Final Report

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by

The Management Entity

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Table of Contents

1. Introduction and Program Review

The 2006-2013 INTSORMIL End of Program Report presents the progress and notable achievements by the Sorghum/Millet and Other Grains CRSP during the period of September 30, 2006 through March 31, 2013. These results are an outcome of partnerships between scientists at six U.S. Land Grant Universities (Kansas State University, University of Nebraska, The Ohio State University, Purdue University, Texas A&M University and West Texas A&M University), scientists of the Agricultural Research Service of the U.S. Department of Agriculture at Tifton, Georgia and the National Agricultural Research Systems (NARS) and National Universities in sixteen countries in Central America, West Africa, East Africa and Southern Africa.

Agricultural research provides benefits not only to producers but also to processors and consumers of agricultural products. Agricultural research has continuously shown that it is able to provide improved products of greater quantity and quality, as well as improved health to consumers and broad-based economic growth which goes beyond producers and consumers.

The Sorghum and Millet and Other Grains Collaborative Research Support Program (INTSORMIL CRSP) has conducted collaborative research through partnerships between 16 U.S. university scientists and scientists of the National Agricultural Research Systems (NARS), IARCs, PVOs, NGOs and other CRSPs. INTSORMIL has been programmatically organized for efficient and effective operation and has captured most of the public research expertise on sorghum and pearl millet in the United States***. The INTSORMIL mission has been to use collaborative research as a mechanism to develop human and institutional research capabilities to overcome constraints to sorghum and millet production, marketing, utilization and technology transfer for the mutual benefit of the Less Developed Sorghum and Millet Producing Countries (LDCs) and the U.S.*** Collaborating scientists in NARS, developing countries and the U.S. have jointly planned and executed research that mutually benefits all participating countries, including the United States.

INTSORMIL has taken a regional approach to sorghum and millet research and funds projects in four regions, western, eastern, and southern Africa, and in Central America. INTSORMIL support to these regions promotes the general goals of building NARS institutional capabilities and creating human and technological capital to solve problems constraining sorghum and millet production, marketing and utilization. INTSORMIL's activities are aimed at achieving a sustainable, global impact by promoting economic growth, enhancing food security, and encouraging entrepreneurial activities.

INTSORMIL continues to contribute to the transformation of sorghum and pearl millet from subsistence crops to value-added, cash crops. Because sorghum and millet are important food crops in moisture-stressed regions of the world, they are staple crops for millions in Africa and Asia. In their area of adaptation, sorghum and millet have a distinctly competitive advantage by yielding more grain than other cereals. The development of both open-pollinated and hybrid sorghums for food and feed, with improved properties, such as increased digestibility and reduced tannin content, is contributing to sorghum becoming a major feed grain in the U.S., Africa and Central and South America. Pearl millet is also becoming an important feed source for poultry in the southeastern United States. Improved varieties and hybrids of pearl millet and improved lines of sorghum can be grown in developing countries, as well as the United States. They have great potential for processing into high-value food products which can be sold in villages and urban markets, where they compete successfully with imported wheat and rice products. In the U.S., pearl millet is sold in niche markets, e.g., heads of pearl millet for bird food and for floral arrangements. These emerging markets, for

sorghum and pearl millet, are results of the training and collaborative international scientific research that INTSORMIL has supported both in the United States and collaborating countries.

Although there have been significant advances in the improvement and production of sorghum and millet in the regions in which INTSORMIL serves, population growth continues to exceed rates of increase in cereal production capacity. Thus, there remains an urgent need to continue the momentum of our successes in crop improvement, improved processing and marketing of sorghum and millet, and strengthening the capabilities of NARS scientists to conduct research on constraints to production, utilization and marketing of sorghum and millet.

The INTSORMIL program maintains a flexible approach to accomplishing its mission. The success of INTSORMIL can be attributed to the following strategies which guide the program in its research and linkages with technology transfer entities.

Developing institutional and human capital*:* INTSORMIL provides needed support for education of agricultural scientists in both developing countries and the United States. The results of this support include strengthening the capabilities of institutions to conduct research on sorghum and millet, development of international collaborative research networks, promoting and linking to technology transfer activities and dissemination of technologies developed from research, and enhancing national, regional, and global communication linkages. INTSORMIL provides essential support to bridge gaps between developing countries and the United States. A major innovative aspect of the INTSORMIL program is to maintain continuing relationships with scientists of collaborating countries upon return to research posts in their countries after training. They become members of research teams with INTSORMIL and NARS scientists who conduct research on applications of existing technology and development of new technology. This integrated relationship prepares them for leadership roles in their national agricultural research systems and regional networks in which they collaborate.

Conserving biodiversity and natural resources: Results of the collaborative research supported by INTSORMIL include development and release of enhanced germplasm, development and improvement of sustainable production systems and development of sustainable technologies to conserve biodiversity and natural resources. The knowledge and technologies generated by INTSORMIL research also enhance society's quality of life and enlarges the range of agricultural and environmental choices available both in developing countries and the United States. INTSORMIL promotes the conservation of millet and sorghum germplasm, resource-efficient cropping systems, integrated pest management strategies that conserve natural control agents and cultivars with improved nutrient and water use efficiencies and evaluates the impacts of sorghum/millet technologies on natural resources and biodiversity.

Developing research systems*:* Collaboration in the regional sites, in countries other than the United States, has been strengthened by employing multi-disciplinary research teams composed of U.S. and NARS scientists focused on unified plans to achieve common objectives. INTSORMIL scientists provide global leadership in biotechnology research on sorghum and pearl millet. The outputs from these disciplinary areas of research are linked to immediate results. INTSORMIL uses both traditional science of proven value and newer disciplines such as molecular biology in an integrated approach to provide products of research with economic potential. These research products, which alleviate constraints to production and utilization of sorghum and pearl millet, are key elements in the battle against hunger and poverty because they provide means for economic growth, generation of wealth, and improved health. New technologies developed by INTSORMIL collaborative research are extended to farmer's fields and to processors and marketers of sorghum and millet

products in developing countries and the United States through partnerships with NGOs, research networks, national extension services and the private sector. In addition, economic analyses by INTSORMIL researchers play a crucial role in enabling economic policymakers to more intelligently consider policy options to help increase the benefits and competitiveness of sorghum and pearl millet as basic food staples and as components of value-added products.

Supporting information networking*:* INTSORMIL research emphasizes working with both national agricultural research systems and sorghum and millet networks to promote effective technology transfer from research sites within the region to local and regional institutions and small farmers. Technology transfer is strengthened by continued links with regional networks, International Agricultural Research Centers, and local and regional institutions. Emphasis is placed on strong linkages with extension services, agricultural production schemes, private and public seed programs, agricultural product supply businesses, and nonprofit organizations such as NGOs and PVOs, for efficient transfer of INTSORMIL-generated technologies. Each linkage is vital to development, transfer, and adoption of new production and utilization technologies. The ultimate goal is to provide economic and physical well-being to those involved in the production and utilization of these two important cereals, both in developing countries, and the United States.

Promoting demand-driven processes*:* INTSORMIL economic analyses are all driven by the need for stable markets for the LDC farmer and processor. Thus, these analyses focus on prioritization of research, farm-level industry evaluation, development of sustainable food technology, processing and marketing systems. INTSORMIL seeks alternate food uses and new processing technologies to save labor and time required in preparation of sorghum/millet for food and feed, and to add value to the grain and fodder of the two crops. Research products transferred to the farm, to the livestock industry, and to processors and marketers of sorghum and millet are aimed at spurring rural and urban economic growth and providing direct economic benefits to producers and consumers. INTSORMIL assesses consumption shifts and socioeconomic policies to reduce effects of price collapses, and conducts research to improve processing for improved products of sorghum and millet which are attractive and useful to the consumer. Research by INTSORMIL agricultural economists and food scientists seeks to reduce effects of price collapse in high yield years, and to create new income opportunities through diversification of markets for sorghum and pearl millet. INTSORMIL socioeconomic projects measure impact and diffusion and evaluate constraints to rapid distribution and adoption of introduced, new technologies.

