	Western Kenya districts: Suba, Homabay, Rachuonyo, Nyando, Rongo, Migori, Kuria, Kisii, Kisumu West, Bondo, Siaya, Busia,Trans-Nzoia, Vihiga, Butere-Mumias, Bungoma, and Teso.
	Uganda	Eastern Uganda(Busia, Bugiri, Budaka, Namutumba, Pallisa, Tororo, Namutumba
	Tanzania	Lake Zone Region (Tarime, Rorya, Musoma, Bunda, Serengeti, Bariadi, Meatu)
Start Date	1st August 2009	
End Date	31st January 2011 (with No-cost Extension to 30th June 2011)	
Kilimo Trust financial contribution	USD 650,359	
Other donor financial contribution (specify donors and amount of funds)	Biovision, Switzerland USD 240,000	
Total Project cost	USD 890,359	

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1 Background

1.1 The problem

Nature and magnitude

The project sought to address major constraints to production of both staple and cash crops which cause serious yield losses with consequent destabilization of rural livelihoods. East African countries experience food insufficiency, declining food production, increasing population pressure on resources, high food prices, and high incidences of environmental unsustainability (World Bank Development Report, 2007). Production of cereals, the major staple food and cash crop for majority of the people is constrained by negative a biotic factors, such as water stress and the degraded soils, and biotic constraints, such as pests and striga weeds, resulting into high levels of food insecurity, malnutrition and poverty. This poverty is worst in rural areas where agriculture is the leading source of incomes and employment (Smil, 2000). Moreover, these are where the poorest segments of the rural population are concentrated. In the heavily infested Striga zones rural poverty rates often exceed 70% or more. Where Striga infestation is lighter, poverty rates are often 20% or less. Consequently, introducing Striga control measures would also have differential impacts on reduction of rural poverty.

Underlying causes

Striga infestation: Striga weeds affect four major cereal production zones in east East Africa: the Lake Victoria zone, the Inland dry zone found in Tanzania, the inland moist zone found in Uganda, the Southern Highlands of Tanzania, and a conterminous coastal zone found adjacent to the Indian ocean in both Kenya and Tanzania, totaling to 1.5 Million acres. Average crop loss due to *Striga* could be calculated at 54% of the estimated potential yield (if *Striga* had not been present) (de Groote, et al., 2007). The economic losses from Striga infestation are significant in many parts of East Africa, reaching as high as $7 million per year in some areas of Tanzania. Across the East Africa region, the economic losses reach $335 million per year. A recent Ex-ante impact assessment by Kilimo Trust showed that Tanzania has the largest economic losses, $173 million per year, which was three times larger than the $46.6 million loss found in Kenya. Uganda's losses amounted to $116 million per year (Striga ex-ante report).

Stemborer infestation: Moreover, the presence in the region of cereal stemborers, which together with the parasitic striga weeds cause up to 100% yield losses to cereal production (Kfir et al., 2002; Oswald, 2005). It is estimated that striga weeds alone cause annual losses of $7 to $13 billion and threaten indirectly the lives of over 100 million people in the region (Lagoke et al., 1991), with the problem being more widespread and serious in areas where both soil fertility and rainfall are low (Oswald, 2005).

Low soil fertility: Soils in such areas are moderately to severely eroded due to continuous monocropping, with none to limited improvement efforts through addition of external inputs. These soils are poor in organic matter and deficient mainly in nitrogen (N), phosphorus (P) and Zinc (Zn).

1.2 Development Opportunity Exploited

Up to the start of the project, *icipe* and partners had developed Push-Pull (http://www.Push-Pull.net), an innovative integrated pest management (IPM) approach which had been successfully used in maize in eastern Africa to control striga weeds and cereal pests, and to improve soil fertility. The technology had been validated and promoted to some extent and adopted by some

23,000 smallholder farmers in East Africa, mainly in Kenya. However, the uptake of the Push-Pull technology had not reached a critical mass where its adoption could be spontaneous. The project needed to institutionalize and scale up the adoption of the Push-Pull technology as a key component of integrated pest, weed and soil management under the aegis Kilimo's regional programme to unlock cereal production through elimination of the Striga threat.

Moreover, Napier stunt disease (caused by a phytoplasma) had attacked Napier grass and had spread to most districts in Western Kenya posing a great challenge to continued uptake of the Push-Pull technology as well as dairy industry in East Africa. *icipe* had therefore started researching ways to control the disease and had identified one vector, a leafhopper, *Recilia banda*. The Push-Pull system had enabled the smallholder farmers who practised it in East Africa to increase their maize production by at least 2 t/ha, with benefit-cost analyses showing that it yields higher returns on labour and investment than other systems. Additionally, all the companion crops are valuable as cattle forage, thereby improving livestock holdings in addition to producing a sustainable cereal crop protected against weeds and pests.

On its part, Kilimo Trust had launched a regional '*Program to Unlock Cereal Production Potential in East Africa by Eliminating the Striga Threat'* on the strength of the ex-ante impact assessment. The current project was therefore formulated to contribute to this program by developing and providing a strong scientific framework to country sub-programs through further technological innovations relevant to *Striga*, stemborer and soil fertility management in cereals (maize, sorghum, rice and millet). The current initiative also sought to address the bottlenecks to wide-scale adoption of the Push-Pull system such as availing sustainable ways of accessing desmodium planting materials within the regional program in the target areas. An integrated management strategy was also to be developed for the Napier stunt disease which threatened the production of Napier grass (*pennisetum purpureum*), one of the trap crops used in the system as well as the smallholder dairy industry. Furthermore, the initiative proposed to determine the effectiveness of cotton in *Striga* control, and a cereal-cotton rotation system developed while identifying the main pests of cotton in the region for targeted control, leading to improved livelihood status of households in the target areas.

2 Project Objectives

GOAL: Poverty alleviated among the smallholder farmers in East Africa through sustained contribution of crop production systems to food and fodder security and household incomes.

PURPOSE: Improved crop production through development and implementation of robust science-based integrated technologies for management of *Striga,* soil fertility and insect pests.

OUTPUTS:

Output 1: New legume-based and Push-Pull approaches developed for *Striga*, stemborer and soil fertility management in rice, millet and sorghum within the regional program on *Striga* threat elimination framework.

1. 1: To develop new technological innovations for *Striga* and soil fertility management within the framework of the regional program on *Striga* threat elimination.

