PN-AAW-627

INTSORMIL

1986

...a team effort

Development

COVER PHOTOGRAPHS
(top to bottom)

1. Niger/INTSORMIL graduate student, Issoufou Kapran, discussing research program with Nkonni Experiment Station Director, Nkonni, Niger.

2. Susceptible sorghum to long smut, Kolo Research Station, Kolo, Niger.

3. Mr. M. Issa, DECOR Director, presenting farm trial results to the Chief of Filinque Village, Niger. INTSORMIL is initiating collaboration with DECOR for on-farm economic evaluation of new technologies in sorghum and millet production.

4. Harvested millet being transported from farmer's field to village near Nkonni, Niger.

5. INTSORMIL External Evaluation Panel and INTSORMIL scientists reviewing Sorghum/Striga resistance screening trial, Nkonni, Niger.

All photos by John Yohe, INTSORMIL Management Entity.

INTSORMIL

1986 Annual Report

Fighting Hunger with Research

A Technical Research Report of the

Grain Sorghum/Pearl Millet

Collaborative Research Support Program (CRSP)

Funding support through

Agency for International Development

Grant: DAN-1254-G-SS-5065-00

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A Research Development Program of the Agency for International Development, Participating Land-Grant Universities, Host Country Research Agencies and Private Donors.

INTSORMIL INSTITUTIONS

Kansas State University
University of Kentucky
Mississippi State University
University of Nebraska
Purdue University
Texas A&M University

The University of Nebraska is an affirmative action/equal opportunity institution.

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Introduction

Sorghum and millet grain is used for human food and as feed for animals. The plant stem and foliage are used for green chop, hay, silage and for pasture. In some areas the stem is used as building material and the remaining plant material after harvest can be used for fuel. Sorghum and millet rank fourth in world food grain production following wheat, rice and maize. They are especially significant sources of human food in South Asia, much of sub Saharan Africa, and certain areas of Latin America and the Caribbean. In Africa alone, sorghum and millet are produced on 31,770,000 hectares. Together, these two crops constitute the "last resort" of crop production where the natural stress conditions of drought and heat predominate. Since much sorghum and millet is grown under stressful environmental conditions in the arid, semiarid, tropical and subtropical regions of the world, yields are relatively low. Thus sorghum and millet, typically subsistence crops, are most important to the survival of low income, low resource farmers. Because of this, these crops are not only important for nutritional and economic reasons but also because of cultural, political, and anthropological aspects in the lives of many millions of people.

In an amendment to the International Development and Food Assistance Act of 1975 that has come to be known as Title XII, the Congress of the United States provided for "long-term collaborative university research on food production, distribution, storage, marketing, and consumption," in ways that "maximized the contributions to the development of agriculture in the United States and in agriculturally developing nations."

One of the most innovative initiatives developed by BIFAD under Title XII is the Collaborative Research Support Program (CRSP), a concept aimed at increasing and making more effective use of this country's land grant and other agriculturally oriented universities in AID's foreign assistance programs. CRSP's thus serve the dual objective of benefiting agriculture in developing countries and in the United States. The Sorghum/Millet CRSP (INTSORMIL) is one of the three CRSP'S which pioneered in developing the CRSP structure and model for implementation. There were no precedents to follow. The Sorghum/Millet CRSP grant (AID/DSAN/XII-G-0149) was made on July 1, 1979. This annual report covers the activities for program year 7.

Seven years of experience have reaffirmed the need for this type of research program aimed at relieving the constraints to improved sorghum/millet production in developing countries. The emphasis by the CRSP on development of collaborative linkages with national programs has been unique. Significant contributions have been made toward resolving constraint problems and enhancing the national program capability to strengthen its human resource base as well as the national institutional capability to conduct collaborative research. Thus, the CRSP's present a unique model for conducting agricultural research in collaboration with developing country agricultural research programs. The INTSORMIL program also demonstrates these characteristics:

-- INTSORMIL has the dual goal of improving agriculture in the developing countries and in the United States.

