

# Contents

## Introduction and Program Overview

## Project Reports

### Sustainable Plant Protection Systems

Agroecology and Biotechnology of Stalk Rot Pathogens of Sorghum and Millet John F. Leslie (KSU 210).....	3
Low Input Ecologically Defined Management Strategies for Insect Pests on Sorghum Henry N. Pitre (MSU 205).....	9
<i>Striga</i> Biotechnology Development and Technology Transfer Gebisa Ejeta (PRF 213) .....	13
Sustainable Management of Insect Pests Bonnie B. Pendleton (WTU 200).....	17

### Sustainable Production Systems

Economic and Sustainability Evaluation of New Technologies in Sorghum and Millet Production in INTSORMIL Priority Countries John H. Sanders (PRF 205).....	25
Cropping Systems to Optimize Yield, Water and Nutrient Use Efficiency of Pearl Millet and Grain Sorghum Stephen C. Mason (UNL 213) .....	31
Soil and Water Management for Improving Sorghum Production in Eastern Africa Charles Wortmann and Martha Mamo (UNL 219) .....	39

### Germplasm Enhancement and Conservation

Breeding Pearl Millet for Improved Stability, Performance, and Pest Resistance Jeffrey P. Wilson (ARS 206).....	47
Breeding Grain Mold Resistance in High Digestibility Sorghum Varieties Dirk Hays (TAM 230).....	53
Development and Enhancement of Sorghum Germplasm with Sustained Tolerance to Biotic and Abiotic Stress Gebisa Ejeta (PRF 207) .....	57
Enhancing the Utilization of Grain Sorghum and Pearl Millet through the Improvement of Grain Quality via Genetic and Nutritional Research Mitch Tuinstra, Joe Hancock, William Rooney and Clint Magill .....	63
(KSU 220A, KSU 220B, TAM 220C, TAM 220D)	
Germplasm Enhancement for Resistance to Insects and Improved Efficiency for Sustainable Agriculture Systems Gary C. Peterson (TAM 223) .....	71

## **Crop Utilization and Marketing**

An Evaluation of New Market Development and Marketing Strategies on Sorghum and Millet Farmers' Income in Tanzania and Zambia Donald Larson and J. Mark Erbaugh (OSU 200) .....	79
Chemical and Physical Aspects of Food and Nutritional Quality of Sorghum and Millet Bruce R. Hamaker (PRF 212).....	85
Food and Nutritional Quality of Sorghum and Millet Lloyd L. Rooney (TAM 226).....	91
Entrepreneurship and Product Development in East Africa: A Strategy to Promote Increased Use of Sorghum and Millet David S. Jackson (UNL 220) .....	95

## **Host Country Program Enhancement**

Central America Stephen C. Mason .....	103
Horn of Africa Gebisa Ejeta .....	109
Southern Africa Gary C. Peterson .....	121
West Africa Bruce R. Hamaker .....	127

## **Educational Activities**

Educational Activities .....	149
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## **Appendices**

INTSORMIL Sponsored and Co-Sponsored Workshops 1979-2007 .....	153
Acronyms .....	155

## Introduction and Program Review

The 2007 INTSORMIL Six Year Report presents the progress and notable achievements by the Sorghum/Millet CRSP during the period of July 1, 2001 - June 30, 2007. These results are an outcome of partnerships between scientists at seven U.S. Land Grant Universities (Kansas State University, Mississippi State University, Ohio State University, University of Nebraska, 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 nineteen 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 Collaborative Research Support Program (INTSORMIL CRSP) conducts collaborative research through partnerships between 20 U.S. university scientists and scientists of the National Agricultural Research Systems (NARS), IARCs, PVOs and other CRSPs. INTSORMIL is programmatically organized for efficient and effective operation and captures most of the public research expertise on sorghum and pearl millet in the United States. *The INTSORMIL mission is to use collaborative research as a mechanism to develop human and institutional research capabilities to overcome constraints to sorghum and millet production, marketing and utilization for the mutual benefit of the Less Developed Countries (LDCs) and the U.S.* Collaborating scientists in NARS developing countries and the U.S. jointly plan and execute research that mutually benefits all participating countries, including the United States.