1. 2: To identify maize varieties with inherent defence mechanisms for stemborer control within the regional program.

Output 2: The effectiveness and long-term sustainability of the regional program on *Striga* threat elimination determined.

2.1: To enhance establishment of *Desmodium* through soil nutritional amendments and understand its contribution to maize nutrition.

2. 2. To provide scientific and technical support to the country programs as they deploy the regional program.

Output 3: An integrated management approach for Napier stunt disease developed within the framework of the regional program on *Striga* threat elimination.

3. 1: To establish patterns of stunt-pathogen acquisition and multiplication as prerequisite to effective transmission studies.

3.2: To identify Napier grass cultivars from East Africa expressing resistance/tolerance to Napier stunt phytoplasma.

3. 3: To identify alternative and farmer acceptable fodder grasses.

Output 4: The role of cotton in *Striga* control determined and cereal-cotton rotation systems developed.

4.1 Establish the effects of cereal-cotton rotation on *Striga* seed bank depletion, and develop cereal-cotton rotation systems and incorporate in the regional program

4.2 Identify the main pests attacking cotton in the region.

3 Methodology

The project was implemented in western Kenya, Eastern Uganda and Northern Tanzania (See Map appendix 8). Strong scientific and backstopping framework was provided to support country teams on striga control. Data collection on *Striga* seed bank was used to develop conceptual models to inform on program extension to new areas and crops, mainly upland rice and investigate effects of cereal-cotton rotation on *Striga* control. Surveys were conducted to; evaluate and identify sustainable ways of availing desmodium planting materials in large quantities and identify major pests of cotton in the region to develop a Push-Pull based approach for the management of striga. Different Napier grass cultivars were collected from the region and PCR screening for tolerance/resistance to Napier stunt disease, were undertaken to evaluate their suitability as trap plants in stemborer control. Soil nutritional amendments were undertaken to investigate contribution of nitrogen from *Desmodium* species to maize, nitrogen budgets to determine the sufficiency of the N transferred to maize nutrition; screening of potential drought-resistant *Desmodium* species and other legumes for stemborer and *Striga* control. Screen house experiments were undertaken to develop new plant protection approaches by identifying maize varieties that show "early herbivory" alert and thus deter further oviposition while attracting natural enemies.

Participatory Impact Assessment methodology was used to assess the impact of Push-Pull technology on the livelihood of the smallholder farmers. Farmer Field days, Agricultural shows, mobile phone based messaging system and print materials were used in the dissemination and training of Push-Pull technology as a strategy to reach new farmers and in new areas. Data was analysed using qualitative and quantitative approaches **(See Appended publications and reports)**.

4 Findings

4.1 Achievement of Out puts

Output 1:	**Objectively Verifiable Indicators:**
New legume-based and Push-Pull approaches developed for *Striga*, stemborer and soil fertility management in rice, millet and sorghum within the regional program on *Striga* threat elimination framework.	Legume-based intercrops developed for *Striga* and soil fertility management in upland rice by end of year 2; Drought-resistant species of *Desmodium* availed for *Striga*, stemborer and soil fertility management in maize, millet and sorghum by end of year 2 Maize varieties with inherent induced defence responses identified by end of year 2.

4.2 Legume intercrops tested for sorghum, millet and rice;

-The project established experimental plots at *icipe* Thomas Odhiambo Campus, Mbita for four seasons to test the efficacy of desmodium in controlling Striga in upland rice. NERICA rice was planted in 6 rice replications of four treatments, namely: (a) rice-desmodium intercrop, (b) rice with nitrogen fertilizer (c) rice-desmodium intercrop, with nitrogen fertilizer, and (d) rice monocrop. Results from the four seasons' data already showed that rice-desmodium intercrop treatments performed best in terms of visible Striga emergence, rice height, soil moisture retention and rice panicles counts. Observed yields were highest in rice-desmodium intercrops. Multi-season data is being collated and analyzed and shared with the country programmes.

-The project participated in the regional striga programme's country planning and inception meetings in the three countries. The project helped country programmes to develop their recommendation domains, clearly identify target areas for implementation for the application Push-Pull in conjunction with other approaches, and to understand the potential of Push-Pull technology in (1) controlling striga - and consistency in reducing the striga seed bank in the soil in maize,

sorghum, rice and millet faming systems, and (2) in improving soil fertility and sustainably contributing to the cereal production value chains.

-The project published a number of peer-reviewed papers related to the development and further up-scaling of Push-Pull technology.

-Interco- operation of Switzerland conducted a study and published a report on "*Impact assessment of Push-Pull technology developed and promoted by icipe and partners in eastern Africa*" (Martin Fischler, 2010). The study broadly confirmed that Push-Pull technology is widely accepted and adopted by smallholder farmers because it addresses their major production constraints. The key drivers of adoption of the technology were: control of striga, stemborer, soil erosion, and increase of soil fertility and fodder production. It is these combined benefits, together with the low cost of the technology, which made it highly attractive to farmers. The assessment report concluded that 'Push-Pull' contributed significantly to reducing the vulnerability of farm families by ensuring higher yields and, even more importantly, better yield stability. In addition, the technology seemed to be a "springboard" for diversifying the farming system, especially incorporating dairy operations. Increased food security, better income, education of children and health of the family, more knowledge and a higher status in the village were all contributing factors for an overall improved livelihood situation of smallholder farmers. At national scale, the economic, social and environmental impacts of 'Push-Pull' were estimated to be an annual additional gross benefit of US$2-3 Million per year. Furthermore, as Push-Pull does not depend on external inputs such as pesticides and mineral fertilizer it is an environmentally friendly technology likely to increase agro-biodiversity and contribute to provision of ecosystem services, the report concludes.

- The Royal Society of UK, in its recent call for a £2 billion "Grand Challenge" research programme on global food security, identified 'Push-Pull' as a technology that could be immediately applied for achieving the massive increase in food crop production in Africa that would be required by 2050 to meet the continent's food demands without damaging the environment (*http://royalsociety.org/news.asp?id=8827*).
- Farmers' perceptions and evaluation studies on the potential of Push-Pull technology in controlling Striga weed in upland rice in East Africa to form the basis for this intervention. The findings showed that the farmers were willing to incorporate the research findings on Striga control in their rice fields.

