Delivering New Sorghum and Finger Millet Innovations for Food Security and Improving Livelihoods in Eastern Africa

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November 2011

International Livestock Research Institute (ILRI)

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Citation: Fetene, M., Okori P., Gudu S., Mneney E., Tesfaye K. 2011. Delivering New Sorghum and Finger Millet Innovations for Food Security and Improving Livelihoods in Eastern Africa. Nairobi, Kenya, ILRI.

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Consortium Project Document – Project 01/2010

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November 2010

1. Executive Summary

Ongoing and longer term predicted climate change scenarios will have serious effects on livelihoods, especially for farmers in eastern Africa, where rising temperatures, variability and changes in precipitation are affecting crop production. These situations become even worse considering that seventy five percent of the more than 100 million people in eastern and central Africa live in marginal areas and are dependent on rain-fed agriculture which forms the basis of the economy. Smallholder farmers cultivate the majority of the cropped area using traditional production methods, generally characterized by low yields that are often attributed to the use of local landraces instead of improved varieties and very few inputs as well as vulnerability to abiotic and biotic stresses such as recurrent droughts, diseases and pests. Eastern Africa also has one of the highest population growth rates in the world and in several countries the quadrupling or quintupling of population size over the past half century was supported by only 2% annual growth in agricultural production. Therefore food security is at the heart of sustainable development in the region and applied research interventions should employ solutions to increase crop productivity - quantity and quality - for food security and climate resilience.

In this regard, sorghum and finger millets are nutritious cereals that form an important part of diets of people dependent on it in its centre of origin in Ethiopia, southern Sudan, northern Kenya and Uganda. They are also widely cultivated throughout the wider eastern African region where they are known to save the poor from starvation when other crops fail due to extreme drought or other biotic stresses aggravated by negative environmental changes.

This project focuses on Ethiopia, Uganda, Kenya and Tanzania and proposes an approach that will employ both upstream and downstream technologies which will enable development of new tools for a neglected crop, finger millet, but also impact directly on farmers' fields by the introduction and adoption of improved, disease and drought tolerant sorghum varieties. Biotechnology approaches will be used to (i) assess the regional genetic diversity of existing and new collections of finger millet, (ii) map novel stay green QTL identified in Bio-Earn III, (iii) employ and/or develop molecular markers linked to genes, QTL or genomic regions associated with drought tolerance and blast resistance in finger millet.

A "lure and kill" biocontrol strategy, using pheromone traps and lethal fungi, will be employed against the sorghum chaffer, which devastates yields in Ethiopia. Improved sorghum varieties from related previous studies, with improved drought tolerance and anthracnose resistance, will be introduced to farmers through the proposed innovation platforms. These platforms will also be used to involve farmers in varietal selection processes and to disseminate the knowledge throughout the participating countries. Producer and consumer preferences for quality characteristics of sorghum and finger millet and the impact of policy changes on these sub-sectors will be analyzed.

This project proposes a framework that links potentially rewarding strategies to opportunities and constraints in agriculture in the region and therefore has potential to stimulate economic growth and sustainable development through more and better food and cash incomes. The project will bring together national, regional and international experts and stakeholders and will employ diverse research approaches that range from participatory on-farm and field experiments to exploitation of comparative genomic tools. Capacity building will occur through exchange of students and researchers from different local, regional and international institutions by involving partners from the four participating countries as well as international collaborators from ICRISAT, the University of Georgia and Swedish Agricultural University and the ILRI/BecA hub.

2. Background and rationale for the proposed project

The effects of climate change, such as rising temperatures and changes in precipitation, are undeniably affecting crop production worldwide. One region where these effects are particularly severe is Africa. The climate of this continent is now warmer than it was 100 years ago and model-based projections suggest that this warming will continue (Hulme *et al*., 2001). Predictions for the eastern African countries of Ethiopia, Uganda, Kenya and Tanzania in particular, are increased temperatures and decreased periods of rainfall in the main season of June-August by 2050, which will also become more erratic in nature (Hulme *et al*., 2001; IPCC, 2001). Moreover, due to the lack of economic, development and institutional capacity, African countries will be among the most vulnerable to the impacts of climate change (IPCC, 2001; Case, 2006).

The agriculture sector contributes 40% of the gross domestic product (GDP) of eastern African countries and provides a living for 80% of the population (IFPRI, 2004). The region depends almost exclusively on rain-fed agriculture, making rural livelihoods and food security especially vulnerable to climate variability (IPCC, 2001; Case, 2006). Moreover, the strong link between climate and livelihoods in eastern Africa, through effects on crop production, further exacerbates food insecurity and poverty in the region. Seventy five percent of the more than 100 million people in eastern and central Africa live in marginal areas and are dependent on agriculture, which forms the basis of the economy where smallholder farmers cultivate the majority of the cropped area using traditional production methods, poor management systems and outdated technology. These farming systems are generally characterized by low yields which can often be attributed to the use of local landraces instead of improved varieties and very few, if any, inputs (Anderson, 1987). In addition, several abiotic and biotic factors such as recurrent droughts, diseases and pests are important constraints that reduce productivity (Boyer, 1982; Rouse, 1988; Hanson, 1992; Dai *et al*., 2004; Monti *et al*., 2006).

Africa has one of the highest population growth rates in the world, ranging from 2.2 % to 2.8 % per year (ECA, 2002). The growth in sub-Saharan Africa is especially rapid; since 1950 the population has increased by 371% with higher rates of growth in eastern Africa (Bongaarts, 2009). The quadrupling or quintupling of population size over the past half century in many countries in the region is supported by only 2% growth in agricultural production per annum. Moreover, the per capita grain production stands at about 131 kgs per year. Projections are that this will further decline to only 84 kg per person per year by 2030 (Funk and Brown, 2009). Therefore food security is at the heart of sustainable development in the region and technological research and outreach interventions will be required to change the picture. In particular, applied research should aim at solutions to increase crop productivity for quantity and quality for food security and climate resilience. In this regard, sorghum and finger millets are known to save the poor from starvation when other crops fail due to extreme drought or other biotic stresses aggravated by climate change, thereby enhancing the capacity of rural communities to cope with negative environmental changes (National Research Council, 1996).

Sorghum

Sorghum (*Sorghum bicolor* (L.) Moench 2n = 20) is the fourth most important cereal crop following wheat, rice and maize. It is a food staple for more than 500 million people in the semi-arid tropics of Africa and Asia and more than 80% of the world area of production is confined to these two continents. In sub-Saharan Africa, over 100 million people depend on sorghum as staple (Serna-Saldivar and Rooney, 1995; Smith and Frederiksen, 2000). It is primarily a crop of resource-poor small-scale farmers and is grown predominantly in low-rainfall, arid to semi-arid environments. The crop is typically produced under adverse conditions such as low input use and marginal lands. It is well adapted to a wide range of precipitation and temperature levels and is produced from sea level to above 2000 m.a.s.l. Due to its drought tolerance and adaptation attributes, this crop is grown in eastern Africa where agricultural and environmental conditions are unfavorable for the production of other crops.

All lines of evidence point to the north-east quadrant of Africa, mainly Ethiopia, as the centre of domestication of sorghum. Therefore, the greatest genetic diversity for both cultivated and wild forms of sorghum is found in Ethiopia and the surrounding eastern African countries. It is the second most important staple cereal crop after maize in the region, making a huge contribution to the domestic food supply chain and rural household incomes with a total acreage of 8,199,741 ha. For instance, in Ethiopia, it is the 2nd staple cereal after tef, *Eragrostis tef*, and ranks 3rd after maize, and tef in total national production.

Finger Millet

The millets (the name means small seeds) represent a diverse group of cereal crops that typically produce small seeds. Millets are a group of highly variable grass species belonging to different genera that originated and were domesticated in tropical and sub-tropical parts of Africa and Asia. The characteristic attributes of these crops are their adaptability to adverse agro-ecological conditions with minimal inputs, and good nutritional properties. Millets represent critical plant genetic resources for the agriculture and food security of poor farmers that inhabit arid, infertile, and marginal lands. One of the most important millets worldwide is finger millet (*Eleusine coracana*) which was originated and domesticated in the eastern African sub-humid uplands (National Research Council, 1996; Hilu *et al*., 1979).

Finger millet (*Eleusine coracana* subsp. *coracana* 2n=4x=36) belongs to the family *Poaceae*, subfamily Chloridoideae and is one of the neglected and underutilized crops of Africa. It is extensively cultivated in the tropical and sub-tropical regions of Africa and India and is known to save the lives of poor farmers from starvation at times of extreme drought (Kotschi, 2006). Finger millet ranks third in cereal production in semi-arid regions of the world after sorghum and pearl millet (Barbeau and Hilu, 1993). It is indigenous to eastern Africa, where the oldest domesticated example of this crop was found in a prehistoric site at Axum, Ethiopia, dating back some 5000 years (Hilu *et al*., 1979). Moreover, vast genetic diversity exists in this center of origin of Ethiopia and Uganda that has not been exploited to its full potential. In parts of eastern and southern Africa as well as in India, it became a staple upon which millions depend for food and rural household incomes. Its annual world production is at least 4.5 million tons of grain, of which Africa produces more than 2 million tons (National Research Council 1996). Finger millet is adapted to a wide range of environments. The crop is grown mainly by subsistence farmers and serves as a food security crop because of its high nutritional value and excellent storage qualities (Dida *et al*., 2007). Despite its importance as a low input crop, its productivity in the region is limited to between 400 and 2,000 kg/ha (Dida *et al*., 2007). One of the major yield limiting factors is blast disease caused by *Magnaporthe grisea* (anamorph *Pyricularia grisea*). This disease has been identified as the highest priority constraint to finger millet production in eastern Africa, since most landraces and a number of other genotypes are highly susceptible (Mgonja *et al*. 2007). Moreover, finger millet is often cultivated in semi-arid and arid agro-ecology, where it is frequently affected by drought.

As a consequence, sorghum and finger millet are important cereals for many rural communities in marginal environments in eastern Africa, where they contribute significantly to the well-being of the local people. Nutritionally, the grains are equal or superior to other staple cereals as they are a good source of quality protein and various minerals. In marginal and medium agricultural zones, sorghum and finger millet are high priority staples in Ethiopia, Sudan and Uganda (Mendelsohn, 2000; Ketema, 2008).

Despite their importance, numerous biotic and abiotic constraints limit production of sorghum and finger millet. These call for the need for more drought tolerant varieties, disease resistant and pest tolerant varieties adapted to low inputs in marginal lands. The average yield of, for instance, sorghum in eastern Africa has been limited to only 0.6-1.5 t/ha compared to the worldwide average yield of more than 4.3 t/ha. The combined biotic stresses reduce sorghum grain yields by at least 60% while drought stress may cause total loss of the crop. Current and predicted climate change will likely result in increased temperatures and unreliable rainfall, and may lead to a larger diversity of pests and diseases attacking these crops. Sorghum and finger millet production in eastern Africa is expected to be greatly affected by the effects of climate change and the livelihoods of millions of people depending on these crops are at high risk. Hence, producing more resilient and drought tolerant varieties that are adapted to the changing climate as well as controlling diseases and pests through innovative biological systems is central to sustain the lives of millions in the region.

One of the most devastating insect pests to agriculture in general and to sorghum in particular is chaffer (*Pachnoda interrupta* (Coleoptera: Scarabaeidae)). Conventional chemical based control has been ineffective due to the immense range of host plant preference (wild and cultivated) which sustains chaffer populations outside sprayed fields, emphasizing the need for more environmentally friendly alternative management strategies such as biological control. Entomopathogenic fungi are good candidates because they are genetically stable, target specific, can be mass produced cheaply, have high virulence and relatively rapid action (Prior and Greathead; 1989, Lomer and Prior, 1992). Recent studies employed pheromone traps to disseminate fungi within populations of insects (Pell *et al*., 1993; Dowd *et al.*, 1992; Vega *et al.*, 1995; Klein and Lacey, 1999). Target insects were lured into specially designed inoculation chambers by host plant volatiles or pheromones where they become contaminated with infective fungal conidia and then returned to their feeding and breeding habitats, disseminating the pathogens among their own population (Jackson *et al*., 1992; Lacey *et al*., 1994). This system is more beneficial than conventional use of mycoinsecticides because it is target specific if the pheromones used only attracts the target pest and only small amounts of pheromones and fungal inoculums are required.

The basic aspects of the *'lure and kill''* strategy is the latest approach in Africa had been studied in a SIDA-funded AAU-SLU joint research project (Wolde-Hawariat *et al*., 2007; Bengtsson *et al*., 2009). As a result, promising and compatible agents (a putative attractant pheromone and a potent indigenous fungal isolate) have been identified. This strategy, as proposed in the current project, will serve as model to manage major agricultural insect pests by combining compatible, environmentally sound and economically feasible management options (a pheromone and a biopesticide) in the region.

Crop improvement through conventional breeding is slow, especially for traits controlled by quantitative gene action like drought tolerance. Hence, the use of modern crop improvement tools such as genomics to transfer information about genes from model species to the species of interest and genetic mapping in order to identify genes controlling traits of interest can provide a more timely and robust response to crop production threats (Sorrells *et al*., 2003; Praba *et al*., 2009). It also provides added opportunities to develop crop varieties with multiple stress tolerance. Therefore, a crop's response to drought and/or pest attacks can be studied by the evaluation of traits that are related to these abiotic and biotic tolerances at the physiological, cellular, biochemical and molecular level. Genomics research has entered a new phase based on next generation sequencing, large-scale expressed sequence tag (EST) projects and cDNA microarray databases for identifying sets of genes associated with the expression of a target trait. Crop species of the Poaceae, such as rice, sorghum, finger millet and pearl millet, display a remarkable level of genetic similarity despite their evolutionary divergence 65 million years ago (Bennetzen and Freeling, 1993; Paterson *et al*., 1995; Gale and Devos, 1998; Devos, 2005). The high levels of conserved colinearity between different grass genomes can facilitate the exploitation of the information and resources available from sequenced genomes in species with less genetic resources such as finger millet to develop superior lines or genotypes that can perform well in drought prone drylands (Srinivasachary *et al*., 2007).

