From: Bill Rooney
To: Joan Frederick (jfrederick1@unl.edu); "Kimberly Christiansen"
Subject: TAM101 work plan, budget, budget objectives
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Attachments: TAM101 Yr 4 and 5 Budget Objs.xls
TAM101 POW Year 4 and 5.doc
TAM101 Years 4 and 5 Budget.xls

Joan and Kim:

I assume that you'll get this in official form from the TAMU RF, but I wanted to send it directly to you as well so that I'm not late (and I'll be out tomorrow and not able to respond).

If there is additional information, please e-mail me or if critical call me on my cell [redacted]

bill

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TAM101: BREEDING SORGHUM FOR IMPROVED GRAIN, FORAGE QUALITY, AND YIELD FOR CENTRAL AMERICA

PRINCIPAL INVESTIGATOR

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Executive Summary

Sorghum is an important feed grain, food grain and forage in Central America. In this region it is produced by a range of groups, from subsistence farmers who consider sorghum as a food security crop to commercial producers, who consider it a cash grain or forage crop. There is substantial need to improve the yield and quality of this germplasm and to incorporate tolerance traits to minimize losses due to drought, disease and insect pests. The overall goal of this proposal is to enhance the genetic yield and quality potential of sorghum genotypes adapted to Central America for use as a feed grain, food grain and forage crop. To meet this goal, previously established linkages with collaborators in the Central American region will be used (i) to coordinate in-country research studies and breeding evaluations, (ii) to identify quality students for training through involvement in ongoing projects at Texas A&M University, and (iii) to enhance technology transfer for sorghum in the Central American region. The specific objectives are: (1) to develop high-yielding, locally-adapted sorghum varieties and hybrids with improved grain and/or forage quality and stress resistance for both Maicillo Criollos-type cultivars and photoperiod insensitive sorghums, (2) to identify disease resistance genes for important diseases in Central America and utilize these sources in breeding, (3) to identify genes related to grain quality and utilize them in breeding, and (4) to provide technology transfer to promote the use of improved sorghums in Central America. To accomplish these objectives, germplasm will be developed at Texas A&M and by collaborators in El Salvador and evaluated across the region to document improvements. Genetic characterization results will be applied to the improvement process when feasible. The success of this project will be measured by the productivity of cultivars and hybrids in Central America that were developed in this project. While the efforts of this project are targeted to Central America, the technology and personnel developed in this project will be useful to sorghum programs around the world. This project will address directly or indirectly all seven major goals of the Sorghum, Millet and Other Grains CRSP.

Introduction and Justification

Throughout Central America, (defined as the countries of Guatamala, Belize, El Salvador, Honduras, Nicaragua, Costa Rica and Panama), sorghum (*Sorghum bicolor* L. Moench)was grown and harvested for grain on approximately 250,000 hectares in 2005 (FAO, 2006). The majority of this production is located in the countries of El Salvador, Nicaragua, Honduras and Guatamala. The crop is typically grown in the dry season due to its enhanced drought tolerance and ability to produce a crop under limited water availability. Average yields in the region vary dramatically and are dependent on the production systems, environment and types of sorghums that are being produced. Depending on the situation, the crop is grown as a feed grain, animal forage and in many situations as a food grain when supplies of corn are limited.

Within the region, there are two distinct sorghum production systems. The first is a traditional hillside sorghum production system that uses landrace and/or improved sorghum cultivars known as Maicillos Criollos. These sorghums are a very distinct and unique group because they are very photoperiod sensitive, meaning that they require short daylengths to induce reproductive growth. In fact, Maicillos require even shorter daylengths to initiate flowering than most photoperiod sensitive sorghum from other regions of the world (Rosenow, 1988). They are primarily grown in intercropping systems with maize on small, steeply sloping farms where the maize matures before the Maicillos begin to flower. Because they are drought tolerant, they are grown primarily as food security crop where the grain is used extensively primarily to produce tortillas. The forage and excess grain produced by these crops are valued as animal feed. Traditional landrace Maicillos Criollos varieties are typically low yielding with relatively low grain quality. Previous research has resulted in the release and distribution of several improved Maicillos Criollos cultivars with higher yield potential and better grain quality (Rosenow, 1988). In addition to Maicillos Criollos, hillside production systems also utilize earlier maturing sorghum (ie, photoperiod insensitive) for food and forage. Significant research has also been devoted to their improvement, resulting in the release release of cultivars such as Sureno and Tortillero that are now commonly grown throughout the region (Meckenstock et al., 1993). These cultivars have been adopted and used in the region as a food grain on small farms as well as a dual purpose crop (grain, forage) in mid-size commercial farms.