1.2 Five promising drought-resistant Desmodium species tested

- Five *Desmodium* spp. *D. distortum, D. tortuosum, D. uncinatum* and *D. intortum* (received from ILRI and *icipe*) and *D. dichtomum* from Sudan were tested under simulated drought. Preliminary results indicate that *D. dichtomum* has drought-resistant properties.

1.3 Maize lines tested for 'early herbivory' defense responses.

- The project screened of more than 60 maize lines from diverse sources mainly from International Maize and Wheat Improvement Centre (CIMMYT) for 'early herbivory' defense responses. The principle was to identify maize varieties that show 'early herbivory' alert and thus deter further oviposition by stemborers, while attracting their natural enemies, principally parasitic wasps.

- **Paper Published:** Midega, C.O, Khan, Z.R., Picket, J.A. & Nylin, S. (2011). Host plant selection behavior of Chilo partellus and its implication for effectiveness of a trap crop. Entomologia Experimentalis et Applicata 138:40–47. (**Appendix 13**).

Output 2:	**Objectively Verifiable Indicators:**
The effectiveness and long-term sustainability of the regional program on *Striga* threat elimination determined.	• Cheaper ways of availing *Desmodium* planting materials, *en masse* evaluated and ways to enhance its establishment availed by end of year 2; • Technology backstopping framework established within the context of the regional program on *Striga* threat elimination by end of year 1.

2.1 Cheaper ways of availing *Desmodium* planting materials, *en masse* evaluated and ways to enhance its establishment availed.

- The project initiated trials with Farm Inputs Promotions Africa Ltd (FIPS-Africa) to test a new model of improving input availability and affordability through small scale seed and fertilizer distribution with technology information. The model (described in **Appendix 4**) emphasises creating demand by improving supply and affordability of inputs (seeds and fertilizer) which are sold in small packages. The main strategy is to stimulate demand for farm inputs by increasing farmers' awareness and knowledge of proper use of agricultural inputs, while increasing availability of inputs through stockists and private sector partnerships, including small-scale village agents.

  The project tested the selling of desmodium seed in small packs (50g and 20g each) during field days and agricultural shows. The packets for sale were provided with information pack on Push-Pull, its planting and management.
- The project initiated a monitoring and evaluation approach involving use of mobile phone calls and Short Messaging Services (SMS) systems, as a strategy to make follow ups to the farmers who, attended field days, demonstrations during agricultural shows and or bought desmodium seeds. In order to establish the effectiveness of mobile phone communication in providing a M&E platform on Push-Pull technology (PPT) dissemination and adoption, a study was conducted in western Kenya where field days and Agricultural Society of Kenya (ASK) were conducted. About 44% of the respondents managed to plant Push-pull in their farms after attending field days while 75% of the farmers who bought Desmodium planted it either in new Push-Pull or in seed bulking plots. Conducting M&E using mobile phone calls with farmers contacted either during field days or ASK shows, program planners are able to assess progress on adoption of the new information disseminated. Through mobile phone calls and text messaging, new information about PPT and farmers' needs is being communicated and feedback obtained in real time. This has facilitated the sharing of new information and knowledge among smallholders and extension service providers. (Full report in **Appendix 6**).

- The project launched an initiative in April 2011 themed: "Push-Pull Technology for a Striga-free Kogelo", aimed at disseminating the Push-Pull technology, and providing desmodium seed on a rotational basis to poor farmers. The initiative started with 200 farmers living in the Kogelo area of Siaya District.

Desmodium Revolving Fund

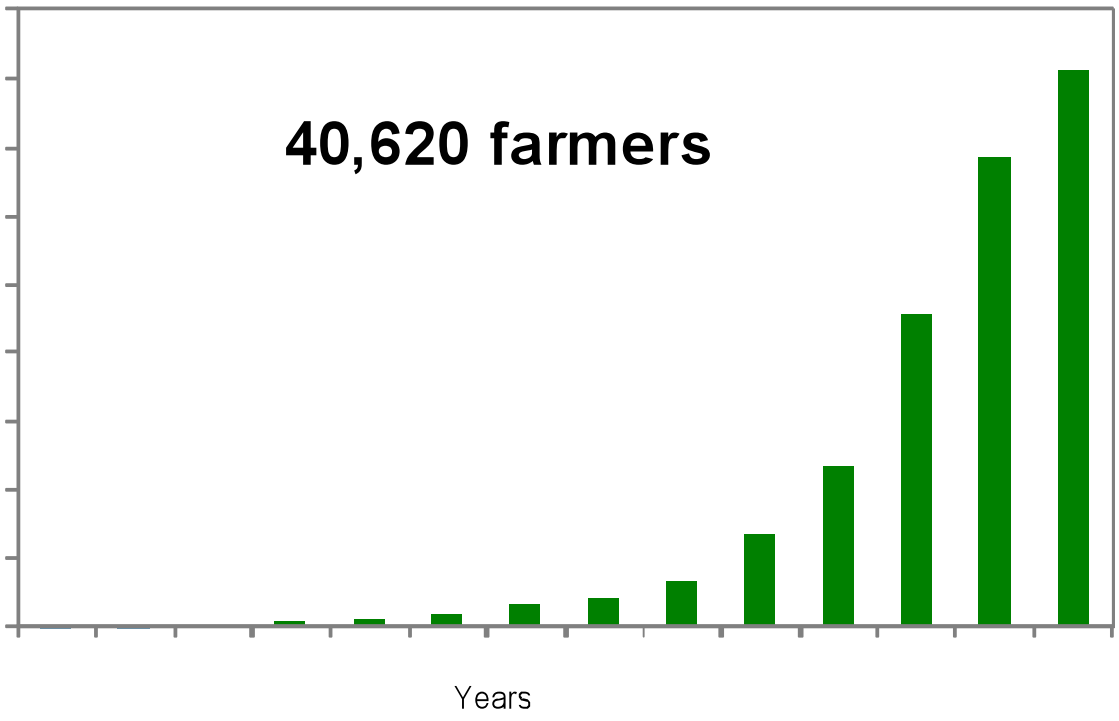
- In 2010, the innovator of Push-Pull technology, Prof. Z.R. Khan, received triple honours from the Entomological Society of America (ESA), including distinguished scientist of the society, Fellow, and was also selected by the ESA as the winner of the Nan Yao Su Award for Innovation and Creativity in Entomology. As part of this honour, Prof. Khan received a US$ 2000 cash award, which he has used to establish a desmodium revolving fund in collaboration with Heifer International. The revolving fund operates on the Heifer International principle of 'passing on' the gift, where a recipient of seed (or dairy animal) passes on harvested seed at the end of season. This is a strategy to ensure sustainable, self-perpetuating supply of desmodium seed.