The success of comparative genomics and breeding programs is usually dependent upon understanding the evolution, amount and distribution of variability present in a gene pool. Understanding patterns of neutral and adaptive diversity from the population to the landscape scale is essential to clarify and identify landraces and populations that are resilient to climate change (Mercer and Perales, 2010). Hence, compiling information on the extent and distribution of the genetic diversity of finger millet populations and their wild relatives in eastern Africa is an important element in the utilization of germplasm resources for breeding superior genotypes (Vinod *et al*., 2006; Mullet, 2009; Krill *et al*., 2010). Understanding the price farmers and consumers are willing to pay for different quality characteristics and value chain analysis of finger millets and sorghum sub-sector can also offer better way for policy formulation that can stimulate economic growth in sorghum and finger millet growing regions of eastern Africa. In addition to crop improvement, enhanced knowledge of marketing opportunities for these crops through engagement with the private sector and farmer participatory approaches will result in increased benefits to smallholder farmers who produce improved varieties of sorghum and finger millet.

This project proposes to map new QTLs/genes associated with drought tolerance in novel stay green sorghum germplasm identified in Bio-Earn III, to disseminate lines tolerant to anthracnose disease and to deploy a biocontrol strategy against sorghum chaffer. Sorghum anthracnose occurs throughout eastern Africa; however, it is more prevalent in warm, humid areas (Tarr, 1962; Pastor-Corrales and Frederiksen, 1980), where grain yields from susceptible cultivars may be reduced by up to 50% during severe epidemics (Harris and Cunfer, 1976). Chaffer is a devastating pest to agriculture crops in general, and to sorghum in particular. Tolerance to this pest will be crucial to contribute to increasing productivity of sorghum in eastern Africa. The project further proposes to explore the genetic diversity of finger millet in eastern Africa and to evaluate its adaptation to drought and blast disease using morpho-physiological and modern genomics tools. Phenotypically characterized traits from genotypes collected in this study will be evaluated for association with genes potentially underlying those traits to identify markers for future use in marker assisted breeding. The project also aims to contribute towards food security in dry lands by identifying stable and high yielding genotypes of sorghum and finger millet that are adapted to the current threats of crop production caused by climate change. Generally, high yielding, drought and disease tolerant genotypes of these crops will be exploited in order to increase the incomes of local farmers and stimulate economic growth for sustainable development in the region.

3. Adding value to existing efforts (relevance and quality of contents of the proposal)

The most important development challenges facing Africans are well articulated in the many Africa Union declarations and programmes such as the New Partnership for Africa's Development (NEPAD) and the UN Millennium Development Goals. The combined impacts of changes in climate on agriculture, food and nutrition crises, combined with the global economic recession, will move a large majority of vulnerable populations into extreme hunger and even starvation (Mendelsohn *et al*., 2000). Climate change is predicted to have drastic effects on the water balance in marginal areas and hence harm the agricultural sector in Africa. These effects will be felt most acutely in semi-arid and arid lands, as well as medium or even high production zones. In eastern and central Africa (ECA), 75% of the population of more than 100 million is dependent on traditional low input agriculture for their livelihoods which supports very low crop and livestock productivity (Omamo *et al*., 2006). These marginal areas cover vast expanses of land in Kenya, Uganda, Tanzania, Sudan and Ethiopia.

The agriculture sector in eastern Africa is exposed to the effect of failed rains or occurrence of successive dry spells during the growing season, which usually leads to food shortage. Moreover, drastic climate changes also render large regions of marginal agricultural lands unproductive. The combined effects of predicted climate change and weak and vulnerable agricultural systems present a strong case for strategic investment to minimize risks and loss of lives, and to promote development and equal opportunity communities in the marginal regions of eastern Africa. For these areas any deliberate attempts to enhance the capacity to cope with imminent environmental change, is thus essential. To this end, it is imperative for countries in this region to apply biotechnological tools to develop crop cultivars that adapt to the changing environment. One priority is the identification and utilization of improved drought tolerant sorghum and finger millet lines and detection of genes responsible for drought and disease tolerance. The promotion and adoption of improved drought and disease tolerant sorghum and finger millet cultivars will increase resilience of these crops to the changing climate and increase productivity under moisture deficit conditions. This in turn will improve food security and livelihoods of the large number of people depending on these crops in the region. Hence, this project fits well to Thematic Area 1 (Climate change adaptability, productivity, value addition and improvement for food and nutrition security) and contributes to reliance to climate change and contributes to food security.

These target crops and intervention strategies have already been prioritized by the ASARECA Staple Crops Programme under the Business Un-usual model meant to stimulate development (Omamo *et al*., 2006, www.asareca.org for Staple Crops Strategy). In addition, BioInnovate has also prioritized investment in sorghum and millets based on available and promising innovations as one of the strategic efforts to strengthen resilience of rural communities and agricultural systems in eastern Africa. In this line, the proposed project will discover, develop and deliver improved technologies and processes for producing sorghum and finger millet that are traditionally the two main African dry land cereal crops.

Previous work and achievements, along with on-going efforts towards improving sorghum and finger millet productivity in eastern Africa, will be given due attention to realize the proposed goals. From a previous Bio-Earn funded project, novel drought tolerant sorghum lines were identified with higher levels of stay green characteristics better than the already identified and characterized lines such as the E36-1 and B35 in some parameters. These novel sources have potential for use in drought prone areas and this project proposes to map the drought tolerance of these genotypes. The previous Bio-Earn and Syngenta Foundation for Sustainable Agriculture (SFSA) model projects as well as ICRISAT's expertise in QTL/gene mapping and marker assisted introgression of stay green from E36-1 will serve as a model. Additional sorghum varieties were also developed under Bio-Earn with improved anthracnose resistance and these will be disseminated within this project. Similarly, a previous SIDA/SAREC funded project made considerable advances towards the management of sorghum chaffer, *Pachnoda interrupat*, a devastating insect pest that has hampered the production of sorghum. The project will also make use of information generated and advanced genotypes of finger millet developed for Ethiopia by African chloridoid cereals project funded by McKnight Foundation (Annual Scientific Progress Report 2009).

The present project is designed in collaboration with scientists from the International Crops Research Institute for the Semi-Arid Tropics Eastern and Southern Africa (ICRSAT-ESA) Regional Office that are affiliated with the BecA/ILRI-Hub in Nairobi as well as with international Universities with relevant expertise such as the University of Georgia, USA (UGA) and the Swedish Agricultural University (SLU). Most importantly, key objectives of the project such as improving productivity by identification of superior genotypes through regional collaborations are in line with the missions and visions of ASARECA and FARA. In addition, capacity building activities, mainly training of PhD students in crop population genetics, breeding, genomics and stress physiology by networking at regional and international level will provide a strategic platform to foster continental and global networks that will reinforce the capacity of eastern African agricultural researchers and align with the FARA objectives. The project is complementary to the on-going Bill and Melinda Gates Foundation (BMGF) funded HOPE (Harnessing Opportunities for Productivity Enhancement of Dryland Cereals) project that is coordinated by ICRISAT, a BMZ funded project on finger millet diversity and improvement of African Chloridoid cereals project. Moreover, this project will anchor and scale up the finger millet genetic enhancement and revitalization project in western Kenya currently funded by the FAO Benefit Sharing Funds of Treaty on Plant Genetic Resources.

4. Potential for economic and social impact

Agricultural productivity in eastern Africa chronically suffers from limited integration into national and regional market value chains and has low investments/benefits from research and development (Padulosi *et al*., 2007). Understanding the specific agricultural development options and focusing on their implications for growth and poverty reduction, requires a framework that links potentially rewarding strategic directions to opportunities and constraints in agriculture in the region. The potential for sorghum and finger millet to catalyze regional development is high. Trade statistics from FAO show that in total, Africa imports up to 1 million tons of sorghum per year. Moreover, yield gains of sorghum and millets, if coupled with other enterprises, can stimulate up to 6% Agricultural Gross Domestic product (AgGDP) needed to stop extreme hunger and poverty (Omamo *et al*., 2006). Also, these crops have the potential to stimulate growth and resilience to the effects of climate change, thereby contributing to the achievement of the Millennium Development Goals (MDGs) which include: eradicating extreme poverty and hunger (MDG1), ensuring environmental sustainability (MDG7), promoting gender equality and empowering women (MDG3), and developing a global partnership for development (MDG8). Generally, this project has potential to stimulate economic growth and sustainable development in the region as the livelihoods of more than 100 million people stand to be improved through more and better food and cash incomes.

5. Regional and International Collaboration

Climate change is expected to place considerable additional stress on livelihood security in Africa (SEI, 2008). The greatest impact will occur from increased water stress, flood risk, food insecurity, losses of biodiversity, livelihoods and economic production, increased health risks and other factors discussed in the IPCC (IPCC, 2007). These effects are complex and not restricted by national borders. Accordingly, regional efforts have been identified as critical to address these challenges, which cannot be achieved efficiently by single country interventions. The generation of a special type of public good, i.e. crop varieties, technologies and processes, that address regional concerns, have been highlighted as examples of products categorized as regional public goods. The sorghum and finger millet based innovations proposed in this project will thus generate regional public goods. Innovation strategies will be applied via a dynamic framework - the Innovation Platform – with built-in adaptability from research and development to production and consumption, taking into consideration the full value chain. The innovation platform approach will focus technology generation processes, address institution linkages, strengthen research networks and partnerships and promote capacity building.

The project aims to bring together experts and stakeholders at national, regional and international levels and employs a diverse research approach that ranges from participatory on-farm and field experiments to exploitation of comparative genomic tools and will provide a strategic platform for sorghum and millets improvement. The proposed project has a unique advantage to achieve its objectives by utilizing advanced genomics tools and on-farm participatory approaches, and exchange of students and researchers from different local, regional and international institutions, by involving partners from the eastern African countries, Ethiopia, Uganda, Kenya and Tanzania as well as international collaborators from ICRISAT-Nairobi scientists based at the BecA/ILRI hub who will provide expertise, technical backstopping and biotechnology facilities for the genotyping and genomics activities. The Departments of Plant Breeding and Biotechnology and Plant Protection Biology of the Swedish University of Agricultural Sciences (SLU) will also provide laboratory facilities to carry out part of the analyses in this project while the Devos laboratory at the Institute of Plant Breeding, Genetics and Genomics at the University of Georgia (UGA) will mainly host and provide a core facility for comparative genomics study of finger millet and other grasses in collaboration with laboratories in the eastern Africa.

6. Project goal and purpose

7.1 Goal

Enhanced sustainable productivity and competitiveness for Sorghums and finger Millet sub-sector in the eastern Africa leads to better food security, incomes and overall livelihoods.

7.2 Purpose

To generate, collate and deliver sorghum and finger millet technologies that minimize the effects of climate change; and raise productivity and income of sorghum and finger millet producing farmers through development-oriented research and action in eastern Africa.

7. Objectives

1. Evaluation, promotion and adoption of sorghum and finger millet genotypes for drought and disease tolerance.
2. Development of breeding tools and technologies for high yielding and adapted finger millet in eastern Africa.
3. Develop and promote best management strategies for sorghum chaffer pest and anthracnose, and finger millet blast disease.

4. Undertake marketing and value chain analyses of sorghum and finger millets in eastern Africa.

8. Outputs

Output 1. Drought and other abiotic stress tolerant novel sorghum genotypes evaluated on-farm and adopted by farmers, and stay green QTLs mapped on sorghum genome.

Output 2. Finger millet genotypes evaluated and characterized for drought and blast tolerance.

Output 3. Modern tools and knowledge to improve breeding of high yielding and adapted finger millet developed and promoted in partner countries.

Output 4. Environmentally friendly and sustainable sorghum chaffer and anthracnose and finger millet blast management options developed and adopted in chaffer, anthracnose and blast affected regions.

Output 5. Data and knowledge to strengthen and expand market opportunities and value chains of sorghum and finger millet in targeted countries generated and promoted.

10. Outcomes

The vision of success for this project is to strengthen the resilience of communities in eastern Africa to drought and biotic stresses by improving productivity and market opportunities. The project proposes to mobilize state of the art science and technology, to generate novel products and technologies, based on sustainable and renewable natural resources. It will also build the region's scientific capacity to innovate, competitively expand and engage other market actors in Africa and globally. The key outcomes envisioned are:

1. Food security of targeted eastern African communities living in drought prone area enhanced.
2. Targeted eastern African communities develop capacity and resilience to climate change, based on sorghum and finger millet technologies.
3. New tools for breeding finger millet strengthened in partner NARS.
4. Capacity of R&D systems that contribute to food security in target countries strengthened.
5. Sorghum production through sustainable management of sorghum chaffer and anthracnose, and finger millet blast leading to improved food security in the region.
6. Strengthened capacity of pest and diseases management research and development in the region.
7. Production, utilisation and market access of sorghum and finger millet enhanced in the region.
8. Livelihood of sorghum and finger millet producers improved.

11. Methodologies and description of project activities

11.1 Overall project design

The project is designed to study, test, and capture and subsequently employ lessons learnt from the diverse ecological and socio-economic contexts of eastern Africa to enhance climate change resilience of the regional community. The project will be implemented in drought prone and medium productivity agro-ecologies of the region. The project innovation pathway will involve characterization of the socio-agro-ecological contexts, discovery and development of technologies, innovations and processes as well as strengthening the functionality of value chains. The project design recognizes the integrated nature of the challenges posed by drought, pests and diseases and has thus integrated a research and development focus. Detailed activities are described in line with these objectives.

11.2 Description of project activities

Objective 1. Evaluation, promotion and adoption of sorghum and finger millet genotypes for drought and disease tolerance.

11.2.1 Sorghum innovation activities

11.2.1.1 Elite sorghum variety development and promotion

A. Farmer participatory breeding activities

1. On-farm evaluations. This will include evaluation of elite materials generated via BIO-EARN Phase III, specifically for drought and also other biotic and abiotic stresses that limit sorghum performance and productivity in most agro-ecologies. Attributes which affect sorghum performance, adaptability and yield will be assessed in Ethiopia, Kenya, Uganda and Tanzania. The field evaluation will be carried out in drought prone sorghum producing areas and other ecologies that provide the suitable screening conditions such as low pH, high and disease pressure in the region. Procedures required for variety release will be included in the design of experiments including the use of known standard for drought, pest and disease resistance. The two, known stay green materials such as E36-1, B35, will be included (Table 1). Based on the advanced sorghum populations in our possession developed in BIO-EARN phase III and the knowledge of sorghum agro-ecologies and its production constraints in the eastern Africa region, the farmer participatory selection and evaluation will be carried out in different countries as shown Table 1 below.