-- The six participating U. S. institutions agree to contribute at least 25% of the cost of the CRSP from non-federal resources (in money or in kind), justified on the basis of benefits that can accrue to their state's agriculture and their institution.

-- Host governments collaborating with INTSORMIL also contribute to the program by providing facilities, money and/or personnel.

-- The INTSORMIL program is designed to stimulate collaboration and program development between scientists of participating U.S. and developing country institutions.

-- Each research activity is designed to address a priority constraint to the improved production/utilization of sorghum and millet as identified by the planning grant activity which identified the major research areas which INTSORMIL should address.

-- Training and institution building are natural parts of the CRSP as it works toward increasing the research capability of collaborating developing countries. During the period of this report, July 1, 1985 - June 30, 1986, there have been 82 LDC students sponsored (total or partial support) in graduate degree programs. Total funding of students by INTSORMIL has been through graduate research assistantships provided under individual research sub projects.

-- INTSORMIL is making a global impact. Collaboration with 17 host countries provides impact in seven major regions: West Africa, East Africa,

Southern Africa, Southeast Asia, Central America, the Caribbean and South America.

GOAL

The goal of the CRSP has been to establish active, collaborative research relationships that will contribute to the alleviation of hunger and malnutrition in developing countries by improving the availability and utilization of sorghum and millet.

PURPOSE

The purpose of the sorghum/millet CRSP is to organize and mobilize financial and human resources necessary for mounting a major, multi-institutional US-host country collaborative research effort which in turn provides the knowledge base necessary to achieve significant advances in alleviating the principal constraints to improved production, marketing, and utilization of sorghum and pearl millet. A second purpose is to improve the capabilities of host country institutions to generate, adapt and apply improved technology to local conditions.

OBJECTIVES

The INTSORMIL program has three general objectives which are common to all projects.

1. Research/technology development - Scientific resources within the INTSORMIL U. S. university community and within the collaborating host country programs address universal constraints to the production, availability and improved utilization of sorghum and pearl millet. Research constraints addressed by the program fall within the general disciplinary areas of breeding, pathology, entomology, cultural practices, physiology, utilization, economics and sociology/anthropology.

2. Institutional development - Improved research capability is enhanced through collaboration between the U.S. and host country counterparts, through exchange of professional visits between the U.S. and the host country scientists, and through support of the LDC national research program in terms of equipment, supplies, travel and personnel.

3. Training - This involves both short term and degree training oriented programs for host country staff at U. S. institutions. On site technical assistance/training is provided by the U. S. scientists in conjunction with the collaborative research activities.

Research is the primary emphasis of the program. But the CRSP's have been planned and organized in such a manner that institutional development and training have been very significant outputs of the program.

MANAGEMENT ORGANIZATION

The University of Nebraska (UNL) is the Management Entity (ME) for the Sorghum/Millet CRSP and is the primary grantee of AID. UNL subgrants are made to the participating U. S. Universities -- Texas A&M, Purdue, Nebraska, Kansas State, Mississippi State and Kentucky -- for the research projects between individual U. S. scientists and their host country counterparts. Country project funds, managed by the ME, flow to the country program in support of the research activities at the host country level. The Board of Directors of the CRSP serves as the top management/policy board for the CRSP. The Technical Committee, Ecogeographic Zone Council, External Evaluation Panel and AID personnel advise and guide the ME and the board in areas of policy, technical aspects, collaborating host country coordination, budget management, and review.