Figure 1: Desmodium Revolving Fund launched

2.2 Technology backstopping framework established within the context of the regional program on *Striga* threat elimination

- The project participated in the Kilimo's study on factors hindering the adoption of striga control technologies (**Appendices 2, 5, 22**).
- The project has established sustainable partnership to facilitate the integration of Push-Pull and livestock enterprises, in collaboration with Heifer International. Over 3000 Push-pull farmers have benefited from dairy goats from Heifer International on account of having sufficient fodder. (**Appendix 25**).
- In addition, the project produced annually over 10,000 copies of Push-Pull flyers, brochures, posters, and comic books (Swahili and English); 5,000 copies each of Farmer Field Schools curriculum and step by step guide which are distributed to farmers and partners in the region.
- As a result the technology has now been adopted by 40,600 farmers.

Figure 2: Adopters of Push-pull technology in East Africa



Output 3:	Objectively Verifiable Indicators:
An integrated management approach for Napier stunt disease developed within the framework of the regional program on *Striga* threat elimination.	An integrated approach in place by end of year 3 for the management of Napier stunt disease incorporating planting of clean resistant/tolerant cultivars, and diversifying resource base (alternative fodder and trap plants).

- The project evaluated other leaf and planthoppers (11 species) associated with Napier grass for their possible role as vectors of stunt phytoplasma. *Recilia banda* (Hemiptera: Cicadellidae), commonly known as a leaf hopper, had been identified as the vector of Stunt phytoplasma in Kenya. Studies continued to identify other possible vectors and natural hosts of phytoplasma vectors. None of the screened insects transmitted the disease, and are thus not vectors of Napier Stunt in Kenya. Since Stunt phytoplasma in Kenya and Uganda belong to the 16SrXI group of phytoplasmas, it is likely that *R. banda* is responsible for the spread of Stunt phytoplasma in Uganda; the vector will be a prime target for the management of phytoplasma disease in East Africa.
- The project developed a molecular based phytoplasma diagnostic assay called: Loop-mediated isothermal amplification of DNA (LAMP). This assay was developed to replace the nested

polymerase chain reaction (nPCR) which is laborious, costly and technically demanding. LAMP primers are designed to target a 184-bp portion of Napier stunt 16S gene (GenBank accession No. AY736374). The assay was 20-fold more sensitive than nested PCR (Published report (**Appendix 12**).

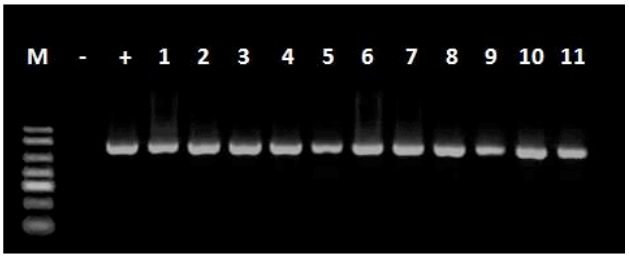
- The stunt pathogen has been discovered in Bermuda grass. Diseased plants were observed at five locations in western Kenya showing symptoms similar to Bermuda grass white leaf (BGWL) disease, caused by a phytoplasma. Affected grasses exhibited whitening of leaves, bushy growing habit, small leaves, shortened stolons/rhizomes, stunting, proliferation of auxiliary shoots and death. This was published in New Disease Reports (**Appendix 7**).
- The project established that Pearl Millet (*Pennisetum glaucum*) is host plant to phytoplasma and its vector *R. banda*. Under sceenhouse conditions, pearl millet was exposed to inoculative insects and later tested for phytoplasma presence by PCR. 8 out of 12 plants exposed were PCR positive. The plants were monitored for phytoplasma by symptoms appearance and PCR testing up to maturity and death. Phytoplasma persisted in infected plants; however, no observable symptom was recorded. Other pennisetum species were also tested (*P. clandestinum* and *P. setaceum*). The vector did not survive and there was no phytoplasma infection. Even within the genus Pennisetum, the vector has a narrow host range, only able to breed on two closely related Pennisetums: *P. glaucum* (Pearl millet) and *P. purpureum.* Phytoplasma infection to Pearl millet is a threat to millet production in the region where the crop is valued for its draught resistance and high nutrition value.
- The project has also established that infected canes can be cured of phytoplasma by hot water treatment (HWT) by boiling seed canes at 52^{0}C for 10 mins under laboratory conditions. At *ICIPE* Mbita, we are optimizing the field application of HWT in the management of Napier stunt disease. A standard protocol which can be applied by farmers will be availed. HWT shall be novel as farmers will disinfect the seed canes before planting. It is a phytosanitary measure to eradicate Napier stunt disease in the region. The method is also a measure against viruses, bacteria and insect pests that present in the seed canes.
- Research undertaken by the project, has identified 3 Napier grass varieties (Malawi, South Africa and Kakamega 5 napier) which have shown some resistant although with delayed response.
- The project conducted as study on Farmers' Knowledge and Perceptions of Napier Grass Stunt Disease(NSD) in Smallholder Farming Systems in Western Kenya. The purpose of this study was to assess farmers' perceptions of the NSD in order to investigate their knowledge and experience of the disease and how they were controlling or managing the NSD. Using a random sample of 150 farmers drawn from Bungoma, Busia and Teso districts in Kenya over 80% of them fed their livestock on Napier grass produced from their farms. The majority (86%) of the farmers knew the disease and 74% identified it as a serious threat to livestock industry during the last eight years. The disease has impacted negatively on the farmers' income earnings from Napier grass sales and milk production. About 60% of the farmers do not know the cause of the disease other than speculations on soil erosion, animals, planting young canes, etc. Farmers' lack of knowledge of the cause of the NSD calls for awareness creation on how to control its spread, research into identification of the cause of the NSD and

generation of new resistant Napier grass varieties or alternative fodder grasses(Full report Appendix 28).

- Hyparrhenia grass white leaf disease, caused by 16SrXI phytoplasma newly reported in Kenya. The Manuscript has been submitted to the New disease reports Journal for publication.