Table 1. Advanced material ready for use in participatory on-farm evaluations

Category of germplasm	**Country of evaluation**	**Nature of population**
1. Drought, Striga, aluminium toxicity and P-use efficiency, earliness	Kenya and Tanzania	Staygreen F4-F5 derived materials, Early maturing types
2. Disease and staygreen	Uganda	F4-F5 derived materials
3. Stay green (new source - Sorcoll 163, Sorcoll 141, Sorcoll 146	Ethiopia	Landrace
4. Stay green (B35)	Uganda and Kenya	BC 3 material

2. Characterization of sorghum and millet seed systems for targeted strengthening. The aim of this activity is to gain full understanding of the sorghum and millet seed supply system and the factors limiting the production, multiplication, and marketing of improved seeds. The study will be conducted in all four countries (Ethiopia, Kenya, Tanzania and Uganda) drawing lessons from the more advanced maize seed systems. The study will (i) identify and characterize sorghum, finger millet, maize seed production organizations in partner countries; (ii) document sorghum, millet and maize varieties marketed by seed merchants in each country; (iii) identify factors negatively influencing efficient deployment of seeds; (iv) make recommendations for addressing critical bottlenecks which contribute to the efficiency of variety release, seed production, and distribution of improved sorghum seed in Eastern Africa. The outputs from this study will be used to strengthen the seed systems. The specific actions to strengthen both formal and informal systems will be targeted. The seed system value chain approach will be used in the design of the study. Farmer preferred cultivars or populations selected in participatory breeding process above will be: (i) multiplied by selected farmer groups, NGOs or sorghum seed merchants who are willing to undertake seed multiplication, (ii) sorghum seed stock lists will be identified and brought together with the seed producers to agree on the terms of business, (iii) agro-dealers in general will also be brought into the consortium. Intellectual property issues and other conditions of release of breeders' seed to producers will be discussed and terms agreed upon.

3. Promoting alternative uses of sorghum. The intention of bioinnovate program is to improve livelihoods of the people of eastern Africa using bioresources in the region. Sorghum and finger millet are traditional bioresources whose production skills are with the local communities. In order to use sorghum and millet to spur economic development in the region, there is need to promote alternative uses that could utilize surplus grains. The East Africa Breweries Limited (EABL) and other small scale local brewing agencies require near limited amount of white sorghum for producing some brands of beer and local brews. Sorghum and millets could be promoted as livestock feed, especially in the dry land areas of eastern Africa. The project will promote use of white seeded sorghum for brewing and livestock feeding.

B. **Validation of new sources of staygreen and elite materials from BIO-EARN Phase III**

1. Phenotyping of new staygreen sources. The new sources of staygreen identified under BIO-EARN III .e. (Sorcoll 163, Sorcoll 141, Sorcoll 146) will be validated and fully characterized using both molecular and physiological approaches. These lines, compared to E36-1 and B35, had higher green leaf area, higher chlorophyll content, higher photosynthetic rates and lower levels of leaf senesces in post-flowering drought in repeated experiments (Addisie, 2010; Dagnachew, 2008). Further evaluation focusing on validation and hence their utility as a source of post anthesis drought tolerant germplasm is needed. Fully characterization of these staygreen sources based on specific higher nitrogen (SLN) is also required. Using SLN it has been shown that stay green is a consequence of the balance between N demand by the grain and N supply during grain filling as well as enhanced transpiration efficiency (Borrell and Hammer, 2000). The evaluations will be done against standards such as B35 and its derivatives. SLN will be measured indirectly by estimating radiation use efficiency (RUE) and transpiration efficiency (TE). This will be done to lay a solid foundation for both mapping and localizing the drought tolerance loci.

C. QTL mapping of identified stay green sorghum lines

The stay green sorghum lines that were found to be better performing than the already identified stay green lines from BIOEARN phase III project (Sorcoll 163, Sorcoll 141, Sorcoll 146) will be used in this study. These lines, compared to E36-1 and B35, had higher green leaf area, higher chlorophyll content, higher photosynthetic rates and lower levels of leaf senesces in post-flowering drought in repeated experiments (Addisie, 2010; Dagnachew, 2008). At least three F2 mapping population will be developed by crossing the stay green lines with a non-tolerant sorghum genotype such as Tx700 in sorghum (Harris et al. 2007). F2 mapping population can be generated in one year by working during the main season as well as during the off-season in the national sorghum research center at Melkassa as there is irrigation facility during the off-season. One hundred fifty seeds of each F2 populations will be sown under simulated moisture deficit condition (under rain-out shelter). Each plant in all populations will be characterized for their tolerance to drought (phenotyped) using parameters such as rate of leaf senescence, green leaf area at maturity, components of leaf greenness, etc. Based on these parameters, each plant will be categorized as drought tolerant or susceptible.

Microsatellite markers from all chromosome regions will be screened for their polymorphism between parents and bulks. Markers that are linked with the already identified stay green genes such as *NPI414, Xtxs1114, BNL15.20, Xtxs584, RZ323, CSU58, A12-420, Xtxs1307, Xtxs1111, UMC5, Xtxs713* etc will be included. SSRs will be amplified and analysed using fluorescent labeled forward primers. All polymorphic markers will be assayed in all individual F2 progenies and parents using the ABI PRISM_ 3100 genetic analyzer (Applied Biosystems). Data will be collected using 3130xl data collection software, v3.0 (Applied Biosystems). The size of the detected alleles will be determined using the GeneMapper software, v4.0 (Applied Biosystems).

The F2 individuals will be classified as homozygous tolerant (identical allele size to the resistant parent), homozygous non-tolerant (identical allele size to the susceptible parent) and heterozygous tolerant (having both parental allele sizes). Later, the goodness-of-fit to the Mendelian segregation patterns will be tested using Chi-squared distribution analyses. Based on these data, the genetic map will be constructed using the software JoinMap, v.4 (Van Ooijen 2006) applying the Kosambi function (Kosambi 1944) and a LOD score 3. Comparison on the position of the genes/QTLs in all populations will be checked with the already identified drought tolerant genes such as *Stg1, Stg2, Stg3, Stg4* to determine their novelty. Location and novelty of new QTLs in the populations will be compared to those already documented from E36-1 and B35 genotypes (Harris *et al*., 2007).

D. Genotyping new material and validation of molecular markers for breeding

The populations identified (For TLB, aluminium Phosphorus and staygreen etc) (Table 1). Molecular markers generated under Phase III of BIO-EARN will be validated and tested on the existing populations developed. Good markers will be used along with phenotypic bases to develop a marker assisted breeding strategy for sorghum. This activity will be linked to ongoing MAB work at ICRISAT and will also involve national sorghum breeders for dissemination purposes.

11.2.2 *Finger* Millets innovation activities

11.2.2.1 Assembling and evaluation of finger millet genetic resources

1. **Assembly of germplasm for assessment**. Finger millet collections that are held at ICRISAT, in Africa under the BMGF funded HOPE project was collected from Uganda, Kenya, Tanzania and Ethiopia in 2009/2010. However, these collections were not exhaustive and there are gaps in collections from some regions, especially northern Uganda and Ethiopia. Hence, collections will be undertaken in locations previously neglected or missed, especially for compatible wild relatives primarily from Ethiopia, Uganda, Kenya and Tanzania. Overall, the project will select genetically diverse materials that were previously collected and maintained by complementary projects and programmes in the region (ICRISAT, HOPE project, Universities, National Gene Banks etc).

2. **Genetic diversity analysis.** The only published study that conducted a finger millet biodiversity study using molecular markers was carried out by Dida et al. (2008) in the Devos laboratory at UGA. Both Dida from MU, Kenya and Devos from UGA, USA are collaborators on this project. The study included both Indian and African cultivated lines and wild *E. coracana* subsp. *africana* germplasm (Dida et al. 2008). A total of 17 accessions from Uganda, 7 accessions from Kenya, 6 accessions from Ethiopia and 2 accessions from Tanzania were included in the Dida et al. (2008) study. There has been no collection of wild finger millets except few collections from Uganda and Kenya. Hence, the Dida et al. (2008) study did not include an in-depth analysis of the variation present in finger millet germplasm in eastern Africa. Moreover**,** genotyping of finger millet germplasm by ICRISAT in India has been limited and used only the 20 markers published by Dida et al. (2008). This genotyping also focused on Indian varieties and did not include African germplasm, therefore leaving a gap which is being addressed to some extent by the HOPE project and that we propose to fill with this proposal.

   In this project, two forms of analysis will be carried out to identify novel genotypes and assess the genetic diversity assembled in sub-activity one above i.e. phenotypic and molecular analyses. Phenotypic analyses will be done using International Descriptors for finger millet (IBPGR, 1985). The same individuals will also be subjected to genetic diversity analysis using microsatellit**e** (SSR) markers (Taberlet *et al*., 1991; Dida *et al*., 2007, 2008). Phylogenetic analysis will be performed to delineate clusters of relatives for potential wider hybridization and later studies.

11.2.2.2 Identification of novel and highly adapted finger millet genotypes

1. **Screening for drought tolerance.** Phenotypic screening will be done in the field in multiple locations and/or across at least two seasons under controlled (rain-out shelter) conditions. Promising lines will be compared with reference materials obtained from ICRISAT. Promising lines will be targeted for breeding programmes.

2. **Screening for diseases.** This activity will focus on screening finger millet for blast resistance (head and neck blast caused by *Magnaporthe grisea*). The work will be done under both controlled and field conditions in Ethiopia and Uganda.

Objective 2. Development of breeding tools and technologies for high yielding and adapted finger millet in eastern Africa.

Generation of molecular tools for marker assisted breeding. Trait mapping can be done either in biparental mapping populations using a traditional QTL approach or can be done in diverse germplasm and/or breeding materials using an association mapping approach. The latter strategy will be used to identify regions of the finger millet genome associated with drought tolerance and blast resistance. The strategies used for association mapping will depend on the extent of linkage disequilibrium (LD) that is present in the species of interest. The faster LD disintegrates, the more markers will be needed in order to be able to detect associations between markers and traits in whole genome scans. To date, no LD studies have been carried in finger millet. Finger millet is an inbreeding species and LD is thus likely to extend over longer distances than in an out-crossing species. Nevertheless, even if LD extends to up to 1 cM, it is still expected to need, at a minimum, a few thousand markers to conduct a whole-genome scan. Since such a large number of markers are not currently available in finger millet, in this project it is propose to use a candidate gene approach.

Drought tolerance has been studied extensively in both model species and crops and a large number of genes have been identified that are involved in drought response. At least 11 blast resistance genes have been isolated from rice. Primers against 20 genes known to be involved in drought/and or blast resistance in other species will be developed. The corresponding gene sequences will be identified from rice, brachypodium, sorghum and foxtail millet, four diploid species with fully sequenced genomes. The rice, brachypodium, sorghum and foxtail millet orthologous sequences will be aligned to identify conserved regions that can be used for primer design (Bennetzen and Freeling, 1993; Gale and Devos, 1998; Devos *et al*., 2000; Devos, 2005; Srinivasachary *et al*., 2007). Primers will be designed to span an intron. These primers will be used to amplify the orthologous regions in a set of 100 finger millet lines. The finger millet amplicons will be sequenced and analyzed for SNP variation that differentiates the 100 lines. The same set of 100 lines will also be phenotyped for drought and blast resistance and genotyped with a set of 30 SSR markers (see Objective 1). The SSR diversity analysis, in addition to providing a measure of the diversity of finger millet germplasm in the region, will also give insight into the population structure of the finger millet association panel. Correction for the population structure in association mapping is necessary to avoid spurious marker-trait associations. The genotypic and phenotypic data will be tested for marker-trait associations using the software TASSEL. Overall results from this activity will be pipelined to national breeding programmes for marker assisted selection and variety evaluation and release.

Objective 3. Develop and promote best management strategies for sorghum chaffer pest and anthracnose, and finger millet blast disease.

Sorghum chaffer management. Develop and promote sorghum chaffer management to reduce national and regional threat as well as increase productivity. The activities will largely be based in Ethiopia such as Ambo Plant Protection Research Center, DLCO–EA, and AAU. Specific activities are described below:

- Explore and screen new fungal isolates for effectiveness as bio-control agent in sorghum chaffer breeding and outbreak areas.
- Formulate dosage and apply selected fungal isolate(s) for sorghum chaffer.

- Develop and evaluate the catching efficiency traps made from locally available materials.
- Evaluate the performance of an auto-dissemination device for attracting chaffer with an appropriate pheromone combined with the application of the selected lethal fungal isolates against chaffer while feeding on wild hosts close to farms compared to on sorghum in the farms.

Develop and promote best management strategies for diseases (anthracnose, blast):- Develop and promote disease management strategies for sorghum and finger millet. Sorghum production as well as finger millet is curtailed by anthracnose and blast for sorghums and millets respectively. The design of appropriate and effective disease management strategies is based on clear understanding of epidemiology (spread of disease over distance and time) and host pathogen interactions (Agrios, 2007). The following activities will be conducted in Uganda, (i) Elucidate and test disease spread and control of anthracnose and blast (ii) Test disease spread management of anthracnose and blast.

Objective 4. Undertake marketing and value chain analyses of sorghum and finger millets in eastern Africa.