The Board of Directors

The Board of Directors consists of six institutional representatives from each of the participating U. S. institutions. The ME representative on the Board is a permanent member. Board members are designated by the chief executive officers of their institutions to represent them on policy and administrative matters. The Board elects a chairperson and vice chairperson on an annual basis. The ME serves as the executive secretariat to the Board. The members of the Board of Directors for FY 86 were:

Dr. D. Woods Thomas, Chair, Director, International Programs in Agriculture, Purdue University, West Lafayette, Indiana

Dr. H. Massey, Director, International Programs for Agriculture, University of Kentucky, Lexington, Kentucky

Dr. Walter Porter, Associate Dean, Mississippi Agricultural Experiment Station, Mississippi State University, Mississippi State, Mississippi

Dr. Kurt Feltner, Associate Dean of Agriculture, Kansas State University, Manhattan, Kansas

Dr. Irv. Omtvedt, Dean, Agricultural Research, University of Nebraska, Lincoln, Nebraska

Dr. John Abernathy, Director, Texas A&M Agriculture and Research Center, Lubbock, Texas

The Board of Directors met four times during the year. Action taken at these meetings included:

1. Approved University of Nebraska proposal that Dr. Glen Vollmar, INTSORMIL Program Director, be appointed on a half time basis for one year (October 1, 1985 to September 30, 1986) while he would also serve as half time Acting Dean and Director of International Agricultural Programs organization, management and research activities.

2. Approved a seven member discipline based Technical Committee with membership representing: Agronomy/Physiology, Agricultural Economics, Breeding, Pathology, Entomology, Sociology/Anthropology, and Quality and Utilization.

3. The Board approved new operational guidelines for the Board of Directors, the Technical Committee and the Ecogeographic Zone Council.

4. The External Evaluation Panel was reduced from a standing committee of eight members to a standing committee of five members. This action was consistent with the AID/BIFAD CRSP Guidelines and the Sorghum/Millet CRSP Grant Document.

5. In response to a notice from AID that the INTSORMIL program would have to absorb an 18% reduction in program activity for the period February 1, 1986 to June 30, 1986, the Board elected to impose a 7.5% reduction for the entire program year of July 1, 1985 to June 30, 1986. This amounted to the same reduced level of activity. For the period July 1, 1986 to June 30, 1987, the Board of Directors, with input from the Technical Committee and Ecogeographic Zone Council, the ME and individual PI's, imposed a $784,000 reduction in program in response to the reduced level of funding proposed by AID.

6. At the initiative of the INTSORMIL Board Chair and the ME, a CRSP Program Directors and Board Chair Group was established. This group met twice during the period March to May, 1986. It was instrumental in working with NASULGC in preparing a briefing, sponsored by Congress, for informing Congressional leaders about the Title XII Collaborative Research Programs.

Technical Committee

The Technical Committee (TC) acts on most technical and operational matters and forwards its recommendations to the Board of Directors and the Management Entity. It reviews all project work plans and budgets and makes recommendations on overall program coordination. The TC consists of seven

members, representing each of the seven disciplinary areas in the Program. Principal investigators are nominated for membership on the TC by members of the discipline. All PI's vote for the candidates proposed by the discipline. The term of office is for three years. Officers of the TC are the chair, vice chair and Secretary.

Members of the present Technical Committee are:

Dr. Larry Butler, Chair, Department of Biochemistry, Purdue Universtiy, West Lafayette, Indiana

Dr. Jerry Maranville, Vice Chair, Department of Agronomy, University of Nebraska, Lincoln, Nebraska

Dr. Richard Frederiksen, Department of Plant Pathology and Microbiology, Texas A&M University, College Station, Texas

Dr. Kathleen DeWalt, Department of Behavioral Science, University of Kentucky Medical Center, Lexington, Kentucky

Dr. Henry Pitre, Department of Entomology, Mississippi State University, Mississippi State, Mississippi

Dr. Lynn Gourley, Department of Agronomy, Mississippi State University, Mississippi State, Mississippi

Dr. Dale Anderson, Department of Agricultural Economics, University of Nebraska, Lincoln, Nebraska

The TC met three times during the year. Significant actions by the committee were:

a. Reviewed and approved Technical Committee Guidelines which were submitted to the Board of Directors for approval.

b. Provided technical input for preparing the scope of work for the EEP prime site reviews which were to take place from October to December, 1986.

c. Proposed one annual TC/EZC joint meeting.

d. Initiated action for development of an INTSORMIL publication series.

e. The TC in collaboration with the EZC polled all PI's through a questionnaire regarding prime sites and collaborating sites, discipline balance, commodity balance, and project activity at international sites. This information was used by the TC in making recommendations to the ME for budgetary action regarding the 18% reduction in program imposed on INTSORMIL February 1, 1986.