Figure 3: Field photograph of diseased thatch grass *Hyparhennia rufa* showing leaves whitened by phytoplasma infection.

Figure 4: Electrophoresis of DNA from *H. rufa* infected with the HGWL phytoplasma



In our research findings, this is the first record of group 16SrXI, '*Ca.* Phytoplasma oryzae' associated with the white leaf disease of *H. rufa,* and the first record of thatching grass as a host for phytoplasma. This report also shows that *H. rufa* is an alternative host plant for Napier stunt phytoplasma and might play a role in the epidemiology of Napier stunt disease in East Africa. As the disease spreads, it will affect the continued use of *H. rufa* as cattle fodder and thatching grass. The disease will also negatively affect soil conservation efforts in parts of East Africa where *H. rufa* is the main border grass.

Output 4: The role of cotton in *Striga* control determined and cereal-cotton rotation systems developed	**Objectively Verifiable Indicators:** • Effectiveness of *Striga* control through cereal rotation with cotton established and cereal-cotton rotation systems developed by end of year 3.

	• Major pests of cotton in western Kenya identified by end of year 2.

- Push-Pull was implemented in the in Mara Region of Tanzania in cooperation with a Tanzania Gatsby Trust (TGT) Conservation Agriculture project, and a cereal-cotton rotation system. In this initiative, the project developed a cereal-cotton rotation system. Initially the project established Push-pull -cotton rotation demonstration plots among 260 cotton farmer business groups in the Mara Region. The outcome of on-farm evaluations and collaboration with TGT shall form the basis for optimizing a cereal-cotton rotation system which can be scaled up in the country programmes.

- The project also undertook on-station screening and on-farm surveys in western Kenya to identify main cotton pests. The Cotton pests were monitored in the on-station laboratory experiments. The project also collected samples of insect pests of cotton and preserved them for identification. Damage to cotton by these pests was also recorded. The data will be used to inform on what needs to be done to develop an integrated management approach for the main pests for the farmers in East Africa. Samples of pests were collected during a survey carried out in Suba and Homabay districts of western Kenya to identify the most common cotton pests and the part of the crop they attack:
    1. Cotton Bollworm (*Helicoverpa armigera)* attacks fruit
    2. Cotton aphids *(Aphis gossypii)* attacks the leaves
    3. Stink bug (*Acrosternum hilare)* attacks leaves
    4. Mites: attacks leaves from underneath and appear red in color
    5. Cotton stonier bug (*Dysdercus sidae)* attacks the fruit part of the crop
    6. Cotton leaf worm (*Spodoptera littoralis)* attacks leaves by punching holes.

5 Conclusion and Recommendations

A. Assessment of Progress towards Impact:

i. Engagement of the key actors (individuals, organizations and institutions) who must take action to turn the project's outputs into outcomes and then impacts. *(Provide evidence of agreements, contracts etc as annexes that proves that the right actors have been engaged by the project)*

- Collaboration with country program on striga threat elimination.
- Collaboration with Tanzania Gatsby Trust and TechnoServe in Tanzania to develop a cereal- cotton rotation system.
- Memoranda of Understanding with NALEP and Heifer Project International to scale up 'Push-Pull technology and integration with livestock.

- Memoranda of Understanding with NARO and INSPIRE Consortium, Uganda), and with LZARDI in Tanzania for technology adaptation and up-scaling.
- Agreements with Western Seed Company to produce sufficient desmodium seed and to distribute and promote it in the market through its network of seed stockists.

ii. Promotion of the project and its results to the right actors. *Describe the products produced for the specific actors (individuals, organizations and institutions)*

B. Dissemination material for farmers and extension service providers:

I. Leaflets

1. Use "Push-Pull" Strategy and produce more maize by controlling stemborers and Striga Weed
2. Okukozesa Enkola "y'okusindika n'okusika" - mukulwanyisa Ndiwulira n'omuddo (kayongo) katiira kikusobozese okukungula kasooli awerako (Push-Pull Flyer in Luganda)
3. Farmers' Guide on Planting a Push-Pull Field
4. Farmers' Guide on Planting a Push-Pull Field using Desmodium Vines
5. Grow Desmodium and Stop Striga: Plant Desmodium as an intercrop and stop Striga weed growing in your maize
6. Grow more Maize and Napier Grass, Make more Money – Control maize stalkborer by planting Napier grass around your maize to trap the pest

II. Booklets

1. A Primer on Planting and Managing 'Push-Pull' Fields for Stemborer and Striga weed Control in Maize – A Step-by-Step Guide for Farmers and Extension Staff, 2nd Edition.
2. Kitabu cha maelozo juu ya upanzi na utunzaji wa mashamba ys 'vuta-sukuma' ya kuzuia buu na magugu ya Striga katika mahindi – Mwongozo wa hatua kwa hatua kwa wakulima na maafisa wa kilimo.
3. Comic Book: Push-Pull Improving Livelihoods
4. Comic book:Mfumo wa Kilimo wa Vuta-Sukuma Waimarisha Hali ya Maisha

III. Poster

1. Push-Pull Technology for management of stemborers, striga and soil fertility

IV. Book

1. Khan Z.R., Amudavi, D.M, Midega, C., Pittchar, J., Nyagol, D., Genga, G., Ndiege, A., Akelo, P., Pickett, J.A., Wadhams, L.J., Muyekho, F.N., and Nyateng, B.(Editors)

(2007). **Push-Pull Curriculum for Farmer Field Schools**. *ICIPE* science Press, Nairobi. ISBN: 92 9064 188 6

C. Scientific publications to provide evidence of the efficacy of the various technology components to the scientific community, policy level organs and development partners (**Appendices 9 – 19, 23, 27 & 29**).