Marketing and value chain analyses. Whenever a new crop variety is introduced, farmers implicitly evaluate them before adoption. The aim of this study is to determine the price farmers and consumers are willing to pay for different quality characteristics of sorghum and finger millet. Findings from this study will inform crop breeders, marketers, and policy makers on the most valued characteristics of sorghum and finger millet. The key activities will include

(i) Assessment of producer and consumer preferences for quality characteristics of finger millet and sorghum in Ethiopia and Kenya using a theoretical model to be adapted from Rosen's hedonic pricing framework (Houston et al., 1989). Rosen postulated that goods are valued for their utility-bearing attributes or characteristics. Rosen postulated that goods are valued for their utility-bearing attributes or characteristics. That is, consumers derive utility from the attributes of a good and not from the good per se. Assuming that a good *i* has *j* different characteristics, then the price of the good will depend on the amount of each characteristic it has as follows:

$$P_i = P(x_{i1}, x_{i2}, \ldots, x_{ij})$$

Where P_i is the price of a good *i* (finger millet or sorghum) and x_{ij} is the amount of some characteristic *j* (production or consumption characteristics) per unit of good *i* (finger millet or sorghum)

(ii) Assessment of the impact of policy changes on finger millet and sorghum sub-sectors. In order to stimulate use of local produce for industrial use the governments in the region apply various tax exemption policies and financial support. This study will use the multi-market partial equilibrium model of Arulpragasam and Conway (2003) to evaluate three related markets comprising the value chains of specialized finger millet/sorghum, namely: input market (seed, fertilizer, and labor), grain market and processed product market. Data required by this model include production, consumption, and prices of finger millet/sorghum inputs, grain, and processed products. Other types of data required include incomes, seasonality, and other supply and demand shifters.

12. Pathway to impact and applicability of results in practice and dissemination

12.1. Potential Development impact areas of the project

In a recent study, eight agricultural development domains that show how strategic investments should be made in Eastern and Central Africa (ECA) have been described (Omamo et al., 2006). For semi-arid and marginal areas of ECA, comprising about 60% of agricultural land, strategic investments that target harnessing of sorghum and finger millet based technologies in concert with other especially livestock enterprises can stimulate a 6% annual agricultural GDP growth needed to reduce poverty and hunger. Realisation of full benefits of technologies however requires strengthening linkages and generating mutual benefits across countries. Accordingly, this regional team has been organized to harness opportunities resident in different countries and cause them to bear on the common regional development challenge of climate and human induced production challenges. The proposed project's research for development at the regional level is built on the premise that agricultural research could help alleviate poverty in many ways. Farm households that adopt the resulting technologies can benefit directly from higher yields and incomes, but benefits are not just experienced by the adopting households. The indirect impacts of research (such as cheaper food and more jobs) can also improve the living standards of the wider population. Schematic representation of the contribution of major activities is indicated in Appendix 3.

12.2 Applicability of results in practice and dissemination pathways

Global circulation models all show that Africa will be most affected by Climate Change (UNCTAD/TIR/2009*).* In eastern Africa, the models predict two scenarios; increased drought and higher but variable precipitation in selected areas of Ethiopia, Kenya, Uganda and Tanzania. This project focuses on two crops – sorghum and finger millet - to deliver technologies that will be used to enhance the resilience of communities to the predicted effects of climate change – for drought via drought tolerant varieties and disease and pest resilience for wetter and more humid scenarios. A number of drought management technologies such as planting of drought tolerant varieties and tillage practices, have been developed to mitigate drought effects in cereals production systems. In addition, decision support tools such as simulation models have been developed. However, farmers have not full benefited from these innovations due to lack of availability of the technologies in an integrated fashion. We propose to increase the impact of research and extension to translate potential into rapid development and wide-dissemination and uptake of productivity enhancing technologies. The dissemination strategy is guided by the fact that failure to incorporate smallholder preferences adequately, as well as insufficient supporting infrastructure, especially seed systems and weak market opportunities account for low progress and adaptability of these cereals. In this project we will employ a value chain approach that links critical stakeholders. Thus a combination of research, development and community action will be used to disseminate technologies and ensure that they are well targeted and adopted. The impact pathway involves **technology** development by core partners who are mainly R4D institutions in the region, product development from technologies generated by combined action involving core and associate partners and ultimate product delivery to end users by mainly the associate partners and selected core members via established product delivery systems eg KARI Seed for example.

12.4. Communication

Dissemination strategy. The project will develop a dissemination strategy that fits local contexts of target countries. Technology implementation will be preceded by detailed needs assessment, market viability and technology assessment studies and other benchmarks. A multi-pronged dissemination approach including the use of formal interest groups- developmental groups and support groups will be followed for better diffusion. A rural growth network model may be used especially where the beneficiaries could be organized into certain type of farmer organisation for collective action by the project.

Communication strategy. The main communication strategy of the project will be a combination of conventional and participatory extension approaches, and agricultural innovation systems.

> **Participatory extension approach**:- Local farmers from on-farm trail sites (district) will participate in all experimental processes (site selection, evaluation trials, selection of best practices/varieties, organizing field days, etc.).
>
> **Conventional extension approaches**:- To disseminate best practices to other farmers of the same agro ecology, the conventional agricultural extension approaches (Field days, Leaflets with local languages, mass media/community radios, training, etc.) will be used.

Innovation system approach:- Different stakeholders (local farmers, agricultural offices, NGOs, seed multiplying agencies, private sectors, etc.) will be consulted at all stages of implementation of the project. Moreover, they will participate on field days, trainings, and evaluation of technological packages.

These strategies will be used to create a network for change in the target communities by enabling different stakeholders to share ideas, experiences and communication materials/ products among themselves.

Role of NARS and other parties. The project will closely work with NARS, national agricultural extension system and agricultural development oriented NGOs in promotion and adoption of technologies. For local seed multiplication, promotion, adoption and marketing, the agricultural extension and local NGOs will play pivotal roles in reaching end users at grass root levels. The project will involve researchers from NARS and subject matter specialists from national agricultural extension services in skill development and packaging of innovations. Furthermore, the proposed project will also benefit NARS in terms of accessing developed genomics technologies such as QTLs and different markers for drought and disease tolerance through the established institutional network.

13. Quality and organization of the consortium

13.1 Overall organization.

The team recognizes the following key attributes that will influence project management, (i) implementation in Africa in partnership with universities in the USA and Europe; (ii) implementation across multiple countries requiring leadership both at country and multi-national level; (iii) each objective involves multiple stakeholders. Accordingly, the project has been organized into a number of mutually reinforcing and related activities that contribute to the final result. Project management has thus been designed to ensure efficiency, effectiveness and result delivery. Oversight and management will be done by the Principal Investigator (PI) who will be supported by Co-principal Investigators (Co-PIs) who will coordinate the project delivery at country level. The Co-PI's will thus be research leaders who themselves undertake tasks, oversee, monitor and collate reports for onward transmission to the Principal Investigator. Project implementers in each country shall be contracted by the BioInnovate secretariat (Figure 1).

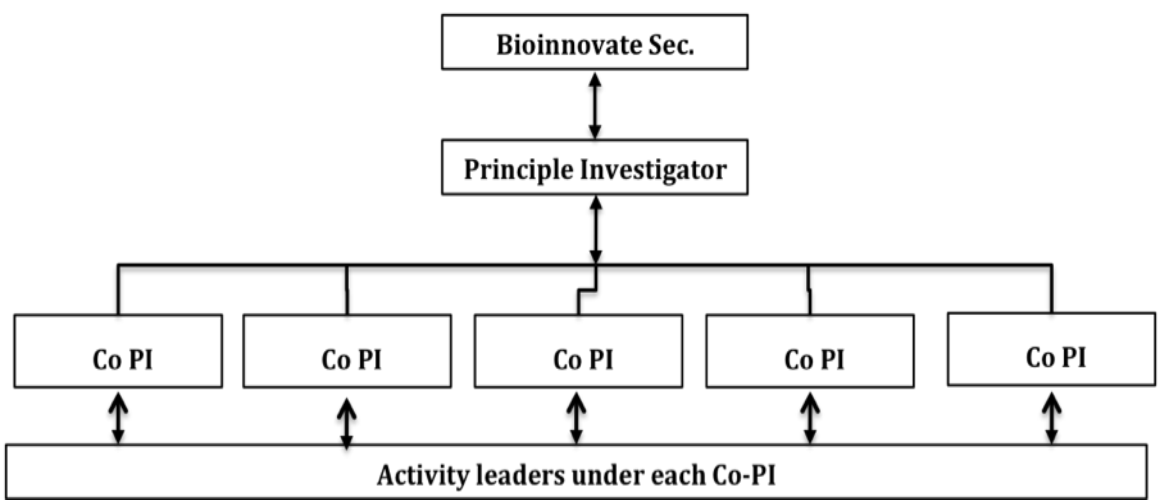

Figure 1. Project Organogram. Activity managers will implement the project activities at country level and report to their respective country managers (Co-PIs).

13.2 Innovation team.

The Innovation, team is comprised of major actors which are R&D institutions and associate partners who are necessary to ensure product delivery to ultimate end users of technologues generated. The main actors include **training and research Universities** (Moi University, Maseno University, Makerere University, Addis-Ababa University, Swedish University of Agricultural Sciences, University of Georgia) and **public research agencies** (Ethiopian Institute of Agricultural Research (EIAR), Kenya Agricultural Research Institute (KARI), National Semi-Arid Resources Research Institute (NaSARRI-Uganda), Department of Agric (MARI) disease management institutes; and a **CG institute** -ICRISAT. The project will also partner with other value chain actors: They will be responsible for undertaking the core activities of research and development, outreach and other value chain related activities. The project will strengthen the capacities of these agencies and partners to undertake and lead knowledge generation for the region. The associate partners are needed for final product development and outscaling. These include Government agencies- extension bodies and other regulatory bodies, private sector and civil society related to farm as well as the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) within the region and internationally as needed in order to deliver certain desired outcomes. These partnerships may involve brokering partnerships, joint resource mobilization, supporting policy development and/or sharing facilities.

13.3 Management and coordination

Principal Investigator (PI). The PI will provide oversight and leadership for the project. The PI shall perform this task with support from the other project leaders - the Co-PIs. The **Project leadership** (PI and Co-PI's) as well as necessary co-opted special interest persons shall meet twice a year to undertake the following key roles and responsibilities:

1. Provide technical guidance on Project implementation, review and approve project work plans and budgets and review progress against targets.
2. Ensure compliance to contractual issues of the project.
3. Boost synergies with other stakeholders at country and regional levels.
4. Examine the sustainability and future institutional arrangements of the project in order to ensure regional ownership, accountability, sustainability and visibility, financing and mobilizing of additional resources and longer term institutional modalities.
5. Recommend changes in the Project needed to ensure high quality to assure projected outcomes.

The **PI** shall specifically (i) Organize the project annual stakeholders and review meetings; (ii) Prepare all Project work plans, progress and financial reports for review by the project leadership before submission to the secretariat for approval; (iii) Engage in marketing, communication, advocacy and public relations activities; (iv) Network with relevant partners and stakeholders and ensure harmonization and synergies; (v) Facilitate development of IP agreements; (vi) Report to the regional secretariat as scheduled;

Co-PIs and Activity leaders. Teams in each member country will be led by a Co-PI. Each major activity will be led by an Activity Leader as agreed upon by the Project Team. Each major activity could have several sub-activities which could be monitored by the Co-PI and Activity Leader in each country. Each output will involve a number of partner institutions. The main function of the Co-PI will be to ensure effective coordination and management of the output team to implement tasks and deliver intended results/outcomes. They shall perform monitoring and evaluation functions as well as report to the PI.

14. **Competence and skill track records of principal investigator**

The Principal Investigator is a stress physiologist at the Department of Biology, Addis Ababa University. He is currently the Vice President for Research of the University. Prof. Masresha Fetene has led several multidisciplinary research collaborations and partnerships at national, regional and international level. He was Co-Principal Investigator of the just completed BIOEARN regional project entitled: Developing biotechnologies to ameliorate biotic and abiotic stresses in Sorghum. 2006-2010. Prof. Fetene was also principal investigator of an international research collaboration "Conservation and use of wild populations of *Coffea arabica* L. in rainforests of Ethiopia" – funded by the German Federal Ministry of Education and Research. He has initiated and generated funds for a multidisciplinary research project on "Regeneration in an Ethiopian montane Forest (Munessa-Shashemene Forest) with special emphasis on tree biology and nurse tree functions" in which the University of Bayreuth, University of Halle and University of Tubingen (Germany), Addis Ababa University (Ethiopia), Ethiopian Agricultural Research Organization, EARO (Ethiopia) and Institute of Biodiversity Conservation, participated and which was funded by the German Research Council (DFG). He was also a PI for SIDA/SAREC supported project on "Drought resistance in indigenous crops of Ethiopia" in which researchers from the University of Uppsala, (Sweden), Swedish University of Agricultural Sciences (Ultuna) (Sweden), University of Bonn, Bonn (Germany) and Addis Ababa University and Debub University from Ethiopia took part. Prof. Fetene has supervised several MSc and PhD candidates and has also published widely on stress physiology in regional and international journals.

15 Project Consortium Management

15.1 Matching funds and commitment from Institutions

This project builds on investments of BIO-EARN Phases 1-3. The project team, through various efforts, will leverage additional resources from ongoing research for development activities in their institutions. The related team will leverage additional resources through co-sharing with the following projects:

- **Makerere University**: Additional resources from RUFORUM-supported sorghum research on improved nutrient use, World Bank Millennium Science Project- on "Unlocking the potential of sorghums" project. Resources to be committed will include: Advanced developed breeding material, research supplies for molecular work and shared costs of technical support.
- **Moi University**: Anticipated McKnight Foundation and Generation Challenge Program (GCP) Research support. Resources to be committed will include: Advanced developed breeding material and research supplies obtained through the project.
- **Mikochene Agricultural Research Institute**: Sorghum research activities on tolerance to abiotic stresses have received support from the Global Crop Diversity Trust-GCDT. Build on activities of earlier investments of BIO-EARN in all partner countries (Kenya, Uganda and Tanzania.
- **Addis Ababa University**. The project will leverage additional support from ongoing projects in the University (SIDA block grant for graduate studies and research) and thematic research grants to the College of Natural Sciences**.**
- **Ethiopian Agricultural Research Institute (EIAR)**. The project shall benefit from its ongoing engagement with ICRISAT HOPE project on millets and sorghum involving the EIAR. Specifically the project shall access the germplasm collected.
- **Maseno University**. The project will complement and further the activities the current FAO Benefit Sharing Funded project to revitalize finger millet production in western Kenya.
- The project will also partner with the ICRISAT HOPE project and ASARECA, especially the Policy Programme (PAAP) for regional policy harmonization issues, and the Up-scaling and Knowledge Management Programme in the regional project meant to test and validate best-bet approaches and models for farmer-led seed enterprises in Eastern Africa.