The INTSORMIL program addresses the continuing need for development of technologies for agricultural production, processing and utilization of sorghum and pearl millet for both the developing world, especially the semiarid tropics, and the United States. There is international recognition by the world donor community that National Agricultural Research Systems (NARS) in developing countries must assume ownership of their development problems and move toward achieving resolution of them. The INTSORMIL program is a proven model that empowers the NARS to develop the capacity to assume ownership of their development strategies, while at the same time resulting in significant benefits to the U.S. agricultural sector. These aspects of INTSORMIL present a win-win situation for international agricultural development as they strengthen developing countries' abilities to solve their problems in the agricultural sector while providing benefits to the United States.

2. Administration and Management

The University of Nebraska (UNL) hosts the Management Entity (ME) for the Sorghum/Millet and Other Grains CRSP and is the primary recipient of the Leader with Associates Cooperative

Agreement from USAID. UNL makes sub-awards to the participating U.S. universities and USDA/ARS for research projects between U.S. scientists and their collaborating country counterparts. A portion of the project funds managed by the ME and U.S. participating institutions supports regional research activities. The Board of Directors (BOD) serves as the top management/policy body for the CRSP. The USAID Acquisition Officer Representative (AOR) serves as a voting member of the Board and provides advice and guidance to the ME and the Board in areas of policy, technical aspects, collaborating country coordination, budget management and review.

3. Education

During the period of 2006-2012, there were 65 students from 32 different countries enrolled in an INTSORMIL advanced degree program and advised by an INTSORMIL principal investigator. Approximately 72% of these students came from countries other than the U.S. The number of students receiving 100% funding by INTSORMIL in 2006-2012 totaled 20. An additional 71 students received partial funding from INTSORMIL. INTSORMIL places high priority on training of women. During the period 2006-2012, 50% of all INTSORMIL graduate participants were female.

Another important category of education which INTSORMIL supports is non-degree research activities, namely postdoctoral research and research of visiting scientists with INTSORMIL PI's in the United States. During this period, 52 host country scientists improved their education as either postdoctoral scientists (8) or visiting scientists (44). Their research activities were in the disciplines of agronomy, food science and animal nutrition, entomology, breeding, economics, pathology and soil science. These scientists came to the United States as postdoctoral scientists or visiting scientists from Bolivia, Brazil, Burkina Faso, China, Colombia, Costa Rica, Cote D'Ivoire, Ecuador, Egypt, Ethiopia, Ghana, Guatemala, Honduras, India, Kenya, Korea, Malaysia, Mali, Mexico, Mozambique, Nicaragua, Niger, Nigeria, Pakistan, Russia, South Africa, Tanzania, U.S., Uganda, Zambia, and Zimbabwe. In addition to non-degree research activities there were 2207 participants (1075 male and 1132 female) who were supported by INTSORMIL for participation in workshops and conferences.

4. Networking

The Sorghum/Millet CRSP global plan for collaborative research has included workshops and other networking activities such as newsletters, webpage, publications, exchange of scientists, and exchange of germplasm. The INTSORMIL global plan was designed for research coordination and networking within ecogeographic zones and, where relevant, between zones. The Global Plan:

- Promoted networking with IARCs, NGO/PVOs, regional networks (ASARECA, ECARSAM and others) private industry and government extension programs to coordinate research and technology transfer efforts.

- Supported INTSORMIL participation in regional research networks to promote professional activities of NARS scientists, to facilitate regional research activities (such as multi-location testing of breeding materials), promotes germplasm and information exchange and facilitates impact evaluation of new technologies.

- Developed regional research networks, short-term and degree training plans for sorghum and pearl millet scientists.

Establishment of networking activities with ICRISAT in India, Mali, Niger, Kenya, Ethiopia, Uganda and Tanzania; Central America and with CORAF and ASARECA/ECARSAM in East Africa, SICNA and the U.S. National Grain Sorghum Producers Association for the purpose of coordinating research activities to avoid duplication of effort and to promote the most effective expenditure of research funds has been accomplished. There also has been efficient collaboration with each of these programs in co-sponsoring workshops and conferences, and for coordination of research and long-term training. INTSORMIL currently cooperates with ICRISAT programs in east, southern and West Africa.

5. Regional Activities and Benefits

West Africa

Twenty-one scientists from Burkina Faso, Mali, Niger, Nigeria, and Senegal focused on "Increasing farmers' and processors' incomes via improvement in sorghum, pearl millet, and other grain production, processing, and marketing systems" led by A. N'Doye and M. Diourte and "Integrated *Striga* and nutrient management for sorghum and pearl millet" led by H. Traore. Projects funded through the Mali Mission and directed by B. Hamaker and J. Sanders provided collaborative assistance with marketing aspects of the West Africa regional program, as did a grant for technology transfer. U.S. scientists who worked in West Africa included B. Hamaker, J. Hancock, B. Pendleton, V. Prasad, S. Staggenborg, J. Sanders, M. Tuinstra, and E. Heinrichs.

The *Striga* sub-project identified 15 resistant sorghums and millets; characterized and implemented systems that used water management, fertilizer, weeding, rotation, or intercropping; determined effects of herbicide seed treatments; and transferred technology through Farmer Field Schools and on-farm demonstrations by farmers for 548 farmers in 27 villages. Resistant seeds of sorghum yielding as much as 3,037 kg/hectare were given to 250 farmers in Senegal. With integrated management, *Striga* per meter decreased 64% and sorghum yield tripled.

The production sub-project used seed multiplication, on-farm testing, and exchange of sorghum and millet varieties to disseminate best cultivars in combination with fertilizer, plant density, and protection from disease and insect pests in the field and storage. Fungi were identified on stored grain. Four sorghums were resistant to leaf anthracnose. Sorghum resistant to downy mildew was disseminated to 2,400 farm families. More than 160 people attended a field day and 260 visited tests of 11 improved sorghum varieties and chemical treatment for seed-borne diseases. Bug-tolerant sorghum was distributed to 42 farmers. Thirteen extension agents and a farmer organization of 80 helped 1,049 farmers in 44 villages adopt and/or multiply seed of two sorghum midge-resistant sorghums which benefited farmers by $490 per hectare on 314 hectares over the local varieties in Niger. Three varieties resistant to millet head miner were transferred to farms in Niger. Surveys with 552 farmers from 20 villages, 25 extension agents, and 11 university interns evaluated storage insects and facilities and assessed protection for millet and sorghum. Sorghum grain in triple bags was much less infested by storage insects. A workshop trained 26 trainers on production and protection of décrue sorghum in Mali. A brochure and posters in French to identify and manage insect pests of stored grain were distributed and explained to hundreds of farmers in Mali. National and local media informed hundreds of farmers.

Tied-ridge technology, fertilizer, and plant population improved sorghum yield 10- fold and was adopted by 180 farmers in Niger. Ten farmers demonstrated the use of micro-dose fertilizer for millet, and several thousand farmers wanted to adopt the technology on several thousand hectares. In Burkina Faso, 1,046 farmers were trained and 544 adopted micro-dose technology on 783 hectares.

Breeders evaluated hundreds of sorghums in West Africa. Farmers compared 160 sorghum lines yielding 2-3 tons and 5 hybrids yielding 3.5-4 tons/hectare in Mali. Fifty hybrids and 39 improved sorghums were spread in Niger. In Burkina Faso, 52 sorghum lines yielded 3-4 tons per hectare. Nine sorghum varieties yielding 4-4.5 tons per hectare were released in Senegal. In Nigeria, 7 millet varieties were accepted by 90% of farmers in 92 villages, each with 200 families. Bagged sorghum grain was sold by a private seed company in Niger.

More than 40 entrepreneur farmers were provided seeds and fertilizer and trained in sorghum production in Mali and Niger. Twenty farmers produced 97 tons of grain from 327 and 58 hectares of sorghum and millet. Ten thousand farmers could benefit from multiplication of sorghum seeds in Senegal alone. Storehouses for grain were built in several countries.

The marketing component focused on processed food and animal-feed markets and expansion through development of quality processed sorghum and millet products for marketing and use of sorghum in poultry feed. Production technologies were transferred to entrepreneurs, local processing groups were assisted to initiate businesses, and sorghum and millet were characterized as "functional foods" for health. In Burkina Faso, 20 women brewers were trained and 3 produced 1.7 times more dolo of better quality than did brew houses. Thirty-two farmer entrepreneurs contracted and produced 135 tons of grain for 79 processor groups of about 30 members. Twenty to 50 tons of grain were needed per year to produce sorghum/millet foods for 49 stores or open markets.