Ecogeographic Zone Council

The Ecogeographic Zone Council's primary responsibilities are planning and implementation of identified host country and U. S. collaborative sorghum/millet activities as related to research, training and networking. The membership on the EZC consists of one principal investigator from each of the ecogeographic zones. In most cases the member is the country coordinator of the host country identified in the Global Plan as the prime site country, plus one at-large member. The at-large member is recommended to the Board of Directors by the ME. Membership of the Council is determined by the Board of Directors, with the composition of the Council to be reviewed annually. Officers of the EZC are the chair, vice chair, and secretary, all serving one year terms.

Members of the present EZC are:

Dr. Darrell Rosenow, Chair, Texas A&M University, Lubbock, Texas

Dr. John Axtell, Purdue University, West Lafayette, Indiana

Dr. Allan Kirleis, Purdue University, West Lafayette, Indiana

Dr. Van Withee, Kansas State University, Manhattan, Kansas

Dr. Lynn Gourley, Mississippi State University, Mississippi State, MS

Dr. Billie Dewalt, University of Kentucky, Lexington, Kentucky

Mr. David Andrews, University of Nebraska, Lincoln, Nebraska

The EZC met four times during the year. Significant actions by the council were:

a. The EZC developed a priority list of international sites for review by the external evaluation panel as follows:

1. Niger and Mali - October, 1986
2. Botswana - May, 1986
3. Dominican Republic - September, 1986
4. Brazil - August, 1986

b. Guidelines for the country coordinators were developed and forwarded to the Board for approval.

c. A Prime Site Workshop for Niger was planned and implemented October 1985.

d. The EZC developed budget options which it submitted to the ME in support actions required for handling the 18% reduction in program. The EZC utilized information obtained from all PI's through a questionnaire submitted by both the TC and EZC.

e. The EZC made considerable progress during the year in coordinating program development and facilitating the principal investigator's collaboration at each of the prime sites.

External Evaluation Panel

The External Evaluation Panel (FEP) consists of five members, nominated by PI's, the TC and institutional representatives. The Board of Directors recommends the EEP members to AID/Washington and BIFAD, which give the final approval. The EEP has a chair and a vice chair. Representatives from international institutions and countries other than the U. S. are included on the EEP. The EEP is charged with overall evaluation of the sorghum/millet CRSP program, which includes research collaboration with host countries. The overall evaluation includes a review of projects and programs of the CRSP and it provides a written evaluation and recommendation for addition, elimination, or modification of component projects and overall objectives to include retention, elimination, or addition of new activities.

The EEP is composed of:

Dr. Bruce Maunder, Chair, Vice President, DeKalb-Pfizer Genetics, Lubbock, Texas

Dr. Clarence Gray, Vice Chair, Virginia Polytechnic Institute, 9945 Great Oaks Way, Fairfax, Virginia

Dr. Glenn L. Johnson, Agricultural Economics Department, Michigan State University, East Lansing, Michigan

Dr. Brhane Gebrekidan, CIMMYT Maize Program, Mexico D. F., Mexico

Dr. Ricardo Bressani, Head, Division of Ag. & Food Sciences, Instituto de Nutricion, Apartado Postal 1188, Guatamala City, Guatamala

External Evaluation Panel activities for the year were as follows: During the period July 1, 1985 to June 30, 1986 there were no EEP activities other than ongoing reviews of INTSORMIL reports and other materials. The schedule for EEP reviews called for initiation of EEP reviews of prime sites beginning in October 1986. Discipline and U.S. site reviews are scheduled beginning in the summer of 1987.