In addition to small farm production, sorghum is also grown in significant quantities on commercial farms in the Central American region. While some of these producers utilize cultivars for this production, most have adopted hybrids and are growing the crop as a feed grain for use in poultry, livestock and dairy production. More recently, there is significant growth of the crop in the region for grazing, hay and silage. This interest in sorghum forage has been increasing due to the increased dairy and beef production in the region, combined with the inherent drought tolerance of the crop, especially in the second, drier cropping season. In both grain and forage, the hybrids that Central American producers use are usually sold by commercial seed companies. In most cases, research and development for sorghum improvement in the region is relatively minimal. Hybrids grown in this region usually rely on improved germplasm from national programs as well as U.S. based sorghum improvement programs.

While the two production regions differ for types of germplasm, the constraints to productivity and profitability are similar. First, there is a continual need to enhance yield of both grain and biomass. The Maicillos Criollos cultivars have low but stable yield potential. Small farmers place a high value on stable yields as they grown to provide food security. Thus, they will adopt higher yield varieties only if they provide stability of yield as well. As feed grain demand continues to increase, yield increases are also needed in commercial hybrid production as well to make their production more economically profitable. Sufficient genetic variation is present in both germplasm pools to enhance yield potential, provided that effective evaluation, screening and selection can be completed in the region (Santos and Clara, 1988).

Improvement in grain and forage quality are also continually in demand. Most of the grain sorghum grown in the region is acceptable as a feed grain, but would not be acceptable as a food grain. The changes needed to make an acceptable food grain (plant color and grain color) are relatively simple and highly heritable traits that are easily manipulated. If adopted, these changes will facilitate to opportunity to partially substitute domestically produced sorghum flour for more expensive imported wheat flour (INTSORMIL report #6, 2006, www.intsormil.org). However, food quality sorghum must possess resistance to grain mold and weathering to protect the quality of the grain prior to harvest. For forage, there has been relatively little improvement in the forage quality of sorghum grown in Central America. The development and adoption of brown midrib forage sorghums in the U.S. indicate that high quality forage sorghums can be produced (Oliver et al., 2005). The challenge is to introduce these characteristics into forage sorghum adapted to the Central American region.

As improvements in yield and quality are made, these must be protected from biotic stresses that are commonly present in the region. Biotic stresses also pose a significant threat to yield and quality in sorghum production. Insect damage due to an early season lepidopterous pest complex known as the langosta by Honduran farmers is major problem for both maize and sorghum producers (Pitre, 1988). For the past twenty years, sorghum downy mildew (SDM) is a significant disease in Maicillos Criollos production. In Central America, the predominant SDM pathotype is P5 and this pathotype is known to cause significant yield reductions in areas of the region where environmental conditions are conducive to disease development (Frederiksen, 1988). While chemical control is a possibility, the most logical and reliable control mechanism is the incorporation of genetic resistance. Another disease of importance is anthracnose (caused by *Colletotrichum graminicola*), a fungal pathogen that is capable of infecting all above ground tissues of the plant that is endemic throughout the region. Because it can infect all above ground parts of the plant, it can cause significant reductions in both forage and grain yield and quality. Again, genetic resistance provides the only effective mean of managing this disease. Finally, grain mold (caused by a complex of fungi) is a common problem throughout the region and it reduces the quality of the grain as both a feed and food grain. In all of these abiotic and biotic stresses, sorghum germplasm has sufficient diversity to enable breeding programs to identify and select for tolerance and/or resistance to the specific stress or pathogen.

As with biotic stresses, abiotic stresses will also reduce the yield and quality of sorghum in the region. Drought stress likely has the greatest effect on yield potential, and given where and how sorghum is typically produced, drought tolerance is always an important trait for sorghum (Boyer, 1982). The impact of drought on the evolution of sorghum is obvious; the plant has evolved many different mechanisms to manage water stress, resulting in a crop that is highly water use efficient compared to other cereal grains (Rosenow and Clark, 1981). Given this natural selection pressure, there is significant variation among sorghum genotypes for a wide array of different drought resistance mechanisms. Over the past twenty years, the genetic control of some of these drought tolerance traits have been dissected and we are now on the verge of being able to use marker-assisted breeding and even transformation to move these resistance genes within and across species (Mullet et al., personal communication). All of these technologies should be used to further improve this important trait.

Objectives and Implementation

Given the goals of the Sorghum, Millet and Other Grains CRSP and the needs of the Central American region, the overall goal of this proposal is to enhance the genetic yield and quality potential of sorghum genotypes adapted to Central America for use as a feed grain, food grain and forage crop. To meet this goal, we will use previously established linkages with collaborators in the Central American region (i) to coordinate in-country research studies and breeding evaluations, (ii) to identify quality students for training through involvement in ongoing projects at Texas A&M University, and (iii) to enhance technology transfer for sorghum in the Central American region.