Grain processing incubation centers with a mechanical thresher to produce clean grain, gas drier, gas steamer, food mixer, baking oven, pasteurizer for milk-degue, and packaging machine were completed and 12 sub-incubation centers established. More than 11 processor associations increased their equipment. Bread making was initiated with 3 bakeries. The incubation centers taught new technologies for sorghum flour, couscous from different particle sizes, biscuits, boulettes, dakuwa (snack like chocolate), degue, extruded fura, moni curu, porridges, weaning foods, and composite-flour bread using as much as 30% millet or sorghum mixed with wheat. Millet/peanut bread was developed for lactose-intolerant school children. Economical millet couscous was developed from semolina instead of flour. Sorghum/millet couscous-yogurt was produced. Couscous was packaged for marketing. A video on processing, pamphlets, stickers, and radio and television publicized the processor incubation centers.

Low-tannin sorghum replaced maize without compromising growth, meat yield, egg production, or health of chickens. A network of scientists and producers taught poultry science to producers and extension in Burkina Faso, Mali, Niger, Nigeria, and Senegal.

More than 20 scientists from 5 countries met in April 2008 in Mali and in May 2010 in Burkina Faso to discuss sorghum and millet production, marketing, *Striga*-management, and technology transfer activities for West Africa. These meetings were very beneficial for planning regional activities. The regional coordinators met in August 2009.

Five Ph.D., 9 M.S., and 48 undergraduate West African students were educated in agricultural engineering, breeding, food science, insect and disease management, molecular biology, or poultry science at universities in Burkina Faso, Niger, Nigeria, Senegal, and the U.S. Two students from universities in France also were trained in Senegal. Funds were not adequate to educate enough host-country scientists at universities in the U.S., but educational opportunities were available from universities in the host countries.

The host-country scientists reported seven publications in scientific journals.

Horn of Africa

The Horn of Africa Regional Program now encompasses four countries- Tanzania, Uganda, Kenya and Ethiopia.

Sorghum and millet constraints in the region continue to be low productivity and limited markets for the grain produced. Major production constraints include water deficits, stem borers, nitrogen deficiency, *Striga*, weeds and *Quelea quelea* (birds). Farm household interviews in Tanzania show a low rate of adoption for production technologies, often due to lack of knowledge and availability of technologies (e.g., seed of improved varieties) or market instability and seasonal price fluctuations. The market limitations are perpetuated by a general lack of reliable quality grain production. Storage and transport infrastructure deficiencies compound the product/market disconnect. The INTSORMIL regional project team continues to address these constraints from developing production technologies, extending these to farmers in the region and exploring new market outlets for sorghum and millet while enhancing and protecting profits for all involved in the supply chain. Studies of the sorghum based clear beer value chain in Tanzania is an excellent example of this holistic approach. The study included interviews with sorghum farmers, traders, transporters, processors, distributors and warehouse owners. There has been a modest increase (4%) of sorghum based product in the clear beer industry in the region over the last two years of the study. The study concludes that continued growth in the sorghum beer industry depends on potential demand of the buyers, consistent and high quality grain from farmers, adequate transportation and storage infrastructure, profitability for all chain members and trust and contract enforcement mechanisms. This study validates the INTSORMIL objectives for regional development.

Although not all planned activities for Years 6-13 of the individual projects comprising the Horn of Africa regional program were accomplished during the seven years, there are clear indications that progress is being made in the region. Production technology development continues through breeding of *Striga* resistant sorghum hybrids, testing and optimization of agronomic practices adaptable to the region. Sorghum and millet constraints are then further addressed through analysis of technology adoption, detailed value chain studies, monitoring of market forces on commodity prices and new product development. The regional program reflects well the major objectives of supply chain/market development, IPM, genetic enhancement and building partnerships. Through all these activities, students who are being trained provide the human capacity for development in the host countries.

Southern Africa

The collaborating southern Africa countries (Botswana, Mozambique, South Africa and Zambia) combined to produce about 91% of the sorghum and 62% of the millet for the region. The regional project included 10 research projects directed by 13 scientists representing 7 agencies in 3 countries. Botswana activity was discontinued to move the program into compliance with Feed the Future guidelines. U.S. collaborating scientists are: Texas A&M University - Gary Peterson, Lloyd Rooney, and Bill Rooney; Ohio State University - Mark Erbaugh and Don Larson; University of Nebraska - David Jackson, Curt Weller and Charles Wortmann; Kansas State University - John Leslie; and West Texas A&M University - Bonnie Pendleton.

Research and Technology Development: Eight sorghum varieties have been proposed for release in Mozambique and are in pre-release testing. In Zambia, the pearl millet varieties Dola, Liseli and Mutatiwa were released to farmers. New pearl millet varieties are in developed with long 'bristles' for enhanced bird resistance. New sorghum variety releases include ZSV-15, WP-13 and (Fram*SC3845). The pre-released variety ZSV-36R exhibits grain yield. Causal mechanisms and resistance to sorghum root rots have been identified. Results will be useful in developing control tactics and host plant resistance. Effect of grain molds on sorghum grain and glume characteristics is on-going. Properties of sorghum for food end-use and brewing have been studied. Sorghum biscuits for use in school food program offer the potential to increase nutrition in at-risk youth. Study of

mycotoxins show that selected strains from sorghum grain have the potential to reproduce fumonisins and moniliformins on maize patty cultures. Sorghum and pearl millet is relatively less damaged by mycotoxins than maize. The sorghum value chain in Zambia was evaluated with constraints and opportunities identified. Improved sorghum varieties were developed with excellent grain yield potential and resistance to the sugar cane aphid.

Technology Dissemination: Seed of sorghum and pearl millet varieties was produced each year in Zambia and Mozambique. During this project about 80t of sorghum and pearl millet were produced for distribution. Sorghum varieties increased for distribution include Sima, Macia, Sureno, ZSV-15, WP-13, Kuyuma, and (Framida*SCS 3845). Pearl varieties increased for distribution include Dola and Lubasi. Seed was distributed to approximately 3,500 farmers in several districts in Mozambique and Zambia. Approximately 50% of the farmers receiving seed were female. Technology pamphlets developed and posted on the INTSORMIL internet site include "Five Simple Methods for Determination of Sorghum Grain End-Use Quality", "Developments in Sorghum Lager and Stout Sorghum Brewing", "Guide to Flour Malting of Sorghum and Millets". Collaboration through a Memorandum of Understanding was established with SABMiller regarding use of sorghum for lager beer brewing.

Human Capital Institutional Development: Twenty-six African scientists representing 8 countries received 12 M.S. and 14 Ph.D. degrees either supported partially or fully by INTSORMIL, or in host country collaborating projects. Two degrees were at U.S. INTSORMIL institutions. Degrees were in Food Science, Plant Pathology, Plant Pathology/Plant Breeding, and Agricultural Economics. One collaborating scientist participated in a short-term training program. Two workshops were co-sponsored by INTSORMIL. In November, 2008 a workshop on "Alternative Cereal Processing Technologies" for about 60 existing and potential sorghum food processors was held at Lobatse, Botswana. Co-sponsors were the Botswana National Food Technology Research Center and Cereal Science and Technology – South Africa. In December, 2010 the "Sorghum Food Enterprise and Technology Development in Southern Africa" workshop was attended by 64 participants in Lusaka, Zambia. *Publications*: Refereed journal, book chapters, proceeding and other publications totaled 68. Included are 56 refereed journal publications, 7 book chapters, three proceedings and 2 miscellaneous publications. A database on performance characteristics of varieties grown in southern Africa was posted on the INTSORMIL internet site.

Central America

Most sorghum production in Central America is in Guatemala, El Salvador, Honduras and Nicaragua. Research projects for INTSORMIL in Central America were primarily in in El Salvador and Nicaragua; with supplemental testing and distribution in Guatemala, Honduras, Costa Rica and Panama. El Salvador and Nicaragua were focal points because these two countries had research infrastructure in place to complete the necessary tasks and then distribute that material to the rest of the region. The participating US PIs have been William Rooney, Lloyd Rooney from Texas A&M University, Joe Hancock from Kansas State University and John Saunders from Purdue University. Sorghum is the crop of interest in the region and it is used as both a grain and forage crop.