Management Entity

The University of Nebraska Management Entity office is located in the Department of Agronomy, 241 Keim Hall, Institute of Agriculture and Natural Resources, University of Nebraska, Lincoln, NE 68583-0723. The ME office is

responsible to AID for technical and administrative matters for the CRSP. As the prime grantee it is responsible to AID for all fiscal matters relating to the grant. Other responsibilities include coordination of all memoranda of agreement, coordinating and implementing all committee meetings, Board and EEP meetings, and all reporting and communications regarding CRSP activities. The ME office coordinates and obtains all travel clearances through AID/W.

Organization

The Management Entity Staff (CRSP Financed) is comprised of:

Dr. Glen J. Vollmar, Program Director

Dr. John M. Yohe, Associate Program Director

Ms. Joan Frederick, Administrative Technician

Ms. Dorothy Stoner, Secretary

Supportive Management Staff (non CRSP financed)

Mr. Carl Mueller, Fiscal Manager, Grants & Contracts

Dr. Glen J. Vollmar, Acting Dean for International Agricultural Programs

Activities and accomplishments for the year include:

1. Coordinated and backstopped the EZC, TC and Board of Directors process in which a $684,000 reduction in program activity was mandated by AID.

2. Published the Annual Report for Year 6 (1985/86).

3. Coordinated INTSORMIL input into a Congressional sponsored briefing to Congress regarding Title XII CRSP Programs

4. Organized four Board of Directors meetings, three Technical Committee meetings and four Ecogeographic Zone Council meetings.

5. Participated in AID meeting for program directors.

6. INTSORMIL cosponsored three workshops during this period:

   a. Niger Prime Site Workshop, October, 1985
      cosponsor: INRAN, Ministry of Agriculture, Govt. of Niger

   b. Sorghum Seed Workshop, October, 1985
      cosponsor: INIA, ICRISAT, CIMMYT

   c. International Pearl Millet Workshop, April 7-11, 1986, ICRISAT/INTSORMIL

7. INTSORMIL provided guest speakers in support of:

a. Fourth Eastern Africa Sorghum and Millet Workshop, Soroti, Uganda, July 22-26, 1987. OAU/STRC/SAFGRAD sponsored workshop.

b. Second Workshop on West African Sorghum Research Network, Bamako, Mali, October 21-24, 1986. Cosponsored by ICRISAT and SAFGRAD/USAID.

Coordination with AID and BIFAD

AID - Liaison is maintained on a weekly basis for advice in program direction and development, securing travel clearances, equipment purchase approvals and for coordination with Regional Bureaus and USAID Missions.

Dr. Harvey Hortik, AID/S&T/AGR/AP is the AID program manager for the Sorghum/Millet CRSP.

BIFAD - The CRSP programs were jointly developed by the BIFAD standing committee, JRC (now called the JCARD), and by AID. Communication and coordination is maintained with the research division of the BIFAD staff office.

Coordination with the International Centers

INSORMIL has a history from the inception of the program of coordinating and collaborating with ICRISAT, the ICRISAT scientist located at CIMMYT for Latin America, with CIAT and with ICRISAT regional activities located in West Africa. ICRISAT management staff have attended INTSORMIL PI annual conferences and INTSORMIL ME staff have met with ICRISAT management staff to discuss coordination and collaboration in order to avoid duplication of activities.

Specific areas of collaboration are as follows:

1. INTSORMIL has posted a scientist at CIAT to conduct research on adaptation of sorghum to acid soils. This was done in joint planning with CIAT/ICRISAT. This activity has been highly successful. A jointly sponsored workshop by INTSORMIL/ICRISAT and CIAT was held in 1984 at CIAT on the topic of sorghum adaptation to acid soils. This technology has potential for Africa also.