The objectives, the location of the research, and the collaborators include:

1. DEVELOP HIGH-YIELDING, LOCALLY-ADAPTED SORGHUM VARIETIES AND HYBRIDS WITH IMPROVED GRAIN AND/OR FORAGE QUALITY, DROUGHT TOLERANCE, AND DISEASE RESISTANCE USING BOTH CONVENTIONAL BREEDING TECHNIQUES AND MARKER-ASSISTED SELECTION TECHNOLOGY. Populations pertinent to this objective will be created and then distributed segregating populations to the international collaborators (Clara, Obando) for selection and cultivar development.
2. IDENTIFY AND CHARACTERIZE GENES RELATED TO DISEASE RESISTANCE IN SORGHUM WITH SPECIFIC EMPHASIS IN DOWNY MILDEW, ANTHRACNOSE AND GRAIN MOLD. UTILIZE THESE SOURCES OF RESISTANCE IN BREEDING IMPROVED CULTIVARS AND HYBRIDS FOR CENTRAL AMERICA. Our program has screened numerous accessions and identified specific sources of resistance to anthracnose, downy mildew and grain mold. These lines and populations derived from them will be evaluated in domestic and Central American sites to determine which sources will provide the most stable resistance. Populations of these will be evaluated to determine heritability and to transfer the resistance to locally adapted sorghum. Phenotypic evaluation of these lines and populations will occur in the appropriate domestic (Texas with C. Magill, G. Odvody and T. Isakeit) and international locations (Clara in Central America and Chisi in Southern Africa).
3. IDENTIFY AND MAP GENES RELATED TO GRAIN QUALITY SUCH PROTEIN DIGESTABILITY, NUTRACEUTICAL POTENTIAL AND GRAIN QUALITY PARAMETERS *PER SE*. Variants that possess unique grain traits such as increased protein digestibility and enhanced antioxidant characters have been identified and characterized in our program. The purpose of this project is to assess the feasibility of producing cultivars that possess these characteristics. In collaboration with the TAMU grain quality program (L. Rooney, D. Hays), we are assessing the feasibility of combining both grain mold resistance and enhanced digestibility. Phenotypic evaluation of this material will occur in Texas and international locations (Central America and Southern Africa) in cooperation with the domestic (Peterson) and international (Clara, Obando, Chisi) collaborators.
4. PROVIDE TECHNOLOGY TRANSFER AND TECHNICAL ASSISTANCE IN PROMOTING THE USE OF IMPROVED SORGHUMS AS A FEED GRAIN, FOOD GRAIN AND A FORAGE CROP IN CENTRAL AMERICA. The purpose of this objective is to

transfer the technology and knowledge needed to effectively produce and utilize the forage and/or grain produced from the improved sorghum cultivars (Maicillos Criollos, lines and hybrids). As appropriate, our program will coordinate these workshops with collaborating scientists in the specific area of expertise, such as animal feeding (J. Hancock) grain quality and utilization for human food (L Rooney), and agronomy and forage quality (J. Blumenthal). The technical assistance efforts will focus on industry and academic leaders in El Salvador and Nicaragua.

These objectives merge together to provide a project that will have both short-term and long-term results. Ultimately, the success of this program will be measured by the productivity of cultivars and hybrids developed in this project and how effectively they are utilized throughout Central America. For objectives 1 through 4, training of students from cooperating countries will be an integral part of the projects and potential students will be identified based on recommendations from researchers in the region and the in-country interaction of the PI with potential candidates. Finally, objective 5 is crucial because if the first four objectives are successful, additional sorghum (both forage and grain) with improved quality will be produced. It is imperative that there be the infrastructure (both technological and scientific) to utilize this grain. The efforts of this project are targeted to Central America, but the technology, basic knowledge, and personnel developed in this project will also be useful to sorghum and millet improvement programs around the world. Because of these factors and their interrelationships, this project will address directly or indirectly all seven major goals of the Sorghum, Millet and Other Grains CRSP.

Approach

In year 4, research trials will be planted in Texas and in cooperation with collaborators in El Salvador and Nicaragua. Other locations will be used as appropriate. Agronomic and Quality research projects in El Salvador and Nicaragua will be complemented by the addition of germplasm developed from this project. For disease resistance and quality components, germplasm is being selected in Texas in Year 4; plans are to test this material in the region in Years 4 and 5. In collaboration with Rene Clara and Rafael Obando, we will used demonstration plots and field days to promote the varieties and hybrids (both grain and forage) released by El Salvadoran and Nicaraguan national programs (with funding from INTSORMIL). In collaboration with Vilma Ruth Calderon, we will utilize improved quality grain sorghums (including varieties, macios, and hybrids) as a substitute for some wheat flour in baked goods.