Research and technology development. In the past five years, the primary technologies developed include sorghum germplasm and varieties that have been distributed throughout the region and milling technologies to produce sorghum flour which is mixed with wheat flour to reduce the amount of imported wheat flour and provide a market for locally produce sorghum grain. Sorghum varieties have been developed for two production systems. First, two improved photoperiod sensitive varieties were developed that fit the small producer who produce sorghum in combination with corn.

Second, a set of dual purpose (forage/grain) varieties with improved forage quality were developed for use in the regions. These varieties possess the brown midrib trait that enhances forage quality.

Technology dissemination (TOT):

1. Demonstration and training workshops were held throughout sorghum producing regions of both El Salvador and Nicaragua from 2008-2012. In total, over 40 workshops were held to demonstrate the processing of sorghum flour and its use in bakery products. In addition, through collaborating programs, ten sorghum mills were purchased and sold to small bakeries in El Salvador. They are in use today.
2. In all six countries in the region, at least one brown mid variety was released from our program for producers in the countries. The particular variety varied from country to country (based on adaptation), the distribution and adoption by producers has been substantial (e.g., over 1,000 growers obtained/purchased seed at cost in Honduras).

Human resource enhancement. Four Central American scientists were supported for higher degrees with one PhD in plant breeding, one MS degrees in food science and two MS degrees in agricultural economics. Numerous collaborators were supported for short term training and as visiting scientists. Two regional workshops were held for scientists I the region to train them in forage utilization, sorghum flour and/or varieties for the region.

Publications. Refereed journal publications, books and book chapters included three in plant breeding, two in agricultural economics and five in food science; approximately half of these had a Central American collaborator or student as the lead author.

The regional programs of the INTSORMIL program are designed to support national research program efforts to develop dynamic, competent institutional research programs which contribute to productivity, economic growth, natural resource conservation and improved nutrition of people in the region. By accessing available expertise and infrastructure in the region, support from INTSORMIL is designed to facilitate and promote interaction between national programs, NGOs, international research centers, private sector and scientists from the U.S. land grant universities to achieve the goals of improving productivity, profitability, economic growth and food security for producers and consumers as well. Since 1999, INTSORMIL program emphasis in Central America has been based in El Salvador and Nicaragua. In-region coordination is provided by Ing. Rene Clara-Valencia and scientists from collaborating institutions in El Salvador and Nicaragua have met to discuss and develop country-based research plans for the next year with projects proposed in plant breeding, utilization, plant protection (entomology and plant pathology) and agronomy, and grain quality/utilization. However, additional support and activities are allowing the INTSORMIL program to extend throughout Central America.

Grain sorghum is the third most important crop in Central America (El Salvador, Guatemala, Honduras, and Nicaragua) after maize and beans. The area devoted to grain sorghum in 2003 was 225,000 ha^{-1}, and produced an average grain yield of 1.5 Mg ha^{-1} (FAO, 2004). More recently, statistics in El Salvador document an average yield of > 2.0 Mg ha^{-1} and given that production area has remained static, the overall sorghum production has increased due to the increased yield. While some of this increase may be due to favorable weather, other reasons include the adoption of improved technology (including improved cultivars and hybrids, herbicides, insecticides, planting date, minimum tillage, seed treatments and fertilizer) available to producers.

6. Associate Awards

Mali Associate Award

In 2007 INTSORMIL received a five year (September 29,2007 – September 30, 2012) $250,000/year award **"**Transfer of Sorghum, Millet Production, Processing and Marketing Technologies in Mali" from the USAID/EGAT/AG/ATGO/Mali. The project was based on successful activities through the INTSORMIL West Africa Regional Project and was designed to rapidly move sorghum and millet production technologies onto farmers' fields, link farmers' organizations to food and feed processors and commercialize processing technologies so as to enhance markets and to significantly expand the existing project, especially into the northern areas of Mali

This report covering the period September 21, 2007 to September 30, 2012 details the major results obtained under the Cooperative Agreement # 688-A-00-007-00043-00 with its four components: (1) Production-Marketing; (2) Décrue Sorghum; (3) Food Processing; and (4) Training. To achieve project goals we followed a value chain approach to improve the supply chain from the farm level to the consumer. The program emphasis in the north was on the development and transfer of décrue sorghum technology, while in the south the transfer of rain fed sorghum and millet technology was accelerated. A training component was designed to strengthen IER technology development and transfer capacities so as to expand and continue the activities initiated by this project. Major Project achievements are summarized below.

Mali Feed the Future Strategy- Based on the success of this project the new USAID-Mali Feed the Future initiative includes millet and sorghum as priority crops. Since grains of these crops are the main ones consumed by humans in Mali, demonstrating the potential of these crops for higher yields, incomes, and market expansion may be our most important contribution.

Perception change- Our results changed the popular perception that 1) sorghum and pearl millet are subsistence crops, 2) sorghum and pearl millet do not respond to fertilizer, 3) farmers cannot increase income by fertilizing their crop and thus will not apply fertilizer and 5) banks will not provide credit to apply fertilizer to sorghum or millet.

Demonstration of a successful production and marketing model- We demonstrated that our model of sorghum and millet production and marketing could substantially increase yields, prices and incomes. Annual reports of these parameters were published in bulletin format.
Demonstration of a successful extension model- We successfully demonstrated a new extension model of village level activity as previous demonstration trials with cereals, in the Sahelian countries, have generally been unsuccessful.

Value chain approach- We followed a value chain approach in our technology development and transfer activities. Our intervention points along the chain were at the following levels: Inputs→ Producer→ Grain storage→ Processor/market/poultry farmer→ Market expansion→ Retail distributor→ Consumer. A value chain is the recognition that the value of the product is created by the producer (farmer) plus a number of activities along the chain to the consumer. A value chain approach is especially important in reducing poverty and increasing food security of vulnerable groups such as smallholder farmers and female headed households because these groups have the fewest commercial relationships and reap the fewest benefits from these economic activities.

Technology development and transfer activities- 1) Five improved sorghum varieties (Grinkan, Niatichama, Seguifa, Tiandougou and Tiandougou coura) and one improved millet variety (Toroniou) have been successfully disseminated to five regions in Mali during the period 2008 to

2012 (See Annex A), 2) Promotion of proper grain storage through the construction of storage structures by collaborating NGOs, providing advice on the management of storage pests and by introducing triple layered hermetically sealed bags to control grain storage insects, 3) Transfer of sorghum production technology to farmers via on farm demonstrations and the formation of farmers' associations and linking the farmers to the value chain in 19 villages covering 2,852 ha, 4) Transfer of millet production technology to farmers via on farm demonstrations and the formation of farmers' associations and linking the farmers to the value chain in 8 communes and 10 villages covering 3,544 ha, 5) 1,860 hectares were placed under improved technologies or management practices in 2012, 6) 1,690 vulnerable households are benefitting from improved technologies or management practices in 2012, and 7) This is the first comprehensive research conducted in the décrue systems in the northern region of Mali.

Success of sorghum cultivar Grinkan- A high yielding IER bred cultivar Grinkan was planted on about 3,000 ha in Mali in 2012 through INTSORMIL and IICEM collaboration. We also introduced Grinkan into Burkina Faso and Niger with excellent results. The project was instrumental in moving Grinkan technology out of the research station and onto farmers' fields.

Rural income- Where improved millet/sorghum varieties + management practices have been adopted in Mali, the farmers have become rich through the sale of the clean grains to traders. As one of many examples, farmers at Garasso annually sell 25,000,000 FCFA of Grinkan. With 1,860 ha under improved technologies and a one ton/ha increase through the use of the Grinkan sorghum variety + the improved package of practices we estimate a 1,860,000 kg increase in sorghum grain in Mali in 2012.

Extension and marketing strategy developed-The integration of the technical extension and marketing aspects of the project are critical to be able to finance the additional inputs needed to overcome the soil fertility constraints. Income gains were achieved by 1) producing clean (sand, dirt and stone free) millet, 2) selling later in the year when prices rebound, 3) finding new markets, especially millet food processors, and later in the marketing chain, village or local town merchants and by 4) increasing the bargaining power of farmers through group sales and input purchases via the farmers' associations.