15.2 Institutional support

Support letters from partners institutions are attached as appendices. They show that overall, the project will access resources (human and infrastructure for research and development). Specifically the scientists (PI, CoPIs and activity leaders) on the project will avail up to 30-40% of their time to the project. Research and research support infrastructure will also available to the project. Further details can be found in Institutional support letters in appendices.

15.3 Monitoring and Evaluation Plan

The project monitoring and evaluation plan shall mainly use a results based management process. Four approaches for monitoring and evaluation will be used to ensure (i) compliance, (ii) progress monitoring and (iii) learning for improvement up and out-scaling purposes within the project (iv) value for money. The approaches to be used will include:

a) The Project Results Framework (PRF) linking outputs to outcomes and impact (Figure 1).
b) The project logical framework (Log frame) clarifying the logical flow between various components of the project from activity to output level. The Log frame will speak to the PRF.
c) Lessons learning framework for capturing lessons in community related interventions
d) An external technical reference group who are to provide technical backstopping to the project.

The roles of each of these monitoring and evaluation approaches is briefly described

1. **Project Results Framework (PRF).** The PRF will be used especially by the project PI and Co-PI's to ensure that the project remains focused and delivers on purpose. The PRF will be used to show contribution to higher order results and clarify any linkages needed as well as contributions by other actors to deliver especially high order results at purpose and goal level i.e. Outcomes and impacts respectively.
2. **Logical framework**. The Logframe will be used by all leaders within the project, especially at the activity level to ensure delivery on output level in terms of focus, budgetary compliance, progress and overall compliance. The logframe shall speak to the PRF.
3. **Lessons learning framework**. Due to the complex nature of the project, outputs related to community engagement shall be monitored using this approach. We propose to use this approach to draw lessons for improving the pace, targeting and impact of innovations. Innovation in this case is defined as the process by which social actors create new value from knowledge. An iterative learning process involving diverse actors along the value chain shall be involved.
4. **The external reference group**. It shall be used to ensure the project remains scientifically and development focused. In the case of this project the programme technical committee shall provide this additional support.

All these mechanisms will be used to ensure the (i) continued project relevance to outcomes, (ii) Project quality by assessing adaptive competencies and resulting outcomes of performance, (iii) Capacity building for better monitoring and evaluation and learning, (iv) Sustainability by reviewing project continuity and impact logical flow pathways. Monitoring and evaluation will be performed by project management team. Participatory monitoring and evaluation will form part of the knowledge management strategy of the project in which partners will reflect on project execution and draw lessons for redesign and steering.

15.4 Intellectual Property and Other Policy Issues

For the most part this project will generate technologies and processes. These include crop varieties, diagnostic tools and approaches for breeding such as molecular markers. The project policy for management of the above IPs shall be guided by both BioInnovate IP policy and country/institutional IP policies. Additionally, IP management tools such as Material Transfer Agreements and Alliance Agreements will be used. The project shall develop alliance agreements during the first quarter of the first year of the project life that specify sources of IP, users of the IP, IP management issues including the mechanisms to address any material transfer, disagreements etc. All these issues will be explored during the project launch meeting. Expertise from the ISAAR will be sought during the project launch meeting to clarify any IP issues and to support streamlining of appropriate management regimes. Additionally, during the project launch workshop, the team shall explore IP issues and agree on the best possible approach to address them. Overall the purpose of clarification of IP issues and their management during the launch meeting is to, among others (i) raise awareness on IP issues within the project; (ii) ensure that research results and IP assets are identified systematically and protected if necessary; and (iii) ensure that third-party intellectual property when accessed is used in a fair and transparent way, (v) put in place acceptable but functional IP systems that meets country specificity as well as international concerns.

16. Milestones and time frame

Objective 1. Evaluation, promotion and adoption of sorghum and finger millet genotypes for drought and disease tolerance.

16.1 Sorghum innovation activities

16.1.1 Promotion and adoption of drought tolerant sorghum

Milestone 16.1.1.1 Participatory varietal evaluation of newly identified stay green sorghum genotypes with multiple stress tolerance (Striga, aluminium toxicity and P-use efficiency, earliness) and nationally released drought tolerant and high yielding varieties in Ethiopia, Kenya, Tanzania and Uganda completed by December 2012.

Milestone 16.1.1.2 At least three drought and/or multiple stress tolerance sorghum varieties with their management strategies adopted by farmers by December 2013.

16.1.2 QTL mapping of identified stay green sorghum lines.

Milestone 16.1.1.1 At least three F2 bi-parental mapping populations derived from (Sorcoll 141, Sorcoll 146 and Sorcoll 163) developed by July 2012.

Milestone 16.1.1.2 Newly characterized staygreen QTLs mapped on the sorghum genome and validated by July 2013.

16.2 Millets innovation activities

16.2.1 Assembling and evaluation of finger millet genetic resources

Milestone 16.2.1.1 Finger millet germplasm and selected cross-fertile wild relatives assembled from various agencies in Ethiopia, Kenya and Uganda for genetic diversity studies drought and blast resistance screening completed by June 2011.

Milestone 16.2.1.2 Additional finger millet germplasm and especially cross-fertile wild relatives assembled from areas not explored previously in Ethiopia, Kenya and Uganda for genetic diversity and trait screening completed by October 2011.

Milestone 16.2.1.3 Phenotypic and molecular characterization of the assembled germplasm for genetic diversity in at least two locations in Ethiopia and Uganda completed by December 2012.

16. 2.2 Identification of novel and highly adapted finger millet genotypes

Milestone 16.2.2.1 Characterization of assembled and collected finger millet germplasm for drought tolerance under controlled conditions and selection of a suitable association mapping population for drought tolerance completed by December 2012.

Milestone 16.2.2.2 Characterization of assembled finger millet germplasm with improved resistance to blast (*Magnaporthe grisea)* under controlled infection conditions and selection of a suitable association mapping population for blast resistance completed by December 2012.

Objective 2. Development of breeding tools and technologies for high yielding and adapted millet in eastern Africa.

16. 2. 3 Generation of molecular tools for marker assisted breeding

Milestone 16.2.3.1 Genotypes that carry traits for genomic sources of drought tolerance and blast resistance identified and mapped onto the finger millet genome using a comparative genomics with rice by June 2013.

Milestone 16.2.3.2 Molecular markers linked to the sources of drought tolerance and blast resistance identified through association mapping and comparative genomics for future marker assisted introgression of these traits by December 2013.

Objective 3. Develop and promote best management strategies for sorghum chaffer pest and anthracnose, and finger millet blast disease.

16.3.1 Sorghum chaffer management

Milestone 16.3.1.1 Performance of available fungal isolates from different institutions (Ambo Plant Protection Research Center (PPRC), DL CO–EA, AAU) evaluated in collaboration with PPRC by Dec 2013.

Milestone 16.3.1.2 At least two new fungal isolates with potential as bio control agents against chafer explored and screened in sorghum chaffer breeding and outbreak areas by Dec 2011.

Milestone 16.3.1.3 At least one selected fungal isolate formulated and applied against sorghum chaffer on-farm by 2013.

Milestone 16.3.1.4 At least ten types of traps manufactured from locally available materials developed and evaluated by Dec 2013.

Milestone 16.3.1.5 The Performance of three auto-dissemination device for combined application of bio control fungal isolates and effective pheromones at semi-field and field levels evaluated by Dec 2013.

16.3.2 Sorghum anthracnose and finger millet blast management.

Milestone 16.3.2.1 Performance of available anthracnose and blast diseases management options will be tested on-farm by Dec 2011.

Milestone 16.3.2.2 At least one management option each for anthracnose in sorghum and blast in finger millet identified for promotion by Dec 2012.

Milestone 16.3.2.3 At least one management option each for anthracnose in sorghum and blast in finger millet adopted by Dec 2013.

Milestone 16.3.2.3 Anthracnose resistant materials from Uganda evaluated at the farmer level in two sorghum growing communities of Uganda by July 2012.

Objective 4. Undertake marketing and value chain analyses of sorghum and finger millets in eastern Africa.

16.4. Marketing and value chain analyses

Milestone 16.4.1 At least 3 sorghum and finger millet value chains in three locations across the region characterized and exploited for strengthening competitiveness and market access by December 2013.

17. Indicators of progress towards results

A project milestones listed in part 16 will be used to track progress towards achieving strategic objectives, whilst the Logframe will be used to monitor progress based on the logframe. Learning and changes at community level will be done using participatory learning framework. Detailed outputs and indicators are indicated in the logframe. A summary of indicators for the project are indicated below. The intermediate indicators for progress towards results for each objective are:-

Result areas	Progress Indicators
Development, Promotion and adoption of drought tolerant sorghum	• Number of localities in each country that participate in evaluation of drought tolerant sorghum genotypes by December 2012. • Number of farmers participated on variety evaluation of promising material by year 2012. • Number of drought and multiple stress tolerance tolerant sorghum varieties adopted by farmers by December 2013 • Number of farmers that adopted drought tolerant sorghum genotypes by year 2013.
QTL mapping of identified stay green sorghum lines	• Number of mapping populations for stay green developed at the end of July 2012. • Number of QTLs mapped on the sorghum genome and validated by July 2013.
Assembling and evaluation of finger millet genetic resources	• Total number of germplasm assembled from Ethiopia, Kenya and Uganda in year 2011 & 12. • Number of accessions phenotyped by year 2012. • Number of accessions genotyped by year 2012.
Identification of novel and highly adapted finger millet genotypes	• Number of accessions screened against drought tolerance by end of year 2012. • Number of accessions screened against blast (*Magnaporthe grisea*) for finger millet by December 2012.
Generation of molecular tools for marker assisted breeding	• Number of species used for genome comparison by year 2012. • Number of new molecular markers identified for tolerance to drought and blast by year 2013. • Number of molecular markers linked to the sources of drought and blast tolerance by year 2013.
Develop and promote best management strategies for sorghum chaffer pest and anthracnose, and finger millet blast disease.	• Number of available fungal isolates evaluated • Number of fungal isolate screened for sorghum chaffer by year 2011. • Number of fungal isolates tested and formulated for sorghum chaffer • Number and performance of traps manufactured from locally available materials by 2013 • Performance of auto-dissemination device evaluated at semi-field and field levels by 2013 • Number of candidate management options included in on-farm trails for anthracnose and blast for sorghum and finger millet respectively in 20011 and 2012. • Number of best management strategy adopted by farmer for anthracnose and blast disease management. by end of 2013.
Marketing and value chain analyses	• Number of farming community characterized for improved value chain analysis at the end of year 2013.

Furthermore, the following mechanisms will be put in place to follow the progress toward results:-

- Reviewing the annual report as an essential part of evaluating the achievements of milestones and implementation of the project activities as planned.
- Biennial cycle of monitoring and reporting of progress on implementation of the activities of the consortium.

18. Project Activity plans

Activity/Roles and Project Component leaders		Partner Institutions[1]	Scientists[2]	Timeline for project activities					
				Year 1		Year 2		Year 3	
				1st	2nd	1st	2nd	1st	2nd
Core Activity:- Development, promotion and adoption of drought and multiple stress tolerance tolerant sorghum	1. **Development, promotion and adoption of drought and** multiple stress tolerance **sorghum genotypes at community level**	AAU, EIAR, Moi, MARI, MAK	MF, TF, TT, SG, EM, PO	■	■				
Core Activity:- Development, promotion and adoption of drought and multiple stress tolerance tolerant sorghum	**2. QTL mapping of identified stay green sorghum lines**	AAU, EIAR, SLU	TF, BA, TT, TB	■	■	■	■	■	
Core Activity:- Assembling and evaluation of millets genetic resources	**1. Assembling and evaluation of finger millet genetic resource**	AAU, ICRISAT, MAK, MARI, MSU	KT, MF, SDV, PO, EM, MD	■	■				
Core Activity:- Assembling and evaluation of millets genetic resources	**2. Genetic diversity analysis, phenotypic & molecular analyses**	AAU, ICRISAT, MAK, MARI, MSU,SLU	KT, MF, SDV, PO, EM, MD,MG		■	■	■		
Core Activity:- Identification of novel and highly adapted finger millet genotypes	**1. Screening for drought tolerance**	AAU, MAK, MARI, MSU	MF, KT, MD, EM, PO		■	■	■		
Core Activity:- Identification of novel and highly adapted finger millet genotypes	**2. Screening for blast disease**	AAU, EIAR, MAK, MARI, MSU	KT, BA, MD, EM, PO		■	■	■		
Core activity:- Generation of molecular tools for marker assisted breeding		AAU, ICRISAT, UGA, MSU, SLU	KT, SDV, KDV, MD, MG			■	■	■	■
Core Activity:- Develop & promote best management strategies for sorghum chaffer pest and anthracnose, and finger millet blast disease.	**1. Exploration and screen new fungal isolates for bio control agent for sorghum chaffer.**	AAU, SLU, WelloU, PPRC	ES, YWH, YH, BW	■	■	■	■		
Core Activity:- Develop & promote best management strategies for sorghum chaffer pest and anthracnose, and finger millet blast disease.	**2. Dosage formulation and application of selected fungal isolate for sorghum chaffer.**	AAU, SLU, WelloU, PPRC	ES, YWH, YH, BW			■	■	■	
Core Activity:- Develop & promote best management strategies for sorghum chaffer pest and anthracnose, and finger millet blast disease.	**3. Evaluation of an auto-dissemination device for attracting chaffer.**	AAU, SLU, WelloU, PPRC	ES, YWH, YH, BW				■	■	■
Core Activity:- Develop & promote best management strategies for sorghum chaffer pest and anthracnose, and finger millet blast disease.	**4. Promote best management strategies for sorghum chaffer pests.**	AAU, SLU, WelloU, PPRC	ES, YWH, YH, BW				■	■	■
Core Activity:- Develop & promote best management strategies for sorghum chaffer pest and anthracnose, and finger millet blast disease.	**5. On-farm participatory evaluation of existing technology on anthracnose and blast management on sorghum and finger millet.**	MAK	PO	■	■	■	■	■	■
Core Activity:- Develop & promote best management strategies for sorghum chaffer pest and anthracnose, and finger millet blast disease.	**6. Promote best management strategies and varieties for anthracnose and blast diseases.**	MAK	PO	■	■	■	■	■	■
Core Activity:- Undertake marketing and value chain analyses of sorghum and finger millets in eastern Africa	**1. Marketing and value chain analyses of sorghum and Finger millet sub-sector**	AAU, EIAR, EOSA, MAK, Moi, MARI	WN, AB, MA, GG, PO, SG, EM		■	■	■	■	

[1]Partners:- AAU=Addis Ababa University; MAK=Makerere University; EIAR=Ethiopian Institute of Agricultural Research; MARI= Mikocheni Agricultural Research Institute; National Semi-Arid Resources Research Institute (SARRI); MSU= Maseno University; Moi= Moi University, WelloU= Wello University; NWI Ltd. = North-West Investment Ltd., PAN-Ethiopia= Pesticide Action Network; ICRISAT= International Crops Research Institute for the Semi-Arid-Tropics, Nairobi; SLU= Swedish University of Agricultural Sciences**, UGA=**University of Georgia Athens.[2]

[2]**Scientists**: - MF= Prof. Masresha Fetene, TF=Dr. Tileye Feyissa, ES=Dr. Emiru Seyoum, BA=Dr. Belayneh Admassu, TT=Mr. Taye Tadesse, PO= Dr. Patrick Okori, EM= Dr Emmarold E Mneney, SG=Prof. Samuel Gudu, KT=Dr. Kassahun Tesfaye, SVD=Dr. Santie de Villiers, KDV=Prof. Katrien Devos, MD=Prof. Mathews M. Dida, AA=Mr.Asfaw Adugna, MA=Dr. Melese Abdisa, EL=Mr. Eshetu Legesse, GG=Mr. Genene Gezu, WN= Dr. Workneh Nigatu, AB= Dr. Adam Bekele, TA=Tadesse Abera, AGM=Mr. Alexander G. Medhin, MG = Dr. Mulatu Geleta, YWH= Yitbark Wolde-Hawariat , YH= Y. Hillbur.