2. INTSORMIL cosponsored two workshops with ICRISAT, the Sorghum Seed Production Workshop and the International Pearl Millet Workshop, Hyderabad, India, April 7-11, 1986.

3. INTSORMIL scientists collaborated by participation and by presentation of invited scientific papers at ICRISAT/CAFGRAD sponsored workshops on sorghum improvement in West Africa and for sorghum and millet improvement in East Africa.

TRAINING

One objective of the Sorghum/Millet CRSP is to improve the research and institutional strength of host country research institutions through short term and degree oriented training programs for host country staff at U.S. institutions. In addition both the host country research and U. S. based research is enhanced through support of U. S. graduate students. The training aspects of the program are summarized in the section on training, page 405.

PROGRAM SUPPORT

The Sorghum/Millet CRSP grant from AID provided $18,150,000 for years one through six (July 1, 1979 to June 30 1985). That included $16,610,000 for program and $1,540,000 for operation of the management entity (Table 2 and Table 3). The one year extension for program Year 7 allowed $3,173,700 for program and $342,000 for operation of the management entity (Table 2). AID funds expended for the seven year period totaled $19,783,700 for program and $1,882,000 for operation of the management entity (Table 2 and Table 3). In addition the U.S. participating institutions contributed $5,730,727 for the same seven year period (Table 4). Management cost for the program amounted to 9.00 percent of the total $21,665,000 granted to the University of Nebraska. This indicates that the management load in relation to total costs is very cost effective. Budget tables are on pages 21 to 24.

Future Funding by AID

The Sorghum/Millet CRSP was administratively approved for a two year extension in May, 1985 for the period July 1, 1985 to June 30, 1987. During program Year 7, INTSORMIL has been requested to hold an EEP review of two international sites to evaluate implementation of the new global plan developed in Year 6. A satisfactory review would establish the basis for a program extension of three more years, July 1, 1987 - June 30, 1990. Plans were made for these site reviews and for a comprehensive review of the whole program by the EEP in preparation for the AID Triennial Review for program extension according to the AID/BIFAD CRSP guidelines.

Collaborating Program Contributions

It is difficult to calculate host country collaborating program contributions because much of the contribution is "in kind". Host governments have contributed substantially to the partnership in research with the U.S. participating institutions.

TABLE 1.

AID-GRANT CONTRIBUTION TO SORGHUM/MILLET CRSP FOR YEARS 1 (FY 80) THROUGH 7 (FY 86) FOR

ALL COLLABORATIVE RESEARCH AND MANAGEMENT ENTITY

Budget Line Items	FY 80-81 Years 1-2	FY 82 Year 3	FY 83 Year 4	FY 84 Year 5	FY 85 Year 6	FY 86 Year 7	FY 80-86 Totals
Salaries & Benefits	2,145,480	1,015,846	1,478,410	1,497,525	1,467,726	1,507,415	9,112,402
Equipment & Facilities	405,310	144,140	252,086	259,921	230,798	281,761	1,574,016
Travel	583,800	318,490	335,711	318,514	305,743	369,461	2,231,719
Other Direct Costs	432,200	213,406	154,535	124,657	94,123	168,122	1,187,043
Technical Assistance	112,000	104,290	45,000	40,000	40,000	12,500	353,790
LDC	224,000	143,475	446,000	534,000	813,480	403,725	2,564,680
Indirect Costs	1,097,210	560,353	788,258	725,383	698,130	772,716	4,642,050
TOTAL	$5,000,000	$2,500,000	$3,500,000	$3,500,000	$3,650,000	$3,515,700	$21,665,700

TABLE 2.