INTSORMIL takes a regional approach to sorghum and millet research in western, eastern, and southern Africa, and in Central America. INTSORMIL focuses resources in the four regions supporting 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 sustainable, global impact, 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 to yield 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, i.e., 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 significant advances have been made in the improvement and production of sorghum and millet in the developing countries of regions in which INTSORMIL serves, population growth continues to exceed rates of increase in cereal production capacity. 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 their research posts in their countries. 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 enlarge the range of agricultural and environmental choices available both in developing countries and the United States. INTSORMIL promotes conserving millet and sorghum germplasm,

developing resource-efficient cropping systems, developing integrated pest management strategies that conserve natural control agents, developing cultivars with improved nutrient and water use efficiencies, and evaluating 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 using multi-disciplinary research teams composed of American 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 fighting hunger and poverty by providing means for economic growth, generation of wealth, and improved health. New technologies developed by INTSORMIL collaborative research are extended to farmers' fields and to processors and marketers of sorghum and millet products in developing countries and the United States through partnerships with NGOs, research networks, extension services and the private sector. In addition, economic analysis by INTSORMIL researchers plays 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. 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, with the ultimate goal being economic and physical well-being to those involved in 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, so 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 in 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, strengthening developing countries' abilities to solve their problems in the agricultural sector while providing benefits to the United States.

## Administration and Management

The University of Nebraska (UNL) hosts the Management Entity (ME) for the Sorghum/Millet CRSP and is the primary grantee of USAID. UNL subgrants are made 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) of the CRSP serves as the top management/policy body for the CRSP. The Technical Committee (TC), External Evaluation Panel (EEP) and USAID personnel advise and guide the ME and the Board in areas of policy, technical aspects, collaborating country coordination, budget management, and review.

## Education

During the period of 2001-2007, there were 116 students from 28 different countries enrolled in an INTSORMIL advanced degree program and advised by an INTSORMIL principal investigator. Approximately 70% of these students came from countries other than the U.S. The number of students receiving 100% funding by INTSORMIL in 2001-2007 totaled 24. An additional 88 students received partial funding from INTSORMIL and the remaining four students were funded from other sources. INTSORMIL places high priority on training of women. During the period 2001-2007, 31% 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 of six years, seventy nine host country scientists improved their education as either postdoctoral scientists (19) or visiting scientists (60). Their research activities were in the disciplines of agronomy, food science and animal nutrition, entomology, molecular biology, and pathology. These scientists came to the United States as postdoctoral scientists or visiting scientists from Brazil, El Salvador, Egypt, Ethiopia, Ghana, Guatemala, Mali, Nicaragua, Niger and Uganda. In addition to non-degree research activities there were 3047 participants (1,753 male and 1294 female) who were supported by INTSORMIL for participation in workshops and conferences.

## Networking

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

- Promotes networking with IARCs, NGO/PVOs, regional networks (ASARECA, ECARSAM and others) private industry and government extension programs to coordinate research and technology transfer efforts.
- Supports 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.
- Develops regional research networks, short-term and degree training plans for sorghum and pearl millet scientists.

Established networking activities have been accomplished with ICRISAT in India, Mali, Niger, Central America and Zimbabwe, SAFGRAD, WCASRN/ROCARS, WCAMRN/ROCAFREMI, ASARECA, ECARSAM and SMIP/SMINET in Africa, CLAIS and CIAT of Central and South America and 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 expenditures of research dollars. 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. Since 2004 INTSORMIL has been executing a Marketing-Processing Project funded by the USAID West Africa Regional Program (WARP) which focuses on responding to emerging market demand with improvements in the supply of consistent quality grain of sorghum and pearl millet. Initial activities (2002-2004 supported by INTSORMIL) were on making contracts between farmers' groups and the rapidly growing sector of millet food processors (couscous, arraw, degue, sankal, tchakri, and yogurt with tchakri) in four countries of the Sahel (Senegal, Mali, Burkina Faso, and Niger). INTSORMIL will continue to promote free exchange of germplasm, technical information, improved technology, and research techniques.