Scaling up- There was a substantial scaling up our technology-marketing-institution model in 2010-2012 by IICEM and Global 2000. With a 5,000 ha goal of IICEM in 2012 and an expected increase of 1 ton/ha this has the potential of increasing production by 5,000,000 kg of grain in the battle against hunger.

Model villages- Development of model agricultural villages in the different regions, which are now very well known for their sorghum and millet production: Garasso in Koutiala, Tingoni in Segou, and Kountogoro in Mopti.

Package of recommended practices from sowing to marketing developed- 1**)** Sorghum (in French), 2) Sorghum (in Bambara), 3) Millet (in French), 4) Millet (in Dogon), 5) Décrue sorghum for North Mali (Mopti/Tombouctou) and 6) Décrue sorghum for South Mali (Kayes Region).These are the first recommendations developed for décrue sorghum in the Sahel.

Incubation Center Model- The food processing project created the "Incubation Center" model for making sorghum and millet processors more competitive and to grow markets for small holder farmers. The Incubation center model established at IER/LTA in Sotuba, was designed to introduce and improve technologies for urban processors and to work with them to strengthen their

enterprises. The goal for the Incubation Centre was to make this an interactive facility where local entrepreneurs are trained in new cereal processing technologies, are able to use the equipment to produce product on a limited scale, test the marketplace, bring feedback to the Center for process improvement R&D, and to access investment funds for their own mechanized operations.

Contributions of the Bamako Incubation Center-High quality sorghum flours were produced from advanced food quality sorghum lines and provided to SOADF, the baking school and training center for Mali. It was demonstrated, that with superior quality flours, baked products can be made with 20% sorghum flour incorporation without loss in quality (or discrimination with 100% wheat flour products). We feel this Incubation Centre concept in Mali would work to provide Bamako and smaller urban entrepreneurs' new processing technologies and technical expertise to grow their enterprises and expand the market for sorghum and millet. This concept is successfully working in Senegal and Niger and has resulted in investment in processors.

Food processing entrepreneurship model-The food processing project developed a model of "food processing entrepreneurship" which was designed to mechanize processors (mostly women) and to work with them to grow their enterprises. Chosen from local processor associations, seven women and their respective teams were financed and constructed structures set to project specifications and their units were supplied with milling equipment to be paid back to the project on the depreciated portion of their equipment. They were trained in technical aspects of processing, business management and marketing concepts. They were linked to the production-marketing component of the project, and bought clean and quality sourced grains from the nearest farmer group associated with the Production-Marketing Project (J. Sanders). High quality was emphasized and processors saw how consistent, high quality products could be sold well in the market. Packaging was developed to maintain a central brand for these competitive products as produced by the different processors. Due to the curtailing of the project after the coup d'etat, the final activities of introducing a centralized mechanized processing line for agglomerated products (using an "incubation" concept of training and usage) and scaling up of production was not done.

Contributions of Mopti/Gao Processing Project-1) We have shown that mechanized food processing can be successful even in rural areas when introduced with care and when attention is paid to details to assure high quality, competitive products, 2) Even though the project terminated in March 2012, due to the coup, IER continued working with the women entrepreneur processors and they have continued their business activities in Mopti and three of the four have paid their installments as per their contracts into the fall 2012 and 3) The Mopti/Gao processing project demonstrates a model that works and is market driven and sustainable.

Long term trainees- Five long term trainees participated in the program. The initial four students (Aly Ahamadou, Fatimata Cisse, Mamadou Dembele and Bandiougou Diawara) arrived in Indiana June 2009 and began a six-month custom English language program through the Indiana University Center for Intercultural Communication (ICIC) in Indianapolis. Home stays with English-speaking families were an important part of the program. The final participant, Sory Diallo, arrived in January of 2010 and began his English language training at Kansas State University (KSU). By June 2011, all five participants were accepted into graduate programs with proposed finish dates ranging from June 2012 to December 2013.

Fatimata Cisse, the only female participant, was admitted to Purdue January 2010 to pursue her Master's in Food Science working with Dr. Bruce Hamaker. Due to her exceptional performance and the potential benefit to Mali/IER, Dr. Hamaker pursued funding support, IER approval and by-pass approval for Cisse to move to a PhD program. Her proposed PhD completion date is May 2014 and

at that time she will return to Mali and continue her research at IER in the Bamako Incubation Center.

Bandiougou Diawara was admitted to the KSU Graduate School and began his Master's program in Agronomy at KSU June 2010. Working with Drs. Vara Prasad and Scott Staggenborg, Diawara successfully completed his coursework and thesis research and in June 2012 returned to Mali and his position at IER.

Sory DIALLO was admitted January 2011 to KSU's Graduate School to pursue his Master's in Agronomy. Working with Drs. Prasad and Staggenborg, he completed his coursework and conducted his research in Kansas. He successfully defended his thesis in late August 2012 and then returned to Mali and his position at IER.

Aly Ahamadou and Mamadou Dembele are both pursuing a non-thesis MSc. In June 2012, when USAID suspended support, WTAMU was able to find non GOM funding to support Ahamadou and Dembele, allowing them to remain at WTAMU to complete their degrees. They are scheduled to complete their degrees and return to IER/Mali by December 31, 2012.

Short Term Trainees- Plant breeding trainee Abocar Oumar Toure completed his two month training at Purdue with Dr. Mitch Tuinstra in September 2010. In October 2011, crop production trainee Abdoul Wahab Toure completed his two month training at Kansas State with Drs. Vara and Staggenborg on sorghum and soybean crop physiology and production. Both returned to IER/Mali.

BMR Associate Award

I. Introduction

Poverty is a real issue in Central America. In 2000, 64 percent of the population lived in poverty and 39 percent lived in extreme poverty. Studies show that about 65 percent of the population lives on farms. Through the Feed the Future Initiative, the United States Agency for International Development (USAID) is contributing to easing the poverty problem in Central America by working with the University of Nebraska-Lincoln-based Sorghum Millet and Other Grains program (INTSORMIL). USAID granted a $1.1 million associate award to INTSORMIL in October 2010 for a three year program in six Central American countries—Guatemala, Honduras, Nicaragua, El Salvador, Panama and Costa Rica—and Haiti in the Caribbean. The project, "Identification and Release of Brown Midrib (bmr) Sorghum Varieties to Producers in Central America and Haiti," aims to help farmers grow more productive forage sorghum crops. Forage sorghum is the green leafy material and stalk on sorghum (not the grain) that farmers can use for feeding dairy and beef cattle. If the forage is more productive, then dairy and beef cattle produce greater amounts of meat and milk.

II. Bmr Forage Sorghum Work plan and progress Report 2010-2012

Name of Program: Identification and Release of Brown Midrib (*bmr*) Sorghum Varieties to Producers in Central America and Haiti
Associate Award Cooperative Agreement No. AID-OAA-LA-10-00009
Execution Time:
October 1, 2010 to September 30, 2013
Name of Primary Grantee: University of Nebraska, Lincoln
Submitted by: E. A . "Short Heinrichs, Assistant Director, INTSORMIL

Summary:
Scientists from the INTSORMIL-CENTA project based at the National Center for Agricultural Technology and Forestry (CENTA) of El Salvador have worked for five years to develop varieties of sorghum for grain and forage that are highly nutritious to cattle. Using the gene *bmr*-12, they combined commercial varieties CENTA S-2, S-3 CENTA, CENTA RCV and VG 146 and produced 75 new varieties. Plants with the *bmr* gene have low fiber cell wall lignin which makes the plant more readily digestible and allows more nutrients to be absorbed in the stomach of animals. Thus, *bmr* sorghum competes with more expensive maize on the nutritive value level. In addition, sorghum is more resilient to weather extremes e.g. flooding and drought and requires less water for production.

Based on the potential impact of these varieties on reducing rural poverty and increasing nutrition USAID/W is supporting a project (2011-2013) to rapidly distribute these CENTA-developed varieties to Costa Rica, Honduras, El Salvador, Guatemala, Panama, Nicaragua and Haiti. Fifteen *bmr* varieties were evaluated in each country in Year 1 and the best performing varieties were selected. These varieties were then evaluated in on-farm field demonstrations and in dairy farm feeding tests in each country in Year 2. Results indicate that dairy farmers had an average increase of 20% in milk production and weight gain of the cattle was 900 g per animal per day (10% increase over conventional sorghum).