D. Dissemination material for policy-level stakeholders

1. **Planting for Prosperity**. Push-Pull: a model for Africa's green revolution. Published for policy-level organs and development partners.
2. **Impact Assessment of Push-Pull Technology**. Published by Intercooperation of Switzerland for policy-level organs and development partners (**Appendix 1**).
3. **Recorded audio and video interviews**, and film clips on Push-Pull by Kenya Agricultural Information Service, Mediae, BBC Television, and Swiss TV for general dissemination.
4. Push-Pull technology website (www.Push-Pull.net). Developed for virtual community.

iii. Monitoring and Evaluating General Outcomes. (*Describe the data and evidence collected by the project to verify that changes such as in the behavior, relationships, practices, actions or performance of the main target actors, took place).*

- Striga ex-ante report
- Push-Pull impact assessment report
- Scientific papers in refereed journals on: the efficacy of Push-Pull technology, performance of its various components, integration, and long-term sustainability;
- publications on different facilitating interventions and dissemination pathways
- Project progress reports.

iv. Monitoring and Evaluation of specific Outcomes related to business development and investments. (D*escribe and provide Evidence of commercial business and investments which have resulted from project's work)*

- The project work has created business opportunities for seed companies to produce desmodium seed, and for over 600 smallholder farmers to grow desmodium seed commercially under contractual agreements with Western Seed Company.
- Sale of desmodium and other inputs has helped develop over 120 agro-dealers' businesses.
- Desmodium seeds sales and marketing by farmers
- Earnings from milk sales by smallholder dairy/Push-Pull farmers
- Earnings from the sale of livestock (dairy animals) fed on Push-Pull fodder
- Earnings from the sale of surplus fodder(desmodium and Napier) by Push-Pull farmers.

v. Monitoring and Evaluating specific Outcomes related to innovations. (*Describe the data and evidence collected by the project to verify that* innovations *(e.g. institutional and technological) were made by actors or their clients).*

- Scientific papers in refereed journals on: the efficacy of Push-Pull technology, performance of its various components, integration, and long-term sustainability; publications on different facilitating interventions and dissemination pathways
- Use of mobile phone calls and SMS in Push-Pull dissemination
- Collaborations with private sector, Research and extension partners/institutions
- Project progress reports

vi. Impact Assessment. (*Describe the data and evidence kept by the project to assess if developmental impact is being attained by a specific group of the target stakeholders)*

Participatory Impact Assessment independent report by Intercooperation, Switzerland (**Appendix 1**)

5. Indicate how the key findings contribute the Kilimo Trust mission in relation to the priority themes listed below.

i. Promotion of efficient value chains

- The Push-Pull project promotes cereal value chains at production level by increasing cereal productivity and individual farmers' outputs, and promotes soil health through ecologically sound management practices.
- The project promoted cereal input value chain by engaging Western Seed Company, a private-sector company to produce desmodium seed and sell it through a network of agro-input dealers.

ii. Support technical and institutional innovations

- Enabling collaboration between public and private sector institutions from local, national to international levels:
    - Farmers and their grassroots associations
    - Ministries of agric in EA countries
    - Private sector; agro dealers and input supplies
    - NARS and International research centers
- The project increased ability of stakeholders to prospect for knowledge by involving KARI, NARO and LZARDI in the R&D of Push-Pull; and working with these organizations, NALEP, INSPIRE and other NGOs to scale up the technology.

iii. Engage the private sector in dealing with subsector wide constraints limiting the exploitation of business opportunities

The project mainly addressed cereal production constraints, leading to availability of marketable surpluses. It has engaged seed producers and agro-dealers in the production, quality-assurance and distribution of input supplies, mainly desmodium seeds.

iv. Facilitate policy dialogue

The project has enhanced the quality and quantity of evidence available for making policy, strategies and plans through quality publication of scientific evidence in refereed journals; through production of dissemination material; and contribution to the development of a regional program on eliminating the threat of Striga. The project participated in the ex-ante assessment study, and in developing country programs. The project engages and works directly with the beneficiaries and policy makers mainly in the ministry of agriculture and livestock sectors.

v. Create economies of scale in production systems

- The project has definitely contributed to creating economies of scale in cereal production by promoting Push-Pull, a productivity-enhancing technology to create cereal surpluses for the effective engagement of small-holder farmers in the production value chains.
- The production and distribution of desmodium seeds enables farmers to enter into cash economy surplus production of cereals for sale and activation of local market activities

vi. Mainstreaming environmental sustainability

- The Push-Pull technology itself is a beneficial conservation agriculture method that leads to soil health improvement, sustainable small-holder land use, and improved agro-biodiversity:
    - PPT promotes mixed cropping and livestock integration
    - Promotes soil biodiversity, soil health and fertility
    - Elimination of biotic constrains through manipulation of plant-host interactions as a strategy to control crop pests.
- Promotes conservation agriculture; desmodium provides ground cover, reduces soil temperatures and Napier grass prevents soil erosion; an d the technology improves agricultural system resilience and adaptation to climate change.

6. Where possible, indicate any follow up activities planned either by your organization or others that will address the issues raised during the implementation.

At the local level, the project is implementing an adaption of Push-Pull technology to climate change. At national, regional and international levels, the project has engaged partners and collaborators to support research and extension activities; National Agricultural Research Systems, Heifer International, Rothamsted Research UK etc.

The project is studying the effectiveness of Participatory Video in Push-Pull technology dissemination among the smallholders in Kenya. This is aimed at improving information communication from one farmer to the other using new and innovative technologies.

5.1 General

Summarise what went well, what did not, and how difficulties were overcome.

What went well in the project.

- The outputs of the project were scaled out and integrated with national programmes under the auspices of Kilimo's regional programme on unlocking cereal productivity through the elimination of Striga threat.
- The project developed innovative approach on the application of Push-Pull technology for *Striga* and stemborer control and soil fertility management in upland rice and other cereals such as sorghum and millet.
- The project addressed the bottleneck of desmodium seed access for to wide-scale adoption of the Push-Pull system by availing the seeds for sale and for free to over 10,000 new farmers.
- An integrated management strategy is being developed for the control of the Napier stunt disease.

What did not go well and how it was overcome

Application of Push-Pull technology in cereal-cotton rotation system to control cotton pests and improving cereal yields, was met with policy obstacles in Tanzania. Inter-cropping cotton with other crops is not allowed. However the project is working with Ukiriguru Research scientists to address the challenge.

Summarise lessons for implementation of similar projects in the East African region and beyond for promotion of Broad-based wealth creation through Agriculture and Agri-business.

- Promoting institutional strengthening and empowerment through scaling up new agricultural technologies using farmers associations.
- Investing in agricultural technologies which promote environmental conservation and sustainability, which in turn lead to economic sustainability
- Need to create multi-stakeholder platforms for dissemination of productivity-enhancing technologies
- Promoting integration of cereal and livestock production systems
- Promotion of activities geared towards stimulating and strengthening of domestic markets to facilitate market-led value chain development.