19. Detailed budget breakdown by institution and budget item per year (USD)

YEAR 2011

Activity	Budget Categories	AAU	MAK	MU	MARI	MSU	ICRISAT	EIAR	UGA	Total
A	Equipment	32,349	8,500	-	4,000	-	-	-	-	44,849
B	Consumables	25,017	22,970	-	3,340	4,215	43,250	-	-	98,792
C	Travel	8,693	2,100	15,726	15,000	8,840	-	5,140	-	55,499
D	Field Costs	45,698	46,100	31,453	23,496	11,000	-	22,865	-	180,612
E	Subsistence in EA	6,920	38,400	-	-	4,940	-	-	-	50,260
F	Management/coordination Costs	21,900	8,400	-	4,710	-	-	-	-	35,010
G	Unforeseen	-	-	2,621	-	1,490	-	-	-	4,111
H	Overheads	7,029	6,324	2,621	2,527	3,049	6,488	1,400	-	29,437
	Sub Total	**147,606**	**132,794**	**52,421**	**53,073**	**33,534**	**49,738**	**29,405**	**-**	**498,570**

YEAR 2012

Activity	Budget Categories	AAU	MAK	MU	MARI	MSU	ICRISAT	EIAR	UGA	Total
A	Equipment	14,500	-	-	-	-	-	-	-	14,500
B	Consumables	35,595	15,570	-	4,574	10,188	66,940	-	22,600	155,467
C	Travel	15,731	2,100	13,979	11,400	4,440	4,000	5,140	5,400	62,190
D	Field Costs	36,198	37,600	27,958	23,552	7,800	-	19,420	-	152,528
E	Subsistence in EA	11,800	-	-	-	3,840	-	-	10,000	25,640
F	Management/coordination Costs	21,900	8,400	-	4,710	-	-	-	-	35,010
G	Unforeseen	-	-	2,330	-	1,363	-	-	-	3,693
H	Overheads	6,786	3,184	2,330	2,212	2,763	10,641	1,228	3,800	32,943
	Sub Total	**142,510**	**66,854**	**46,597**	**46,447**	**30,394**	**81,581**	**25,788**	**41,800**	**481,971**

Activity	Budget Catogories	AAU	MAK	MU	MARI	MSU	ICRISAT	EIAR	UGA	Total
				YEAR 2013						
A	Equipment	2,000	-	-	-	-	-	-	-	2,000
B	Consumables	1,500	10,500	-	140	1,490	43,030	-	-	56,660
C	Travel	10,400	6,000	5,242	3,600	5,600	-	5,600	-	36,442
D	Field Costs	34,844	19,400	10,484	9,432	2,800	-	5,600	-	82,560
E	Subsistence in EA	3,624	-	-	-	-	-	-	-	3,624
F	Management/coordination Costs	21,900	8,400	-	2,460	-	-	-	-	32,760
G	Unforeseen	-	-	874	-	500	-	-	-	1,374
H	Overheads	3,713	2,215	874	782	1,039	6,455	560	-	15,637
	Sub Total	**77,981**	**46,515**	**17,474**	**16,414**	**11,429**	**49,485**	**11,760**	**-**	**231,057**
	Total Budget	**368,097**	**246,162.0**	**116,492**	**115,934**	**75,357**	**180,803**	**66,953**	**41,800**	**1,211,598**

20. Log frame for the project (Annexed at the end)

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Appendix 1. Project Logical Framework

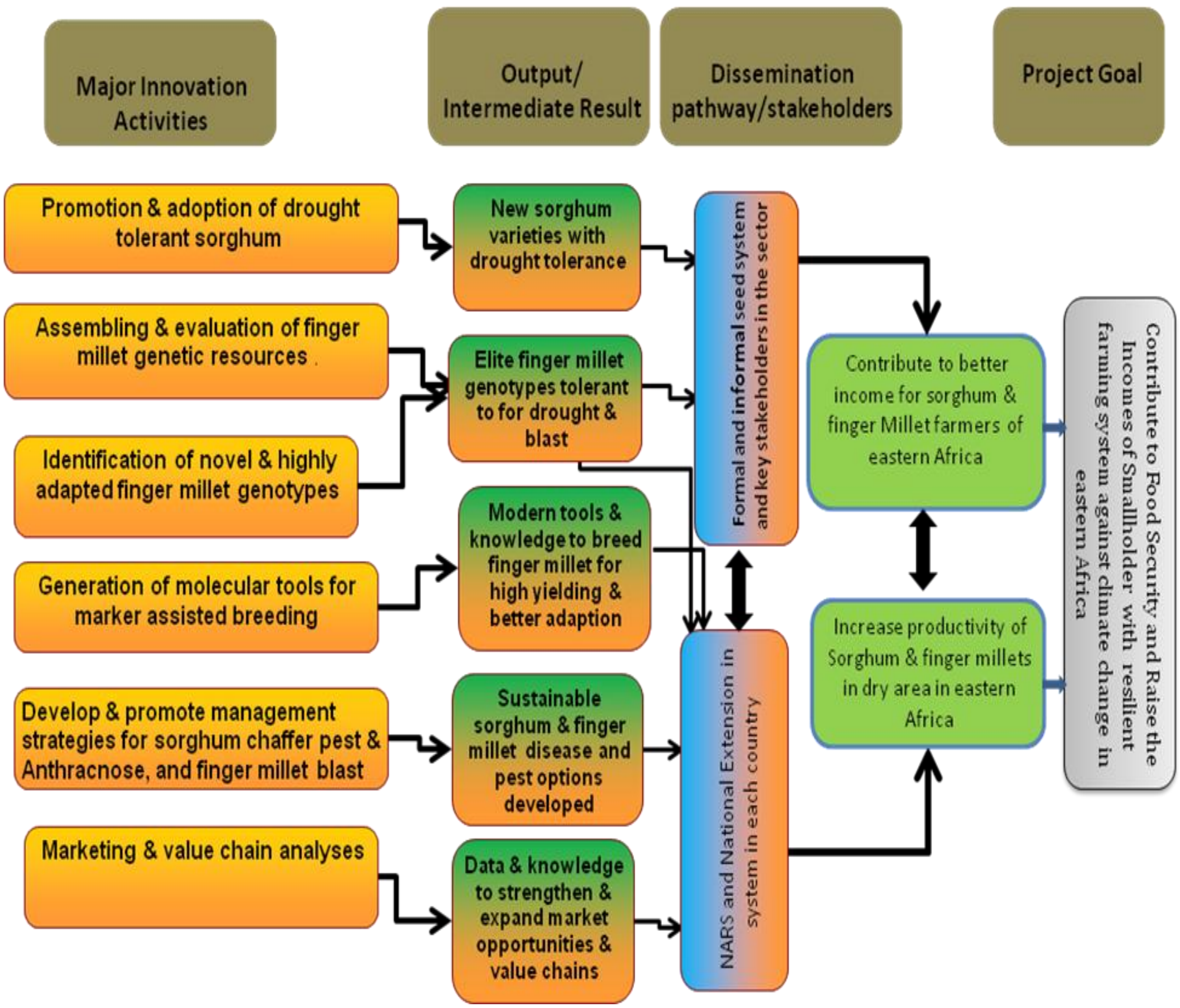
Outputs	Outcome	Outcome Performance Indicator	Data Source	Data Collection Method	Assumptions
Development Objective					
Sorghum and finger millet technologies that minimize the effects of climate change and raise the incomes livelihood security of sorghum and finger millet producing farmers generated, collated and delivered through development-oriented research action in Ethiopia, Kenya, Tanzania and Uganda					
Program Specific Objectives					
Objective 1. Evaluation, promotion and adoption of sorghum and finger millet genotypes for drought and disease tolerance.					
• Drought and multiple stress tolerant novel sorghum genotypes evaluated on-farm and adopted by farmers, and stay green QTLs mapped on sorghum genome • Finger millet genotypes evaluated and characterized for drought and blast tolerance	• Food security of targeted eastern African communities living in biotic and abiotic stress prone area enhanced. • Targeted eastern African communities develop capacity and resilience to climate change, based on sorghum and finger millet technologies	• At least seven drought and/multiple stress tolerant and high yielding sorghum genotypes evaluated on farm involving farmers by Dec. 2012. • At least three drought and/or multiple stress tolerant sorghum varieties with their management strategies adopted by farmers by December 2013. • At least three mapping sorghum populations derived by July 2012. • At least three stay green QTLs mapped on the sorghum genome by July 2013 • At least 100 finger millet germplasm assembled and collected by October 2011 • At least 100 finger millet germplasm phenotyped and genotyped by December 2012 • At least 100 finger millet germplasm screened for drought and blast tolerance by December 2012	• Program reports • Project reports • Partner Institutional reports • Ex post ante study reports of the program • National statistical reports	• Project reviews • Commissioned studies -*Ex ante* studies in partner countries -*Ex poste* studies in partner countries	• Governments continue provide services that support access to markets and agro inputs for agricultural production in the region • Governments of the region continue to develop and pursue policies that favor science and technology its use in development
Objective 2: Development of breeding tools and technologies for high yielding and adapted finger millet in eastern Africa.					
• Modern tools and knowledge to improve breeding of high yielding and adapted finger millet developed and promoted in partner countries.	• New tools for breeding finger millet strengthened in partner NARS. • Capacity of R&D systems that contribute to food security in target countries strengthened.	• Knowledge on genomic sources of drought tolerance and blast resistance identified and mapped onto the finger millet genome using a comparative genomics with rice by June 2013.	• Program reports • Project reports • Institutional reports	• Project reviews, • Commissioned studies	• Governments of the region continue to develop and pursue policies that favor science and technology use in development • Public and private sector agencies

		• Molecular markers linked to the sources of drought tolerance and blast resistance identified through association mapping and comparative genomics for future marker assisted introgression by December 2013.	• *Ex poste* study reports of the program • National statistical reports.		continue to provide suitable goods and services that promote the use of environmentally friendly technologies in eastern Africa.
Objective 3: Develop and promote best management strategies for sorghum chaffer pest and anthracnose, and finger millet blast disease.					
• Environmentally friendly and sustainable sorghum chaffer and anthracnose, and finger millet blast management options developed and adopted in chaffer, anthracnose and blast affected regions.	• Sorghum production through sustainable management of sorghum chaffer, anthracnose and blast leading to improved food security in the region. • Strengthened capacity of pest and diseases management research and development in the region	• Performance of available fungal isolates known by December 2013. • At least two new fungal isolates with potential as bio control agents identified by December 2011. • At least one selected fungal isolate formulated and applied on-farm by December 2013. • At least one efficient trap manufactured from locally available materials selected by December 2013. • At least one efficient auto-dissemination device selected in Ethiopia by December 2013. • At least one management option for sorghum anthracnose with improved variety adopted by local farmers in Uganda by Dec 2013. • At least one management option for finger millet blast with improved variety adopted by local farmers in Uganda by Dec 2013. • At least 10-15% yield losses due to sorghum chaffer pest in Ethiopia and anthracnose and blast in Uganda reduced by the end of the project year.	• Program reports • Project reports • Project partnership agreements	• Project reviews, • Commissioned studies	• Governments of the region continue to develop and pursue policies that favor science and technology use in development • Public and private sector agencies continue to provide suitable goods and services that promote the use of environmentally friendly technologies in E. Africa
Objective 4: Undertake marketing and value chain analyses of sorghum and finger millet in eastern Africa.					

• Data and knowledge to strengthen and expand market opportunities and value chains of sorghum and finger millet in targeted countries generated and promoted.	• Production, utilisation and market access of sorghum and finger millet enhanced in the region • Livelihood of sorghum and finger millet producers improved	• At least three sorghum and finger millet value chains in three locations characterized and exploited for strengthening competitiveness and market access by December 2013. • Increased utilization of millets and sorghum by 10% in partner countries by 2013 • Increased linkages with the processors and traders by 30% by the end of 2013.	• Program reports • Workshops report • Institutional reports • Program website hits	• Program reviews, • Commissioned study reports	• Governments continue provide services that support access to finance and markets agricultural production and processing in the region • Governments of the region continue to develop and pursue policies that favor science and technology use in development • Public and private sector agencies continue to provide suitable goods and services that promote the use of environmentally friendly technologies in eastern Africa

Appendix 2. Detailed budget breakdown by major activities and budget items per year per institution is submitted as per the format provided by PMO

Appendix 3- Path way to impact



Appendix 4. Curriculum vitae for the PI and CO-PIs of the Project

The project will be run by a competent multi disciplinary team of scientists from different countries of eastern Africa (Ethiopia, Kenya, Tanzania and Uganda) selected on the basis of their competence. The CV's of the PI and CoPIs (short CV) involved in the project is shown below.