## Regional Activities and Benefits

### West Africa

(Burkina Faso, Ghana, Mali, Niger, Nigeria, Senegal)

The West Africa Regional Program now encompasses six countries of the Sahelian region – Burkina Faso, Ghana, Mali, Niger, Nigeria, and Senegal. During this six year period on-farm testing, field tours, and farm days were organized for maximal exchange with other farmers and to promote acceptance of improved cultivars by farmers. On-farm testing included on-farm evaluation of soil fertility management options for millet yield increases including use of poultry manure and microdose fertilizer applications. Improved elite sorghum hybrids, insect and *Striga* resistant lines were evaluated on-farm. Countrywide evaluation and demonstration of the marketing potential for value-added sorghum and millet products including poultry feed was accomplished. This is strengthening the linkages between production and utilization activities.

Thus, the West Africa INTSORMIL program is active in working towards enhancement of sorghum and millet markets through high-yielding, quality grain production, supply-chain management, and processed product and animal feed endpoints. INTSORMIL's support for sorghum and millet improvement has been significant in terms of human resource enhancement and vision for technologies that can be transferred and adopted by farmers and other end-users. For example, sorghum and millet breeders and food technologists work together to demonstrate feasibility of the use of improved seeds to increase food production, diversify uses for local consumers, and stimulate entrepreneurial processing businesses. A new project during this period has been in poultry nutrition aimed to encourage poultry producers to use sorghum and millet for feed.

### Horn of Africa

(Ethiopia, Eritrea, Kenya, Tanzania, Uganda)

Ongoing collaborative research has progressed in each of the countries. However, activities were terminated in Eritrea in late 2005. Host country PIs in each country have taken a keen interest in collaborating with U.S. PIs where partnerships have been developed. Because of expanded collaborative involvement in several countries in the Horn of Africa Region more U.S. PIs are needed to provide collaborative linkages with host country scientists. Sorghum breeding efforts in Ethiopia have particularly gone well. Work on development and evaluation of experimental sorghum hybrids have resulted in identification of elite hybrids with potential for wide cultivation in lowland areas of the country. Efforts on *Striga* control have focused on regional testing of an integrated package of technologies that included tied-ridging as a water conservation measure, nitrogen fertilization, and resistant sorghum cultivars. This collaborative activity has expanded over years and at present constitutes almost half of sorghum research activity in Ethiopia. The most rewarding outcome of this collaboration was the release of three *Striga* resistant varieties, originally developed by Purdue University, for large-scale production in Ethiopia. As discussed in the Horn of Africa report, these varieties are making significant impact in changing the course of sorghum production

in *Striga* infested regions of the country. Progress being made in identification of suitable hybrid cultivars in Ethiopia is also very encouraging. This activity is managed and implemented as a pilot project with supplemental funding from the Office of Foreign Disaster Assistance (OFDA) of USAID. *Striga* resistant sorghum varieties have been officially released for wide cultivation and the integrated *Striga* management pilot project has aroused interest in the technology and a community-based seed multiplication effort has been started.

Farmers participating in INTSORMIL funded research activities at one of the research sites in Tanzania produced and sold to Nile Breweries over 30 MT of sorghum grain worth > USA \$ 5000 during the first rains of 2006. They have now formed a Saving and Credit Co-operative Society so as to improve production, food security and their livelihood.

In Uganda, soil fertility management practices, as well as reduced tillage, were found to be cost effective in increasing sorghum yield in predominantly smallholder agriculture where small amounts of organic fertilizer were only occasionally used. On-farm profitability and food security for sorghum production systems can be improved by use of inorganic fertilizers, manure, mucuna fallow, sorghum-cowpea rotation, and reduced tillage. This confirms that low soil fertility is a constraint to sorghum production and that the alternative strategies are effective in addressing it.