5.1.1 Partnership and Collaboration

- Summary of partnership/participation arrangement with partner institutions/ organizations including farmers, farmer institutions, external service providers and other project users.

Table 1: Collaborating partner roles in technology development and dissemination

Name of the collaborator/partner institution	Role in Push-Pull technology development and dissemination	Region of work
Heifer Projects International	- Training Push-Pull farmers on livestock production - Provide livestock to Push-Pull farmers - Promoting Push-Pull as an integral system in smallholder livestock production	Kenya and Tanzania
Kenya Women Trust Fund and Equity bank	- Provides financial incentives to Push-Pull farmers	Kitale
National Agriculture and Livestock extension programme	- Technical backstopping and providing policy direction on Push-Pull technology - provides inputs enough for one acre to farmers (maize Seed, Fertilizer and Stem borer dust) - Mobilization of the farmers through groups	The lake region of Kenya and Trans-Nzoia
KARI, NARO and LZARDI	- Research on Push-Pull technology and dissemination	Lake Victoria region of Kenya, Uganda and Tanzania
National Environmental Management Authority (NEMA)	- Promotes conservation agriculture	Western Kenya and lake region
Syngenta East Africa	- Promotes and supports plant health under Push-Pull systems for higher yields	Western Kenya
Agricultural Society of Kenya shows (ASK)	- Promotion of Push-Pull through practical demonstration	Western Kenya, Kisumu, Kakamega, Kisii and Trans-Nzoia
Kenya seed	- Produces and promotes Hybrid seeds, mainly maize for Push-Pull system	The lake region of Kenya and Trans
Western seed company	- Produces and distributes desmodium seeds for Push-Pull system	western Kenya
World Vision	- World Vision provides dairy goats to Push-Pull farmer groups	Suba
Rothamsted Research	- Centre of international multidisciplinary research on: crops and products from crops; crop and soil management practices; and the	UK and in Developing countries

	diverse interactions that occur between crops, other organisms and the physical environment.	
Ministries of Agriculture and Livestock	- Policy guidance and direct implementation of the technology among smallholder farmers	Kenya, Uganda and Tanzania

- Comment on the partnership and collaboration arrangements for the project (i.e. Memorandum of Understanding, Articles of Association, Verbal Agreement with community groups, local leaders, individuals etc)

a) With farmers and farmer institutions;

The project actively partnered with farmers, farmer groups and their support systems to enhance the adoption of Push-Pull and farm productivity.

b) With project partners (in terms of the original roles and responsibilities indicated in the project proposal)

Memoranda of Understanding were executed with national partners in implementing the project. Specific memoranda were signed between *icipe* and:

- Heifer International – Kenya
- NALEP – National Agriculture and Livestock Extension Programme, Kenya
- INSPIRE Consortium, Uganda / Africa 2000 Network

c) With your host organization and other concerned organizations;

The project financial and human resource management was facilitated by the *icipe's* office of Finance and Administration director.

d) With the Kilimo Trust. What went well, what difficulties were faced and how were these overcome?

The project enjoyed commendable professional support from Kilimo Trust during its implementation. One difficulty faced was that respective country programmes were slow in taking off – which slowed down the integration of project activities at country level. Some of the experimental trials by country-level partners was repetitive not scientifically rigorous enough. The consultancy work assigned at regional level to develop market value chains did not achieve sufficient depth.

5.1.2 Economic Impact:

What has been or shall be the expected effect of the project on beneficiaries' economic well being?

The main economic impact of the project has been to increase the contribution of cereal production to wealth-creation by ensuring a predictable and sustainable cereal production level leading to marketable surpluses. The farmers who adopted Push-pull contributed an additional 142,000 tons of maize and sorghum to the cereal market, representing a monetary value of $213,000 per annum at the 2010 mean market rate.

5.1.3 Environmental Impact

Briefly describe any environmental impact/likely future impact of the project (positive or negative). If there are any negative effects, what steps do you propose to mitigate this?

The main technology being extended, Push-pull, relies on locally available plant material, with minimal external inorganic inputs. It continually improves soil fertility and reduced land degradation by preventing loss of top soil to erosion and rain water runoff. Because it uses a live mulch, desmodium, the technology conserves soil moisture. Previous scientific findings also indicated that the Push-pull agronomic arrangement promoted agro-biodiversity and abundance of beneficial arthropods. Thus the project has had a positive environmental impact, which has promoted agro-ecosystem stability and sustainability.

5.1.4 Stakeholders

Briefly describe the primary and secondary stakeholders with whom you have worked, and the project impact/ likely future impact upon them.

Table 2: Impacts of the project on different stakeholders

Output	Stakeholders	Impacts
Output 1: New legume-based and push-pull approaches developed for Striga, stemborer and soil fertility management in rice, millet and sorghum within the regional program on Striga threat elimination framework	Smallholder cereal farmers	More cereal farmers in *Striga* –and stemborer infested areas in Kenya, Tanzania and Uganda have sustained cereal production (e.g. in maize > 3t/ha), food secure, earning regular incomes from the sale of surplus cereal, milk and surplus fodder.
	Kilimo regional program on striga threat elimination	The effect of *Striga* weeds reduced in the crop lands currently infested in East Africa through implementation of integrated *Striga* and soil fertility management package, cereal grain yields improved by at least 2t/ha among Push-pull users, and Napier grass and cotton production significantly improved ensuring farmers' food security and improved livelihoods.