Appendix 4-1. Curriculum vitae for PI: Masresha Fetene (Prof.)

Contact Address: Department of Biology, Addis Ababa University, P.O. Box 1176, Addis Ababa, Ethiopia. Tel no: . ++251-11-1239756 (Office)
E-mail: masfetene@yahoo.com

Current Position: Vice-President for Research and Dean of Graduate Studies and Professor of Plant Ecophysiology (Department of Biology), Addis Ababa, Ethiopia

EDUCATION

- PhD in Plant Ecophysiology - December 1990, Institute of Botany, Technische Hochschule Darmstadt, Darmstadt, Germany (1987-1990).
- MSc in Botany - November 1985, School of Graduate Studies, Addis Ababa University, Ethiopia (1983-1985).
- BSc in Biology - July, 1982, Department of Biology, Addis Ababa University, Addis Ababa, Ethiopia (1976-1982).

EMPLOYMENT RECORDS

- Vice President for Research and Dean of School of Graduate Studies, Addis Ababa University
- Full Professor – Department of Biology, Faculty of Science, Addis Ababa University, Addis Ababa, Ethiopia, July 2002 -
- Associate Dean for Research and Graduate Programs of the Faculty of Science, Addis Ababa University, **2001- 2004**
- Co-ordinator of the Environmental Science Program of the Faculty of Science **2001- 2004**
- Head, Department of Biology, Addis Ababa University, **1997- 2000**
- Associate Professor, Department of Biology, Addis Ababa University, 1996-2002
- Assistant Professor, Department of Biology, Addis Ababa University, 1992-1996
- Research Assistant- Universität Bayreuth, Lehrsthul für Pflanzenphysiologie, Germany, 1991-1992

CURRENT ACADEMIC RESPONSIBILITY

- Vice President for Research and Dean Of School of Graduate Studies, Addis Ababa University
- Director and General Editor of **Addis Ababa University Press**
- Subject editor Of **Biotropica**

ACADEMIC/ PROFESSIONAL RESPONSIBLIITIES

- Associate Dean for Research and Graduate Programs of the Faculty of Science, Addis Ababa University, **2001- 2004**
  - Established the Office, generated fund to equip it and streamlined the office into office service, student record and research and theses documentation centers.
  - Coordinated Faculty graduate program expansion and worked on increased graduate intake
  - Developed faculty research review and evaluation schemes, and facilitated fund utilization
  - Organized use of pulled resources enhancing and facilitating research
- Co-ordinator of the Environmental Science Program of the Faculty of Science **2001- 2004**
  - Initiated and established an inter-departmental Masters Program in Environmental Science
  - Led the successful development of a multidisciplinary Masters environmental science curriculum and its teaching
  - Coordinated research on relevant environmental problems
- Head, Department of Biology, Addis Ababa University, **1997- 2000**
  - Coordinated the internal and external review of the activities of the Department on teaching and research
  - Generated fund and established partnership program with three universities of Germany (University of Marburg, Darmstadt and Bayreuth) on a joint graduate teaching and research program that still runs successfully.
  - Assisted in the establishment of the East African Research Network for Research in biotechnology, bio-safety and molecular biology
  - Worked with ICIPE- International Center for Insect Physiology and Ecology for the creation and realization of the ARRPIS -African Regional Postgraduate Program in Insect Science, hosted several meetings of the Academic Board in Addis Ababa, and coordinated the program in Addis Ababa for the East African node.
  - Worked for the establishment of an East African wide regional graduate program in biodiversity studies- RPSUD – Regional Program in Sustainable use of Dry land resources, run the program successfully at Addis Ababa University.
- Secretary of the Biological Society of Ethiopia **(1996-2000)**
  - Raised over half a million Birr for the activities of the Society
  - Increased membership of the Society by three fold
  - Worked on wide participation of members and professionals at large in regular conferences and symposia
  - Organized several widely attended workshops, symposia and panel discussions and conferences with prominent participants on actual and pertinent problems on topics such as the recurrence of drought and preparedness in Ethiopia, the value of our biodiversity, investment enhancement and environmental protections.
- Associate Editor; Editor and **Editor-in-Chief** of *SINET- Ethiopian Journal of Science* (**1996-2004**)
  - Led and guided the growth of the journal to regional and international importance by working on quality review system, faster publication process, and increased and wide distribution

INTERNAIONAL AND REGIONAL RESEARCH FUNDS AND COLLABORATIONS

- Was Co-Principal Investigator of the BIOEARN regional project entitled: DEVELOPING BIOTECHNOLOGIES TO AMELIORATE BIOTIC AND ABIOTIC STRESSES IN

SORGHUM. 2006-2010

- Initiated and generated fund for a multidisciplinary research project on "Regeneration in an Ethiopian montane Forest (Munessa-Shashemene Forest) with especial emphasis on tree biology and nurse tree functions" in which University of Bayreuth, University of Halle and University of Tubingen (Germany), Addis Ababa University (Ethiopia), Ethiopian Agricultural Research Organization, EARO (Ethiopia) and Institute of Biodiversity Conservation. Funded by the German Research Council (DFG)- In progress.
- Generated grant from SIDA/SAREC for a project on "Drought resistance in indigenous crops of Ethiopia" in which researchers from University of Uppsala, (Sweden), Swedish University of Agricultural Sciences (Ultuna) (Sweden), University of Bonn, Bonn (Germany) and Addis Ababa University and Debub University from Ethiopia take part. Size of Fund Sek 1,500,000.
- Was subproject principal investigator of an international research collaboration "Conservation and use of wild populations of *Coffea arabica* L. in rainforests of Ethiopia" – funded by the German Federal Ministry of Education and Research, Center for Development and the German Research Council – DFG.
- Generated fund for research on "Regeneration ecology of woody plants at tropical timberlines." with the Martin-Luther-University Halle Wittenberg, and University of Marburg, Germany and Institute of Biodiversity Research and Addis Ababa University, Ethiopia. Financed by the German Research Council and German Federal Ministry of Education and Research, Center for Development. In Progress.
- Generated fund for research on "Ecological investigations on the vegetation of upland ecosystems in Ethiopia, a collaborative research between Addis Ababa University (Ethiopia) and University of Bayreuth, Germany. Funded by Volkswagen-Stiftung, Germany. Completed
- Generated fund for research "Towards a sustainable management of the Munessa Forest, Ethiopia: Fundamentals of geobotany, soil science and plant physiology" - from the German Research Foundation (DFG) (with several Ethiopian and German scientists from University of Bayreuth). 2000- 2003 – Completed
- Obtained fund for a joint research project with the University of Bayreuth, Germany, for a project entitled "Ecological investigations on the vegetation of afroalpine regions in Ethiopia", funded by Volkswagen-Stiftung, Germany. Completed.

OTHER FUNDED RESEARCH PROJECTS

- Ecophysiological investigations on influence of drought stress on local chickpea accessions. Funded by the Ethiopian Science and Technology Commission B Local Projects Program. In progress
- Ecophysiological investigations on indigenous woodland trees species for use in agroforestry systems. Funded by the Research and Publication Office, Addis Ababa University. Completed.
- Investigations on the growth characteristics of woodland tree species. Funded by United Nation Food and Agriculture Organisation (FAO) Contract Research Agreement. Completed.
- Germination and seedling establishment of selected woodland tree species. Funded by the African Academy of Sciences (AAS). Completed.

CURRENT RESPONSIBLIITIES AND MEMBERSHIP IN PROFESSIONAL ASSOCIATIONS

- Founding member of the *Biological Society of Ethiopia*, Since 1990
- Founding member of the *Ethiopian Society of Humboldt Fellows*, Since 2002
- Member of the *Ethiopian Wildlife and Natural History Society*, Since 1986.
- Member of the *Ethiopian Heritage Trust*, since 1996.
- Founding member of the *Getachew Bolodia Foundation*, since 1998.
- Member of the *Ethiopian Soil Science Society*, since 1998
- Member of the *Ethiopian Crop Science Society*, since 2003
- Founding member of *NAPRECA* (Natural Products Network for East and Central Africa), since

1984.

AWARDS AND FELLOWSHIPS

- German Academic Exchange Service (DAAD) PhD Fellowship (1987-1991)
- Research Fellowship, University of Bayreuth, German Research Foundation (1991-1992)
- UNESCO-ICRO - Short term Research Fellowship Award (Summer 1994)
- DAAD Short term Research Visit Award (Summer 1995 and 2003)
- Alexander von Humboldt Research Award (July 2000- September 2001)

PUBLICATIONS IN PEER REVIEWED JOURNALS, (last five years)

1. Girma, A., R. Mosandl, Hany El Kateb, and **M. Fetene** (2010) Restoration of degraded secondary forest with native species: A case study in the highland of Ethiopia. *Scandinavian Journal of Forest Research*, 25: 1-6.
2. Tesfaye G, Teketay, D., **Fetene M**., Beck, E. (2010). Regeneration of seven indigenous tree species in a dry Afromontane forest, southern Ethiopia. *Flora : Plant Morphology, Distribution and Functional Ecology* 205: 135-143.
3. Maria Johansson, **Masresha Fetene**, Anders Malmer, Anders Granstrom (2010) Browser selectivity alters post-fire competition between Erica arborea and E. trimera in the sub-alpine heathlands of Ethiopia. *Plant Ecology*, 207 149-160.
4. Yitbarek Tibebe Weldesemaet, Satishkumar Bellietahtahan and **Masresha Fetene** (2010). Economic Value of Biological Gully Rehabilitation and the Benefit of sustainable fortification *Ecological Restoration* In Press
5. Aster Gebrekirstos, Ralph Mitöhner, **Masresha Fetene** and Demel Teketay (2009) Plant water relations as indicators and regulators of bush encroachment in Awash National Park, central Ethiopia *Forest Ecology and Management* In press
6. Gebrekirstos A, Worbes M, Teketay, D **Fetene M**, Mitlöhner R (2009). Stable carbon isotope ratios in tree rings of co-occurring species from semi-arid tropics in Africa: Patterns and climatic signals. *Global and Planetary Change* **66**: 253–260
7. Zewedie, S., Olsson, M., **Fetene, M**. (2008). Effect of drought /irrigation on proximate composition and charbohydrate content of two Enset (*Enset ventricosum* Welw Cheesman) clones. *Sinet: Ethiopian Journal of Science* **31**: 81–88.
8. Solomon Zewdie, **Masresha Fetene** and Mats Olsson (2008). Fine root vertical distribution and temporal dynamics in mature stands of two enset (*Enset ventricosum* Welw Cheesman) clones *Plant and Soil* **305** 227–236.
9. Wesche, Karsten, Arne Cierjacks, Yoseph Assefa, Susanne Wagnera, **Masresha Fetene** and Isabell Hensen (2008). Recruitment of trees at tropical alpine treelines: Erica in Africa versus Polylepis in South America. *Plant Ecology and Diversity* **1**: 35–46.
10. Solomon Zewdie, Mats Olsson and **Masresha Fetene** (2007). Growth, gas exchange, chlorophyll a Fluorescence, biomass accumulation and partitioning in droughted and irrigated plants of two Enset (Ensete ventricosum Welw. Cheesman) clones. *Journal of Agronomy* **6**: 499–508.
11. Yigremachew Seyoum and **Masresha Fetene** (2007). Plant water relation and growth response of *Cordia africana* Lam. seedlings of three seed sources exposed to different water regimes. *Ethiopian Journal of Natural Resources* **9**:247–262.
12. Tadesse Woldmariam and **Masresha Fetene** (2007). Forests of Sheka: Ecological, social, legal, and economic dimensions of recent laduse/landcover changes- overview and synthesis In: Masresha Fetene (ed): *Forests of Sheka: Multidisciplinary casestudies on impact of landuse/landcover change , Southwest Ethiopia*. MELICA Mahiber
13. **Masresha Fetene** (ed) (2007). *Forests of Sheka: Multidisciplinary case studies on impact of landuse/landcover change, Southwest Ethiopia*. MELICA Mahiber
14. Aster Gebrekirstos, Demel Teketay, **Masresha Fetene** and Ralph Mitlohner (2006) Adaptation of five

co-occurring tree and shrub species to water stress and its implication in restoration of degraded lands. *Forest Ecology and Management* **229**:259–267.

15. Fritzsche, F, Asferachew Abate, **Masresha Fetene**, Beck, E, Weise, S and Guggenberger, G (2006) Soil-plant hydrology of indigenous and exotic trees in an Ethiopian montane forest. *Tree Physiology* **26**, 1043–1054.
16. **Masresha Fetene**, Yoseph Assefa, Menassie Gashaw, Zerihun Woldu, and Erwin Beck (2005). Diversity of Afroalpine vegetation and ecology of treeline species in the Bale Mountains, Ethiopia and the influence of fire. *Global Mountain Diversity*. P 250-267

Appendix 4-2. Curriculum vitae for Co-PI (short version) for Kenya: Samuel Gudu (Prof)

Contact Address: Department of Botany, Moi University, P.O. Box 3900, Eldoret, Kenya.
Tel No: 254-53-43321 OR/ 254-53-43319
E-MAIL: samgudu2002@yahoo.com OR/ dvcpdmu@yahoo.com

Current Position: Professor (Dept of Botany) & Deputy Vice-Chancellor (Planning and Development) Moi University.

Educational Background: PhD in Plant Genetics and Molecular Biology (1993, University of Guelph, Ontario Canada), MSc. (Genetics and Plant Breeding (1985, university of Nairobi) and BSc. (1983, Hon, Agric. University of Nairobi).

Current Research Program: low soil pH research in the area of aluminium toxicity and phosphorus acquisition efficiency in cereals, agro-forestry trees. The project deals with selection, breeding and development of tolerant populations for use in low pH soils. The focus is to trying to understand mechanisms behind the genetics of tolerance to Al toxicity and P uptake efficiency. The project investigates the effects of lime and phosphorus addition on acid soils and crop productivity. The use of QTLs and Marker assisted selection is also one of the focus. Prof. S. Gudu is involved in 5 funded projects, of which he is the PI. He has published over 35 Refereed publications and many non-refereed publications.