El Salvador, Nicaragua, Honduras and Guatemala have already commercially released these varieties to dairy farmers in 2012 (See Annex A) and further releases will follow in the other countries in 2013. The *bmr* varieties are rapidly spreading throughout Central America. In 2012 there were 8,000 ha of *bmr* varieties and these varieties benefitted 5,800 vulnerable households. By 2014 it is projected that these varieties will cover 40,000 ha in Central America and Haiti and will benefit 23,000 vulnerable households.

The *bmr* varieties are poised to have a significant impact on increasing rural income and promoting food security throughout Central America and Haiti. If the entire 388,800 ha of sorghum in these seven countries is in *bmr* sorghum 381,550 farmers would benefit and total income would increase by $163,227,090 per year.

Future Directions

Prices of many basic foods skyrocketed in 2008 resulting in a major food crisis that affected millions of poor people throughout the world. The causes of the crisis are many and complex. An increasing demand for food and energy at a time of low food stocks, poor harvests and weak credit have led to record prices for oil and food. However, in an interview with Reuters, World Bank Agriculture Sector Manager for Africa Karen Brooks said, “Food price hikes are hitting Africa's urban populations harder now than in 2008 and pose a serious challenge to some of the continent's leaders, who face elections this year….

Brooks said investors were excited about African agriculture but that the continent was still missing out due to lingering fears over land rights, taxation and stability as private funds flow into Latin America and Central Asia. African leaders have committed to devoting 10 percent of their budgets to agriculture as part of efforts to bridge investment gaps. But Brooks said results were mixed….

Meanwhile, some African nations have made progress in adopting policies and most have recognized the urgency, but just a handful are meeting the 10 percent budget target. Better weather has

supported harvests this year, but the deficit remains vast…. Brooks said the World Bank was focusing on four main issues: land and water management, technology, agricultural markets and infrastructure, and food security and vulnerability…. Poor infrastructure, weak financial services and concerns over land rights are among the key concerns the World Bank is trying to tackle to encourage investors to turn to Africa, rather than other regions where returns are quicker, she added." [Reuters/Factiva]

Without appropriate interventions, the food crisis is not likely to resolve itself. In determining the proper response we must take into consideration that "Food crop prices were expected to remain high in 2010/11 and then start to decline as supply and demand respond to high prices; however, they are likely to remain well above the 2004 levels through 2015 for most food crops. Forecasts of other major organizations (FAO, OECD and USDA) that regularly monitor and project commodity prices are broadly consistent with the projections. It is unlikely that demand will decline markedly in the future so in order to lower prices supply must be increased. Increasing agricultural production will require input from developing countries, international organizations, and donors.

The new Sorghum, Millet and Other Grains CRSP Leader with Associates Cooperative Agreement was authorized and funded by USAID effective October 1, 2006. Strategies under this new CRSP have maintained INTSORMIL's highly productive momentum, built on its record of success, and continues to work toward accomplishing a whole new set of goals. INTSORMIL's new vision to improve food security, enhance farm incomes, and improve economic activity in the major sorghum, millet and other grains-producing countries in Africa and Central America is proving to be successful as indicated in this report. The CRSP is demonstrating international leadership in leading efforts to promote profitable markets for sorghum, pearl millet and other grains by working with agencies that identify and develop markets, assess economics, and facilitate the evolution of a production-supply chain and by expanding markets that deliver quality grain to end users. Future strategies will maintain the new CRSP's highly productive momentum, continue building on the old CRSP's record of success, and accomplish a new set of goals.

During the past 31 years, INTSORMIL has educated more than one thousand scientists through degree programs, visiting scientist experiences, postdoctoral training, workshops, and conferences. About one-third of those trained are from the U.S. and two-thirds are from developing countries. The bridges built by this training are crucial to maintain scientific and peaceful linkages between the United States and developing countries. The collaborative research supported by INTSORMIL continues to produce benefits for both developing countries and the United States. Food production, utilization and marketing in both developing countries and the United States are strengthened by INTSORMIL. The health benefits of the two nutritious cereals, sorghum and millet, are enjoyed by millions of people. Sorghum is a significant element in the food chain of the United States, being a key feed for livestock. So what is the future for collaborative, international sorghum and millet research supported by INTSORMIL? The future is bright.

There continues to be a need for highly qualified researchers for these two crops both in developing countries and the United States. INTSORMIL fulfills a unique role in providing postgraduate training (M.S. and Ph.D. level) to meet this need. As the demand for water in cities continues to put greater pressure on the use of water for irrigated crop production, sorghum and millet, which are for the most part rainfed, will gain increased importance in meeting the caloric needs of developing countries, particularly in the semiarid tropics, and needs of the livestock feed industry in the United States. Recent INTSORMIL research on the nutritional benefits of sorghum and millet forms a strong base for future research to enable the commercialization of nutritionally superior sorghum. Based on its achievements, the INTSORMIL team is well positioned to contribute even more

effectively to ending hunger and raising incomes. With the increasing strength of scientific expertise in developing countries, INTSORMIL is now able to more effectively reduce constraints to production and utilization of sorghum and millet to the mutual benefit of developing countries and the United States. Advances in sorghum and millet research over INTSORMIL's 31years and the training of sorghum and millet scientists in the United States, Africa and Central America by INTSORMIL now enables these scientists from developing countries and the United States to jointly plan and execute mutually beneficial collaborative research. These collaborative relationships are key components to INTSORMIL's success and will continue as fundamental approaches to meeting the INTSORMIL mission. In the future, INTSORMIL will target NARS collaborative ties that reflect regional needs for sorghum and/or millet production. These ties are in the sorghum and millet agroecological zones of western, eastern, and southern Africa, and Central America. By concentrating collaboration in selected sites, INTSORMIL optimizes its resources, builds an enhanced scientific capability on sorghum and millet, and creates technological and human capital that has a sustainable and global impact.

8. Annex 1: Varietal Release History (2006-2012) of INTSORMIL Supported NARS Breeding Programs

VARIETAL RELEASE HISTORY (2006-2012) OF INTSORMIL SUPPORTED NARS BREEDING PROGRAMS

Year	Crop (Sorghum or Pearl Millet)	Country	Name of Variety Released	On-farm Yield of New Variety	Yield of Local Check Variety	Amt. of Seed Produced (Breeder, Basic/Foundation, Certified)	Qualities other than Yield (Drought Tol./Forage Quality/Food Type, etc.)	Comments
2000-2006	Pearl millet	Mozambique	Kuphanjala1	600-1200 kg/ha	200 kg/ha	50 kg breeder seed, 500 kg foundation seed	Drought tolerance good for forage quality, and Stay green	Bird attack when planted early November
	Pearl millet	Mozambique	Kuphanjala2	1000 kg/ha	400 kg/ha	50 kg breeder seed, 500 kg foundation seed	Drought tolerance good for forage quality, and Stay green	Bird attack when planted early November
	Pearl millet	Mozambique	Changara	1200 kg/ha	300 kg/ha	50 kg breeder seed, 500 kg foundation seed	Drought tolerance good for forage quality, and Stay green	Bird attack when planted early November
	Sorghum	Mozambique	Macia	3,0 – 5,0 ton/ha	400 kg/ha	1500 kg foundation seed	Drought tolerance good for forage quality, and Stay green	Bird attack when planted early November, suitable for low land and semi-

								arid areas of South and South of Tete Province
	Sorghum	Mozambique	Chokwe	2,0 – 4,0 ton/ha	400 kg/ha	1000 kg foundation seed	Drought tolerance good for forage quality, and Stay green, moderate susceptible to grain mold in areas with more than 4 months of rainfall season	Bird attack when planted early November, suitable for low land and semi-arid areas of South and South of Tete Province
2006	Sorgo	El Salvador	85 SCP 805 and ES-790	Photosensitive varieties identified as more efficient use of nitrogen in the system corn-sorghum association. With fertilizer produced 3.5 MT / ha without fertilizer 2.5 ton / ha, 18% more than local.	2.8 and 2.0 mt / ha with and without fertilizer.	The artisanal seed is produced by the same farmer each year. Currently, some 20,000 small farmers planted about 25,000 ha in Central América.	Allow harvest maize and sorghum in the same area simultaneously without competition between them.	These varieties are used by small farmers in an area of 35,000 ha in the partnership system corn-sorghum.
	Sorgo	El Salvador	CENTA SS-44	35 mt / ha /	25tm/ha/ of green	35 mt / year of	Green fodder cutting 18% of	21% increase in milk