### ***Southern Africa***

*(Botswana, Mozambique, Namibia, South Africa, Zambia)*

Progress has been made in this period (2001-2007) to increase the productivity of sorghum and pearl millet and begin moving the crops from a subsistence level to a value added cash crop. The progress includes technology of use in lager beer brewing, identification and increased understanding of major disease and insect constraints and development of technology to reduce the constraints, and release of varieties and hybrids with improved productivity. However, much remains to be done. Sorghum and pearl millet are poised to make a dramatic step forward in productivity and utilization through research and a better understanding and increased employment of supply chain management strategies.

There are two major constraints to development of sorghum and pearl millet in southern Africa at this time. First is the lack of regional sorghum and pearl millet scientific expertise. Although INTSORMIL has trained many Southern Africa students over the last 20-years few returned to their home institutions to conduct research in either sorghum or pearl millet. Within each institution and discipline there is basically one scientist available for collaboration. This is contributing to the increasing emphasis of regional scientists collaborating across national boundaries. As capable students are identified and matched with available advisors additional graduate education will occur. The students need assurance of positions in sorghum and pearl millet research upon returning from their degree programs. The second constraint is the continued decline in the number of hectares devoted to sorghum and pearl millet production. As in most semi-arid regions the decline can be attributed to government policy, lack of a marketing

system to handle either traditional grain or grain with enhanced end-use traits, and consumer preference for other grains.

However, there are indications that the status of sorghum and pearl millet is improving in Southern Africa. Increasing emphasis on sorghum and pearl millet as food security crops and repeated drought induced failures of other crops is improving the outlook for sorghum and pearl millet. In collaboration with the Zambia national program, INTSORMIL has contributed to the production and distribution to NGOs of several tons of improved seed which was distributed to farmers. There is increasing recognition of the importance of developing cash generating markets for sorghum. An excellent example is the collaboration of the Zambia national program with CARE in the production of white grain sorghum (produced on tan plants) for the lager beer market. In the second year of collaboration with CARE, the number of participating farmers more than doubled. Sorghum and pearl millet should play a significant role in food security and new commercialization activities that generate cash income. The many favorable attributes of both commodities should contribute to an increased supply of high quality food available to farm families, especially those affected by HIV/AIDS.

### ***Central America***

*(El Salvador, Nicaragua, Honduras)*

Multi-disciplinary, multi-organization, multi-country research and technology transfer efforts were conducted between 2001 and 2007. This resulted in release and transfer of sorghum hybrids and varieties, identification and transfer of the high NUE photoperiod sensitive variety 85-SCP-805, development and release of SS-44 (INTA Forajero) with increased forage sorghum yield and quality resulting in increased dairy production, identification and integrated pest management programs for major insect and diseases and development of sorghum flour production capability and sorghum based sweet bread products. All of these activities contribute to economic growth, particularly for small farmers and processors. Institutional capabilities have been improved through collaborative research and technology transfer activities, graduate education and short-term training. Collaboration among sorghum programs, extension services, private seed companies and non-governmental agencies has increased. Extension efforts have been improved through publication of production guides and other extension bulletins. Scientific capability of collaborators has improved through publication of scientific journal articles, and participation in PCCMCA meetings. Much has been accomplished, but much remains to be done in coming years to raise all of our Central American brothers and sisters out of poverty.

### ***Future Directions***

During the past 28 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. What then 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 the livestock feed industry in the United States. Recent INTSORMIL research on the nutritional benefits of sorghum and millet form 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 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 28 years and the training of sorghum and millet scientists by INTSORMIL in the United States, Africa and

Central America now enable 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.

As the present INTSORMIL program comes to a close, a new Sorghum, Millet and Other Grains CRSP has been authorized and funded by USAID. Future strategies under this new CRSP will maintain INTSORMIL's current, highly productive momentum, build on its record of success, and work toward accomplishing a whole new set of goals. INTSORMIL's new Vision is 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. The CRSP will lead efforts to promote profitable markets for sorghum, pearl millet and other grains by working with agencies that identify and expand markets, assess economics, and facilitate the evolution of a production-supply chain and expanding markets that deliver quality grain to end users. Future strategies will maintain the new CRSP's highly productive momentum, build on the old CRSPs record of success, and accomplish a new set of goals.