	National extension programs	Capacities of national extension programmes enhanced to support on-going extension of Push-pull and other complimentary technologies
	NARES	NARES more involved in responding to emerging R&D needs for further technological development, adaptation and integration in regional farming systems.
Output 2: The effectiveness and long-term sustainability of the regional program on Striga threat elimination determined	Smallholder cereal farmers	More cereal farmers in *Striga* –and stemborer infested areas in Kenya, Tanzania and Uganda have sustained cereal production (e.g. in maize > 3t/ha), food secure, earning regular incomes from the sale of surplus cereal, milk and surplus fodder.
	Kilimo regional program on striga threat elimination	The effect of *Striga* weeds reduced in the crop lands currently infested in East Africa through implementation of integrated *Striga* and soil fertility management package, cereal grain yields improved by at least 2t/ha among Push-pull users, and Napier grass and cotton production significantly improved ensuring farmers' food security and improved livelihoods.
	National extension programs	Capacities of national extension programmes enhanced to support on-going extension of Push-pull and other complimentary technologies
	NARES	NARES more involved in responding to emerging R&D needs for further technological development, adaptation and integration in regional farming systems.
Output 3: An integrated management approach for Napier stunt disease	Smallholder cereal farmers	Push-pull and dairy farmers having sustained sufficient fodder from healthy Napier grass.

developed within the framework of the regional program on Striga threat elimination	Kilimo regional program on striga threat elimination	Improved sustainability of the push-pull technology, as Napier trap plant is saved.
Output 4: The role of cotton in Striga control determined and cereal-cotton rotation systems developed	Smallholder cotton and cereal farmers	Cotton farmers having a better pest management framework, and sustaining higher production of cotton lint; cereal farmers able to progressively reduce Striga seed bank on their land, and earning extra income from cotton.
	Kilimo regional program on striga threat elimination	Improved sustainability of the push-pull technology, through rotation with cotton growing as an off-season cash crop.
	Cotton ginners	Cotton ginneries having improved supply of cotton.

5.1.5 Social Equity (gender roles, disadvantaged groups, access to resources)

Briefly describe the project's effects on different social groups. If the project successfully produced the stated outputs, how have these affected different sectors of the community? Indicate any special benefit that you think the project brought to disadvantaged groups.

The Push-pull technology promoted by the project has enabled resource-limited smallholder farmers improve cereal crop yields by more than 2 tons per hectare. The smallholder farmers produce staple cereals mainly for food. The project, by promoting cereal and fodder production, has improved food availability - cereals and milk to the most vulnerable, usually women and children. The technology has also enabled these vulnerable categories of farmers to sustainably intensify cereal-livestock production with very little external resources.

5.1.6 Sustainability

Describe how the changes brought about by the project will continue in the long term

The project has resulted in irreversible yield gains among the smallholder farmers who have adopted the Push-pull technology which is economically and ecologically sustainable. The project has anchored future sustainability in fostering partnerships with NARES, NGOS and farmer groups.

6. Financial Annual Report - Summary

Analysis of actual against budgeted expenditure during the project period. *In less than 250 words, give the summary of actual expenses against budget for the project cycle, pay particular attention to linking expenditure to the actual work that was done. In case of divergence from the budget attach detailed schedule and notes to explain material divergences. Attach certified copies of vouchers and receipts.*
Analysis of actual against budgeted incomes during the project period: *In less than 200 words, give the summary of major highlights or material differences in actual against budgeted incomes for the reporting year.(Attach as an Annex the detailed schedule and notes)*
Details of capital expenditures during the project period: *Please provide details of any capital expenditures and the identification marks for capital equipment bought by the project funds*
Financial statements: *1. There is need to provide 2 copies of a standard set of the project annual financial report as at the end of the year together with comparatives for the last two years certified by the Accounting Officer of the Organization (normally the CEO).* *2. The financial statements should be accompanied by an opinion or comments from the auditors of the Grantee Organization, regarding the particular project funds utilization.* *3. Copies of any annual returns submitted to respective authorities if any e.g. company annual return and NGO registration renewals.*

*** Financial statements should be audited.**

7. Appendices

Appendix 1. Impact assessments of push pull technology by inter cooperation, Switzerland

Appendix2. Report of Uganda country mission

Appendix 3. Report of field trip to Mara region Tanzania with Tanzania Gatsby trust

Appendix 4. FIPS model for input distribution and marketing

Appendix 5. Main challenges facing the researchers, input suppliers, extension and famers with regards to striga weed control in Kenya

Appendix 6. Monitoring the dissemination of push pull technology using mobile phones during farmer

Appendix 7. First report of phytoplasma associated with Bermuda grass white leaf disease in Kenya. New disease report vol. 21, 23.

Appendix 8. Map of east Africa showing district where push pull technology has been adopted

Appendix 9. Hooper et al, 2010.isoschaftoside, a C-glycosylflavonoid from desmodium uncinatum root exedute, phytochemist

Appendix 10. Bruce et al 2010. Is quality more important than quantity insect behavior responses to changes in a volatile blend. Biology letters

Appendix 11. Midega et al 2010. Integrated management of striga hermonthica and cereal stem borers in figure millet (eleusine corocana(l.) Gaern)

Appendix 12. Obura et al. detection ofv phytoplama by loop mediated isothermal amplification of DNA(LAMP)

Appendix 13. Midega et al 2011 host selection in chillo partellus (2)

Appendix 14. Amudavi et al., 2009. Evaluation of farmer field days as a dissemination tool of push pull technology in western Kenya

Appendix 15. Midega et al 2009. Non target effects of the push pull habitat management strategy parasitoid activity and soil fauna abundance

Appendix 16. degroote et al 2010. Participartory evaluation of integrated pest and soil fertility management options.agric.systems 103 233-244

Appendix 17. degroote et al . 2010. Economic analysis of different options in integrated pests and soil fertility management in maize systems of western Kenya

Appendix 18. Pickett,J.A, et al., 2010.Companion cropping to manage parasitic plants.ann.rev.phytopatholo.2010.38.8.1-8.17

Appendix 19. Khan et al 2010. Exploiting phytochemicalsfor developing a push pull crop protection strategy for cereal farmers in Africa. Exp.bot(in press)

Appendix 20. Jonne Rodenburg mission report may 2010

Appendix 21. Report on farmers' evaluation of the striga threat and potential of push pull technology in upland rice

Appendix 22. Report of the training workshop on striga control technologies,Tarime Tanzania 17-18 may 2010

Appendix 23. Murage et al . Determining small holder farmers' preference for technology dissemination pathways.

Appendix24. Stakeholders meeting on the control of striga weed in Tanzania 30 June 2010

Appendix 25. Joint field mission with heifer international on crop livestock integration

Appendix 26. Farmer perception of the potential if cotton rotations in a push pull system

Appendix 27. Amudavi et al., 2009. Assessment of technical efficiency of farmer teachers in uptake and dissemination of push pull

Appendix 28. Farmer perception and knowledge of Napier stunt disease

Appendix 29. Khan et al., 2009. Integration of edible beans into the push pull technology developed for stem borer and striga control in maize based cropping systems.