				cut green forage forage cut	corage for cutting.	certified seed	total protein and disease tolerant.	production.
	Sorghum	Mali	GRINKAN	3000	1500	Breeders seed Seed foundation is certified	Human food and Forage quality	Very white flour allows various industrial uses such as cakes, biscuit
	Sorghum/Millet	Niger	90-SN-7					
	Pearl Millet	Zambia	Mulatiwa	600	520	200	Medium-tall, early, disease-tolerant, grey grain	Adapted in all millet areas. 2.9 t/ha yield potential.
	Pearl Millet	Zambia	Liseli	750	520	250	Tall, medium-early, long panicles, disease-tolerant, grey grain	Adapted to Regions I & II. 2.7 t/ha yield potential.
2007	Sorghum	Mozambique	Adaptation and yield stability evaluation	3,0- 5,0 ton/ha On-station 1,5 2,0 ton/ha	1,0-1,5 ton/ha	Breeder seed maintenances		Under National Plant Trials with rain feed conditions
	Sorghum	Mali	Niatichama	2500	1000	Seed foundation is certified	poultry feed and human food	Very white flour allows various industrial uses such as cakes, biscuit
	Sorghum/Millet	Niger	SSSD-35			1200T		Early maturity type; high

								resistance to Sorghum midge very serious Sorghum pest in Niger; the damage of this pest can estimated up to 85% of yield lost .
	Pearl Millet	Zambia	Dola	1030	630	300	Medium-tall, Bristled-Bird and disease-tolerant, medium –early, grey –nutritious grain	Nationally and Regionally demanded, Adapted to all millet areas. 3.0 t/ha yield potential.
	Pearl Millet	Zambia	Mulatiwa			500		
	Pearl Millet	Zambia	Liseli			650		
2008	Sorghum	Mozambique	Adaptation and yield stability evaluation			Breeder seed maintenances		Under National Plant Trials with rain feed conditions
	Sorgo	El Salvador	ZAM 911	2.7 tm/ha of grain.	2.4 tm/ha of grain.	25 tm artisanal seed each year, each farmer produces additional seed.	Good adaptation to allow intercrop with maize, the small farmer harvest maize and sorghum in the same area..	Medium plant height with good production of stover and grain quality.
	Sorghum	Mali	SANGATIGUI	2000	1500	Seed foundation is certified	Human food	Very white flour allows

								various industrial uses such as cakes, biscuit
	Sorghum/Millet	Niger	L-861			2000T		
	Pearl Millet	Zambia	Dola			3,000		
	Pearl Millet	Zambia	Mulatiwa			500		
	Pearl Millet	Zambia	Liseli			550		
2009	Sorghum	Mozambique	Adaptation and yield stability evaluation			Breeder seed maintenances		Under National Plant Trials with rain feed conditions
	Sorgo	El Salvador	ZAM 912	3.9 tm/ha of grain + 50 tm of stover (hay) perha.	2.6 tm/ha of grain.	20 tm artisanal seed each year. Additionally each farmer produces its seed.	Dual purpose grain and forage Good adaptation to allow intercrop with maize harvest maize and sorghum.	Medium plant height and good grain quality.
	Sorghum Hybrid	Mali	SEWA,	3500	1000	Seed foundation is certified	Human food and Forage quality	Very white flour allows various industrial uses such as cakes, biscuit
	Sorghum	Niger	L861;L724C;Serie of lines derived from crossing MDK by Sureno; developed through Single Seed descent Method MDSU-55-2;MDKSU-29-1;MDK-SU-55-1;MDK-Su-53-2:MDKSU-49-1;MDKSU-30-			1615T	Good food quality; Drought tolerance;	Most of those new lines had good Combiner with our 2 females: NE223 A and ATX623;on our

			1:MDKSU-2-2;MDKSU-10-1;MDKSU-79-1;MDKSU-47-1;MDKSU-47-1;MDKSU-29-2;MDKSU-66-1;MDKSU-53-1;MDKSU-60-1;MDKSU-55-2					Hybrids development program. On farm tests will be carry out in the coming years
	Pearl Millet	Zambia	Dola			3,000		
	Pearl Millet	Zambia	Mulatiwa					
	Pearl Millet	Zambia	Liseli					
2010	Sorghum	Mozambique	8 varieties			400 kg breeder seed produced	Good grain qualities, wide range of adaptation over sorghum production areas, drought tolerance and stay green suitable for forage	Submitted to committee of plant release
	Sorghum	Mali	TIANDOUGOU COURA	2500	1000	Seed foundation is certified	Human food and Forage quality	Very white flour allows various industrial uses such as cakes, biscuit
	Sorghum	Nicaragua	SR-16	3.5 tm/ha of grain.	3.0 tm/ha of grain.	35 mt of certified seed each year. The farmer also produces its seed for future crops.	Hybrid Grain, Food Quality; Macio PS Sorghum Varieties for Subsistence in Dry Areas of Nicaragua, Red Sorghum Grain Growing	Sorghum variety, suitable for mechanical harvesting.

	Sorghum/Millet	Niger	I-28			3500T		Good adaptation to sandy soil; good grain quality; having B reaction. Conversion into an adapted A line for our Hybrid program is in the Selection process.
	Sorghum	Zambia	[SDS5006xWSV–187)23-2-1	5 – 8 tons/ha	4-6 tons/ha	80 kgs	White tan plant, food quality bold grain, drought tolerant	Ideal for regions I and II
	Pearl Millet	Zambia	Dola			600		
2011	Sorghum	Mozambique	Matica 1	On-farm 1,400 kg/ha; On-station 2,500 – 3,000 Kg/ha	600-1,000 kg/ha	Breeder 200 mˆ2 Planted	Good grain qualities, wide range of adaptation over sorghum production areas, drought tolerance and stay green suitable for forage	Material still in the field
	Sorghum	Mozambique	Matica 2	On-farm 1,250 kg/ha; On-station 2,500 – 3,000 Kg/ha	600-1,000 kg/ha	Breeder 200 mˆ2 Planted	Good grain qualities, wide range of adaptation over sorghum production areas,	Material still in the field

							drought tolerance and stay green suitable for forage	
	Sorghum	Mozambique	Tocole	On-farm 1,400 kg/ha; On-station 2,500 – 3,200 Kg/ha	600-1,000 kg/ha	Breeder 200 mˆ2 Planted	Good grain qualities, wide range of adaptation over sorghum production areas, drought tolerance and stay green suitable for forage	Material still in the field
	Sorghum	Mozambique	Otela	On-farm 1,500 kg/ha; On-station 2,500 – 3,500 Kg/ha	600-1,000 kg/ha	Breeder 200 mˆ2 Planted	Good grain qualities, wide range of adaptation over sorghum production areas, drought tolerance and stay green suitable for forage	Material still in the field
	Sorghum	Mozambique	On-farm 1,200 kg/ha; On-station 1,300 – 3,000 Kg/ha	600-1,000 kg/ha	Breeder 200 mˆ2 Planted	Good grain qualities, wide range of adaptation over sorghum production areas, drought tolerance and stay green suitable for forage	Mozambique	Mussequesse
	Sorghum	Mozambique	On-farm 1,250 kg/ha; On-station 2,200 – 3,000 Kg/ha	600-1,000 kg/ha	Breeder seed 200 mˆ2; 6 ha Foundation seed Planted	Good grain qualities, wide range of adaptation over sorghum production areas, drought tolerance and stay green suitable for forage ; intermediate maturing	Mozambique	Sima

	Sorghum	Mozambique	On-farm 1,300 kg/ha; On-station 2,500 – 3,000 Kg/ha	600-1,000 kg/ha	Breeder 200 mˆ2 Planted	Good grain qualities, wide range of adaptation over sorghum production areas, drought tolerance and stay green suitable for forage	Mozambique	Mapupulo
	Sorghum	Mozambique	On-farm 1,800 kg/ha; On-station 3,000 – 4,000 Kg/ha	600-1,000 kg/ha	Breeder 200 mˆ2 Planted	Good grain qualities, wide range of adaptation over sorghum production areas, drought tolerance and stay green suitable for forage	Mozambique	Mucuvea
	Sorghum	El Salvador	CENTA S-2 bmr.silage forage	2.5 tm/ha of grain and 45 tm/ha of biomass.	2.0 tm/ha of grain and 50 tm/ha biomass	29 mt / y over the seed certified seed that produced by artisan farmers.	Sweet forage silage, 25% more digestible than normal sorghum.	Increased production of milk and meat in cattle.
	Sorghum Hybrid	Mali	NIELENI	3000	1000	Seed foundation is certified	Human food	Very white flour allows various industrial uses such as cakes, biscuit
	Sorghum Hybrid	Mali	GRINKAN YEREWOLO	3000	1000	Seed foundation is certified	Human food and Forage quality	Very white flour allows various industrial uses such as cakes, biscuit
	Sorghum	Nicaragua	ESHG-3	5.7 tm/ha of white and good quality. grain	4.3 tm/ha	28 MT / ha of certified seed each year	Hybrid Grain, Food Quality; Macio PS Sorghum Varieties for Subsistence in Dry Areas of	Good adaptation tropical high grain yield and good quality.