Collaboration between sorghum, millet and other grain PIs, scientists in the target area as well as existing collaborations with U.S. scientists are critical to the success of this project. The U.S. collaborators described in this proposal will provide technical assistance for addressing questions related to cereal chemistry, plant pathology, and molecular biology. These scientists represent some of the world's leading sorghum experts in their respective research fields. The international collaborators identified in this proposal have been carefully selected as they are the experts in sorghum in Central America. Our program has over ten years of collaboration history with these scientists. Based on this history, we fully expect to be able to complete the described research in an efficient and effective manner. In addition, these international linkages will ensure rapid deployment of improved varieties and hybrids in these regions.

Benchmarks and Indicators, Throughputs

Objectives	**Targets**	**Benchmarks and Indicators**	**Throughputs**	***Milestones***
1. Supply chain/market development	- Increased yields and incomes - Increased grain sorghum quality -Increased use of sorghum as a feed source	- Increased farmer incomes - Increase in production area - Elimination of tannin in feed–type cultivars	- Farmer incomes increased by 30% - Farmer incomes increased by 20% - 200% increase in markets for sorghum as a feed source	*- 15% increase by Yr 4 and 30% by Yr 5* *- 5% increase by Yr 4 and 20% by Yr 5* *- 60% increase by Yr 4 and 200% by Yr 5*
2. Nutrition, health and grain quality	-Higher grain quality cultivars -New cultivar acceptance - Increased nutrition of food and feed products	- High digestibility cultivars selected - Widespread adoption of cultivars	- 4 high grain quality varieties developed - 30% of farmers accept new cultivars	*- 4 varieties released by Yr 4 and 10 by Yr 5* *- 20% of farmers accept new cultivars by Yr 4 and 60% by Yr 5* *- 10% decrease by Yr 4 and 25% by Yr 5*

3. ICSM	- Increased and stable grain yields - Improved crop, soil and water management	- Integration of ICSM components into packages	- 30% yield increase due to ICSM adoption - 70% of farmers using ICSM practices	*- 10% increase by Yr 4 and 30% by Yr 5* *- 25% using ICSM practices by Yr 4 and 70% by Yr 5*
4. IPM	-Increased grain and forage yield and quality - Efficient pest management tactics	- Tolerance or resistance to grain insects, pathogens - IPM packages developed	- 20% decrease in pest damaged grain and forage - 2 lines/hybrids or varieties with disease resistance released	*- 5% decrease by Yr 4 and 20% by Yr 5* *- 1 variety released by Yr 3 and 2 released by Yr 5* *- 20% decrease by Yr 4 and 50% by Yr 5*
5. Genetic enhancement	-Stable yielding genotypes -More efficient water use by genotypes	- Genotypes with less variation in yields - Decrease in drought damage	- 3 stable yielding genotypes released - 5 drought tolerant genotypes released	*- 2 genotypes released by Yr 4 and 3 by Yr 5* *- 3 genotypes released by Yr 4 and 2 by Yr 5*
6. Genetic resources and biodiversity	- Germplasm with unique genes for valuable traits.	- Screening and selection of sorghum to identify unique variants. - Decrease in rate of loss of biodiversity sensitive areas	- 10 new lines with biotic or abiotic stress resistance	*- Completed by Yr 5*
7. Partnerships and networking	*- Increased joint programs with partners*	*- Networks established involving all stakeholders (private industry, NGOs, farmers, international agencies, CG centers, research and technology transfer agencies)*	*- High research throughputs and high level of technology transfer activity*	*- 20% increase in grain production and 50% of farmers using best management practices by Yr 5*

Description of Proposed Training

Capacity Building Programs	**Benchmarks**
Degree Education	1 M.S. Graduate by 2010 1 Ph.D. Graduate by 2010, each partially funded by INTSORMIL
Visiting Scientists and Post-Doctoral Fellows	2 Visiting Scientist 1 PostDoctoral Scientist
Short-Term Training	15 - Number of Participants in Workshops, Seminars, Conferences 30 - Number of Participants Who Adopt the New Technologies and Methodologies 10 - Number of Participants Who Transfer Information Learned to Other Professionals, Scientists, and Entrepreneurs
Internet – Distance Education	0 - Functioning Interactive Internet Site 0 - Number of Participants in Distance-education Programs

Texas A&M Research Foundation
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YEAR FOUR

Project Dates: 9/30/2010 - 9/29/2011

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