Selected Recent Publications:

Dangasuk, O.G and **S Gudu 2000** Allozyme variation in sixteen Natural Populations of African Feitherbia albida L Hereditas 133:133-145 3.41

Dangasuk,O.G, P. Seurei and **S. Gudu** 1997. Genetic variation in seed and seedling traits in 12 African Provenances of *Faidherbia albida* (Del.) A. Chev. Trials at Lodwar Kenya. Agroforestry Systems Journal 37:133-141.

Ligeyo D.O, G.O. Ombakho, SM. Maina, S.Gudu and A.O. Onkware 2004 Identification of maize germplasm tolerant to aluminium toxicity for use in acid soils of Kenya. Friessen, DK, AF.L Palmer (Eds) *In Integrated Approaches to higher Maize productivity in the New Millenium: Proceedings of the 7th eastern and Southern Safrican Regional Maize Conference pp216-222 ISBN 970-648-120-6*

Were B.A., A.O. Onkware and S.Gudu 2003. Yield and storage quality of improved sweet potato (Ipomoea batatas L) cultivars in the lake Victoria basin, Kenya E. Afr For. Agric Journal 68940: 197-204.

Gudu S, D.A Laurier, K.J. Kasha and j.W. Snape 2001. RFLP Mapping of Hordeum bulbosum highly expressed gene in the pistils, and its relationship to the homeologous loci in other Graminea Species. Theor Applied Genet. 105:271-276

Gudu S.and K.J. Kasha. 2001. Ocurrence and Developmental expression of a nuclear gene in wild barley (Hordeum bulbosum L). E. Afri For, Agric Journal 63: (2) 40-49

Were B.A, Onkware A.O., Gudu S, Welander M and Carlsson A.S 2005. Stability of seed oil content and fatty acid composition in sesame cultivars evaluated in western Kenya (Submitted, Journal of Agric and Food chemistry)

Gudu S., Obura P.A., Okalebo J.A., Othieno, C.O. and D.O. Ligeyo 2004. Response of maize genotypes to nitrogen, phosphorus and lime in acid soils of western Kenya. Presented to the 22nd annual Conference of the Soil Science Society of East Africa, in Nov/Dec in Arusha Tanzania.

Appendix 4-3. Curriculum vitae for Co-PI (short version) for Uganda: Patrick Okori (Dr.)

A. Contact Address: Crop Science Department, Faculty of Agriculture, PO Box: 7062 Kampala, Uganda, Mobile tel +256 772683623, Fax +256 414 531641, Email Patrick.okori@yahoo.com, or pokori@agric.mak.ac.ug

B.Current Position: Senior Lecturer, Crop Science Department, Faculty of Agriculture, Makerere University

D. Education

Period	Qualification	Award
1990- 1995	1995 Bachelor's Degree	BSc Agriculture
1996	1997 M.Sc.	MSC Crop Science (Genetic and Breeding)
1999	2004 Ph.D.	PhD (Breeding and Molecular genetics)

E. Scientific Leadership

Dr Okori's research group focuses on developing technologies to enhance the use of cereals (maize and sorghum) in Uganda and the wider region. The team mainly focuses on basic, strategic and applied studies of biotic stresses (diseases and pests) with sole purpose of strengthening breeding and management. The group also focuses on the development of value-added products to expand the niche and use of sorghums and cereals. The research team comprises of PhD students, MSc students, technicians and PhD level researchers. Table 1 shows major grants.

Table 1. Major research grants (2004 – present)

Funding source	Grant Title (Principal investigators)	US$	Period
DANIDA Fellowship Program.	Saving a precious crop: sustainable management of the Black Sigatoka disease of banana.	430,000	2010-2014
World Bank through a grant to the government of Uganda	Unlocking the potential of sorghum and maize as food feeds and industrial crops.	800,000	2008-2011.
BIOEARN Programme	Project I Biotress Component	500,000	2005-2010
RUFORUM.	*MAS systems for Beans. breeding*	60,000	2006-2009
RUFORUM.	*Plant nutrient efficient use sorghum*	60,000	2006-2009.

F. Capacity Building

Dr Okori has trained 4 PhDs and 20 MScs since 2004. He has also authored over 30 research articles in both local and international journals and other media. Dr Okori was core to the developed of the regional PhD Plant Breeding and Biotechnology and and MSc in Pant Breeding and Seed systems at Makerere

G. Contribution to Regional Development

Dr Okori was instrumental in the development of strategic and operationals plans for RUFORUM (www.ruforum .org), the Staple Crops Programme, ASARECA (www.asreca.org), One Bio-EARN Programme Grant (www.bioearn.org) and the BioInnovate Programme, Development of the FARA Africa-wide led initiative–SCARDA (see www.fara.org) and part of an international team that conducted studies underpinning the current DFID-UK Research Strategy 2007-2017.

H. Selected Journal Publications (2008-2009)

a) Nakyanzi, M., Fahleson, J., Okori, P., Seal, S Kenyon, L. and Dixelius, C. 2009. Genetic analysis of *Mycosphaerella fijiensis* in the Ugandan Lake Victoria region reveals a homogenous population. Plant Pathology 58: 888–897.

b) Nyadoi P., Okori, P., Okullo, J. B. L. Obua, J., Burg, K., Magogo Nasoro, Haji Saleh, Temu, A. B. and Jamnadass, R 2009. Tamarinds' (*Tamarindus indica* L.) niche tree species diversity characterisation reveals conservation needs and strategies. International Journal of Biodiversity and Conservation 1 (4) : 151-176.

c) Fahleson, J. Okori, P. Åkerblom-Espeby and Dixelius, C. 2008. Genetic variability and genomic divergence of Elymus repens and related species. Plant Sytematics and Evolution 271: (3), 143-156.

d) Okori, P. Fahleson, J., Rubaihayo, P.R., Adipala, E., and Dixelius, C. 2004. Genetic characterization of *Cercospora sorghi* from cultivated and wild sorghum and its relationship to other *Cercospora*. Phytopathology 94:743-750.

Appendix 4-4. Curriculum vitae for Co-PI (short version) for Tanzania: Emmarold E Mneney (Dr.)

A. Contact Address: ARI-Mikocheni, P o Box 6226, Dar Es Salaam
Tel +255 (0) 22 2775663, Mobile +255 (0) 754 387662
Fax +255 (0) 22 2775549, E-mail emneney@yahoo.com

B. Current Position: Cashew Biotechnology Section Head and Senior Researcher

C. Education

PhD (Biotechnology)	University of London, Wye College, UK. (Jan. 1995-Dec. 1998)
MSc (Tropical Horticulture)	University of Reading, Reading, UK (Sept. 1992-Sept. 1993)

D. Work Experience

1998 - To date	Cashew Biotechnology Section Head, Mikocheni Agricultural Research Institute (MARI)
1987 – 1995	Planting Material Production Unit head, Cashew and Coconut Tree Crops Project (CCTP)
1977 – 1987	District Agricultural Development Officer: Ministry of Agriculture, Dar-Es Salaam

E. Research Programme

Dr Mneney is a Principal Agricultural Research Officer with 25 year experience in studying various agricultural biotechnologies. His current research interests are molecular breeding, tissue culture and diversity studies among cashew, sweet potatoes, sorghum, maize, cassava, banana and tomato. He also has experience in technology transfer technologies and biosafety. Dr Mneney has worked on several collaborative programs, current research projects include: (i) Characterization and evaluation of sorghum (*Sorghum bicolor L. Moench*) collections from Tanzania using agronomic and morphological markers (ii)

Genetic transformation of maize addressing drought stress tolerance, (iii) Morphological and molecular characterization of sorghum hybrids for tolerance to drought and acid soils of Tanzania and (iv) Genetic, physiological, and molecular approaches to improve heat and drought tolerance in tropical tomato.

F. Selected Publications

Ringo, J.H; E.E Mneney; A.O. Onkware; B.A. Were; E.J. Too; J. O. Owuoche and S. O. Gudu (2009) Genetic Variation for Tolerance to Aluminium Toxicity among Tanzanian Sorghum Germplasm; 5th Annual International Conference on “Research and Knowledge Dissemination towards building Health and Socio economically stable Nations Production” Kenya: August 2009.

Ringo J.H; **E. E Mneney;** B.A. Were; E.J. Too; A.O. Onkware; and S.O. Gudu (2008). Breeding Sorghum (Sorghum bicolor L. Moench) for adaptation to low soil pH in Tanzania; A paper presented “Crop Production In Acid Soil” Eldoret, Kenya: June/July 2008.

Mneney, E. E., Mantell, S. H and Mark, B. (2001). Use of random amplified polymorphic DNA (RAPD) markers to reveal genetic diversity within and between populations of cashew (*Anacardium occidentale* L). *Journal of Horticultural Science and Biotechnology* 76 : 375-383.

Mneney, E. E. and Mantell, S. H (2002). Clonal propagation of cashew (*Anacardium occidentale.* L) by tissue culture. *Journal of Horticultural Science and Biotechnology* 77:649-657.

Masumbuko L Bryngelsson, T **Mneney, E** and Salomon, B (2003). Genetic diversity in Tanzanian Arabica coffee using random amplified polymorphic DNA (RAPD) markers. Hereditas 139: 56-63.

Mello, D and **Mneney, E. E**. (2004). Agricultural Biotechnology Research Partnerships in Tanzania. UNU-INTECH- Technology policy briefs, 8-10.

Madege, R. R., R. N. Misangu, A. P. Maerere and **E. E. Mneney (**2008) Evaluation of selected crop starches as cheap alternative gelling agents for micropropagation of Sweet potato (*Ipomoea batatas* (L.) Lam.). BioEARN/Vicres Scientific Conference, Entebbe, Uganda on November 2008.

Tairo, F., **Mneney, E E** and Kullaya, A. (2008). Morphological and Agronomical characterization of Sweet potato [Ipomoea batatas (L.) Lam.] germplasm collection from Tanzania. African Journal of Plant Science, 2 (8) 077-085.

Appendix 4-5. Curriculum vitae for Co-PI (short version) for Ethiopia: Kassahun Tesfaye (Dr.)

Contact Address: Department of Biology, Addis Ababa University, P.O. Box 1176, Addis Ababa, Ethiopia. Tel no: . ++251-911-882067
E-mail: kassahuntesfaye@yahoo.com or kassahuntesfaye@bio.aau.edu.et

Current Position: Assistant Professor, Department of Biology, Addis Ababa University Addis Ababa, Ethiopia

Educational Qualifications

BSc: Haramaya University, Ethiopia, Year 1995
MSc: Addis Ababa University, Ethiopia, Year 2000
PhD: University of Bonn, Germany, Year 2006

Professional Experiences

-March 2009 until present :- Ass. Professor, Addis Ababa University, Ethiopia.
-Sept2006 to Feb 09:- Senior Researcher at Center for Development Research, University of Bonn, -Germany and Ethiopian Coffee Forest Forum, Ethiopia.
-Oct2002 to Aug 06:- PhD student & Junior Research Fellow at University of Bonn, Center for Development Research, Germany
-Sept1995-Sept1998:- Crop Breeder & Genetist, Breeding & Genetics Research Division, Sinana Agricultural Research Center, Ethiopia.

Leadership

-January 2010, Coordinate and Lead, Training workshop on Application of Molecular Markers on biodiversity evaluation, Addis Ababa, Ethiopia.
-2007-todate:- Supervise several MSc students of genetics at Addis Ababa University, Ethiopia.
-Since 2002-03:- Member of Conservation & use of wild populations of *Coffea arabica* in the montane rainforests of Ethiopia & actively involved in administrative activities in the genetics sub-project.
-Aug 2000-Sept2002:- Center Director for Sinana Agricultural Research Center (SARC), Ethiopia.
-Year 2001:- Member and Counterpart for international expatriates group for three months study of effects of cereal monocropping in the highlands of Bale.
-2000-02:- Deputy Chairman of Bale Zone Research Extension Advisory Council, Ethiopia.
-1997-1998, SARC Team Representative of Highland Food & Forage Legume Research Project.
-1997-1998, Chairman of SARC Social Center, Ethiopia.
-1996-1998, Secretary, SARC Saving and Credit Association.

Selected Publications

1.Girma G., **Tesfaye K.,** Bekele E., (Accepted). Relationship between wild rice species of Ethiopia with cultivated rice based on ISSR marker. African Journal of Biotechnology..

2.Tesfaye K., et al, 2007. Characterisation of chloroplast microsatellites & evidence for the recent divergence of the *C. arabica* & *C. eugenioides* chloroplast genomes. Genome 50:1112-1129.

3. Fikiru E., **Tesfaye K.** & Bekele E., 2007. Genetic diversity and population structure of Ethiopian lentil (*Lens culinaris* Medikus) landraces as revealed by ISSR marker. African Journal of Biotechnology 6:1460-1468.

4.Kassahun Tesfaye, et al, 2008. Genetic Diversity & Population Structure of Wild *C. arabica* Populations in Ethiopia Using Molecular Markers. *Coffee Diversity and Knowledge*, Pp. 109-120. [ISBN: 978-99944-53-21-4]

5. Kassahun Tesfaye, 2006. Genetic diversity of wild *Coffea arabica* populations in Ethiopia as a contribution to conservation and use planning. CUVILLIER VERLAG, Gottingen, Pp. 137 [ISBN: 3-86727-986-1]. PhD dissertation, University of Bonn, Germany.

6. Padmapati Chintalapati, Kefyalew Girma, **Kassahun Tesfaye**, Qi Gubo, Andray Rodiyonov, 2001. " The shift to cereal monocropping, threat or blessing? " towards sustainable agricultural production in the highlands of Southeast Oromia, Ethiopia.ICRA,2001, Wageningen, The Netherlands. Working Document Series 92.

7. Kassahun Tesfaye (2000) Morphological and Biochemical Diversity of Emmer Wheat (*Triticum dicoccum*) in Ethiopia. Science Faculty, Addis Ababa University, Ethiopia.

9.Getachew T., Amsalu M., and **Tesfaye K.,** 1996. An overview of Varietal improvement on major crops in Bale Zone of Oromiya Region. A paper presented at the workshop technology generation, transfer and gat analysis, 9-11, July 1996. Nazareth Research Center, Melkasa, Ethiopia.