							Nicaragua, white Sorghum Grain Growing	
	Sorghum	Nicaragua	INTA Segovia	4.9 ton/ha of grain	3.5 tm/ha of grain.	10 mt annually plus artisanal seed produced by each farmer.	White grain, Food Quality; Sorghum Varieties for Subsistence in Dry Areas of Nicaragua,	Variety for intercrop sorghum-maize intercrop system Allow harvest maize and sorghum simultaneously.
	Sorghum	Nicaragua	INTA-943bmr	2.8 mt/ha of grain and 45 mt/ha of biomass	2.2 tm/ha of grain and 50 tm/ha biomass	20 mt/year of certified seed over the seed that produces artisanal farmer.	Sweet forage silage, 27% more digestible than normal sorghum. Medium plant height	Increased production of milk and meat in cattle.Good tropical adaptation.
	Sorghum	Nicaragua	INTA-947bmr	2.5 tm/ha of grain and 45 tm/ha of biomass.	2.2 tm/ha of grain and 50 tm/ha biomass	25 mt/year of certified seed over the seed that produces artisanal farmer.	Sweet forage silage, 25% more digestible than normal sorghum. Medium plant height	Increased production of milk and meat in cattle.Good tropical adaptation.
	Sorghum/ Millet	Niger	L-724-C;New Generation of Hybrids was released:NE223AX90SN-1;NE223AX 90SN-2;NE223AX90SN-3;NE223A X 90SN-4;NE223A XL-724-C;NE223AX P9405;NE223AXP9402;NE223A X Macia;NE223AX L-861;NE223A X SERIE of MDK-			5000T		

			SU (all give good Hybrid)					
	Sorghum	Uganda	SESO1	2205	1883	~3 t?	White grain, suitable for clear beer	
	Sorghum	Uganda	SESO2	2137	1883	~3 t?	--ditto--	
	Sorghum	Uganda	SESO3	2570	1883	~3 t?	Good storage	
	Sorghum	Zambia	ZSV – 36R	5 – 7 tons/ha	4-6 tons/ha	60 kgs	Red seeded OP variety, brewing	Ideal for bird prone areas in Regions I, II & III
	Pearl Millet	Zambia	Dola			2,500		
2012	Sorghum	Mozambique	03CS-GWT 115	2,300-3,500 kg/ha	600-1,000 kg/ha	Breeder 200 mˆ2 Planted	Grain mold and drought resistant and stay green	Material still in the field and not yet submitted to committee of variety release; Suitable to semi-arid areas
	Sorghum	Mozambique	02CS-30932	2,300- 2,900 kg/ha	600-1,000 kg/ha	Breeder 200 mˆ2 Planted	Grain mold and drought resistant and stay green	Material still in the field and not yet submitted to committee of variety release; Suitable to semi-arid areas
	Sorghum	Mozambique	04CS-523-2-1	2,500- 3,800	600-1,000	Breeder 200 mˆ2	Grain mold and	Material still in

				kg/ha	kg/ha	Planted	drought resistant and stay green	the field and not yet submitted to committee of variety release; Suitable to semi-arid areas
	Sorghum	Honduras	Sureño bmr	2.5 tm/ha of grain and 45 tm/ha of biomass.	2.0 tm/ha of grain and 50 tm/ha biomass	29 mt/year of certified seed over the seed that produces artisan farmer.	Sweet forage silage, 25% more digestible than normal sorghum.	Increased production of milk and meat in cattle.
	Sorghum	Honduras	DICTA-10bmr	2.5 tm/ha of grain and 45 tm/ha of biomass.	2.0 tm/ha of grain and 50 tm/ha biomass	20 mt / y over the seed certified seed that produces artisan farmer.	Sweet forage silage, 25% more digestible than normal sorghum.	Increased production of milk and meat in cattle.
	Sorghum	Honduras	DICTA-29bmr	2.5 tm/ha of grain and 45 tm/ha of biomass.	2.0 tm/ha of grain and 50 tm/ha biomass	20 mt/year of certified seed over the seed that produces artisan farmer.	Sweet forage silage, 25% more digestible than normal sorghum.	Increased production of milk and meat in cattle.
	Sorghum	El Salvador	CENTA-Liberal	3.6 tm/ha of quality grain	2.0 tm/ha of grain	22 mt of certified seed over the seed that produces artisan farmer.	Good quality grain, early, and drought tolerant	Good tropical adaptation in dry areas
	Sorghum	El Salvador	CENTA S-3bmrsilage forage	2.5 tm/ha of grain and 45 tm/ha of biomass.	2.0 tm/ha of grain and 50 tm/ha biomass	29 mt/year of certified seed over the seed that produces artisan farmer.	Sweet forage silage, 25% more digestible than normal sorghum.	Increased production of milk and meat in cattle.
	Sorghum	El Salvador	CENTA S-4bmr silage forage	2.5 tm/ha of grain and	2.0 tm/ha of grain	29 mt/year of certified seed over the seed that	Sweet forage silage, 25% more	Increased production of

				45 tm/ha of biomass.	and 50 tm/ha biomass	produces artisan farmer.	digestible than normal sorghum. Medium plant height	milk and meat in cattle.Good tropical adaptation.
	Sorghum	Guatemala	ICTA F 947bmr	2.5 tm/ha of grain and 45 tm/ha of biomass.	2.0 tm/ha of grain and 50 tm/ha biomass	25 mt/year of certified seed over the seed that produces artisan farmer.	Sweet forage silage, 25% more digestible than normal sorghum. Medium plant height	Increased production of milk and meat in cattle.Good tropical adaptation.
	Sorghum	Guatemala	ICTA 85	Photosensitive varietie identified as more efficient use of nitrogen in the system corn-sorghum association. With fertilizer produced 3.5 MT / ha without fertilizer 2.5 ton / ha, 18% more than local.	2.3 mt/ ha with and without fertilizerin intercrop with maize.	The artisanal seed is produced by the same farmer each year. Currently, some 20,000 small farmers planted about 25,000 ha in Central América.	Allow harvest maize and sorghum in the same area simultaneously without competition between them.	These varieties are used by small farmers in an area of 35,000 ha in the partnership system corn-sorghum.
	Sorghum	Guatemala	ICTA Línea RV	5.7 mt/ha of grair quality	3.0 mt/ha and 50 mt/ha of forage.	50 mt/year of certified seed over the seed that produces artisan farmer.	High yield potential and grain quality. Plant medium height suitable for mechanized planting.	Variety with good stability of grain yield and produces good quantity and quality of forage. dual

							Good tropical adaptation.	purpose varietie.
	Sorghum	Ethiopia	Melkam/WSV-387			20 basic and pre-basic seed	Drought tolerant and good for *injera* making	INTSORMIL Partially supported the national program
	Sorghum	Mozambique	S35	2,000- 4,060 kg/ha	600-1,000 kg/ha	Breeder 200 mˆ2 Planted	Triple purpose, grain for food, steam for forage and juice for ethanol production	Material still in the field and not yet submitted to committee of variety release; Suitable for high rainfall areas
		Sorghum	Mozambique	KARI-MTAMA 1	2,200-3,600 kg/ha	600-1,000 kg/ha	Breeder 200 mˆ2 Planted	Triple purpose, grain for food, steam for forage and juice for ethanol production