AID-GRANT CONTRIBUTION TO SORGHUM/MILLET CRSP FOR ALL COLLABORATIVE RESEARCH, U.S. INSTITUTIONS (Florida A&M University, University of Arizona, Kansas State University, University of Kentucky, Mississippi State University, University of Nebraska, Purdue University, Texas A&M University), AND THE MANAGEMENT ENTITY

Budget Line Items	FL	AZ	KS	KY	MS	NE	PR	TX	INSTITUTIONAL TOTAL	ME BUDGET	ME TA-LDC	TOTAL GRANT REQUEST
Years 1-6 (FY 80-85) AID GRANT - AID/DSAN/XII-G-0149												
Salary & Benefits	85,270	191,675	896,270	287,013	828,186	1,622,402	1,224,363	1,833,520	6,968,699	636,288		7,604,987
Equipment & Facilities	35,500	41,529	134,655	4,600	34,968	159,889	129,863	726,750	1,267,754	24,501		1,292,255
Travel	14,500	27,523	276,950	136,390	177,094	233,533	216,753	435,559	1,518,302	343,956		1,862,258
Other Direct Costs	7,500	5,670	142,027	55,271	112,537	148,359	217,751	242,370	931,485	87,436		1,018,921
Technical Assistance											341,290	341,290
LDC											2,160,955	2,160,955
Indirect Costs	35,106	58,283	397,575	165,476	447,465	762,315	661,080	894,215	3,421,515	447,819		3,869,334
TOTALS	$ 177,876	$324,680	$1,847,477	$648,750	$1,600,250	$2,926,498	$2,449,810	$4,132,414	$14,107,755	$1,540,000	$2,502,245	$18,150,000
Year 7 (FY 86) AID GRANT - AID/DAN-1254-G-SS-5065-00												
Salary & Benefits			230,274	100,954	120,909	246,564	262,733	411,684	1,373,118	134,297		1,507,415
Equipment & Facilities			31,159	800	25,056	85,640	47,289	88,076	278,020	3,741		281,761
Travel			43,225	27,684	25,500	52,593	58,738	96,721	304,461	65,000		369,461
Other Direct Costs			24,127	17,213	21,973	8,500	23,880	38,929	134,622	33,500		168,122
Technical Assistance											12,500	12,500
LDC											403,725	403,725
Indirect Costs			90,240	54,999	56,312	134,928	153,110	177,665	667,254	105,462		772,716
TOTALS			$419,025	$201,650	$249,750	$528,225	$545,750	$813,075	$2,757,475	$342,000	$416,225	$3,515,700

TABLE 3.

MANAGEMENT ENTITY OFFICE BUDGET DETAILS

Budget Line Items	FY 80-81 Years 1-2	FY 82 Year 3	FY 83 Year 4	FY 84 Year 5	FY 85 Year 6	FY 86 Year 7	TOTALS FY 80-86 Years 1-7
Salaries & Benefits	179,280	93,200	107,071	123,050	133,687	134,297	770,585
Equipment & Facilities	7,510	3,640	1,540	6,311	5,500	3,741	28,242
Travel							
International		14,000	29,000	37,900	16,000	10,000	
Domestic		5,000	10,000	9,000	5,000	6,000	
Board of Directors		5,000	6,000	10,000	6,000	8,000	
Technical Committee		6,000	10,000	17,000	11,000	8,000	
Administrative Council		1,600	4,000		5,000		
Country Coordinators						8,000	
EEP		10,000			10,477	15,000	
Workshops		5,140	500	2,739	6,000	5,000	
Total Travel	97,600	46,740	59,500	76,639	59,477	60,000	399,956
Consultants		2,600	1,000	3,000		5,000	11,600
Other Direct Costs	28,600	7,720	18,000	16,000	14,516	33,500	118,336
Total Direct Costs	312,990	153,900	187,111	225,000	213,180	236,538	1,328,719
Indirect Costs	87,010	46,100	112,889	85,000	116,820	105,462	553,281
ME TOTAL COSTS	$400,000	$200,000	$300,000	$310,000	$330,000	$342,000	$1,882,000

TABLE 4.

SORGHUM/MILLET CRSP SUMMARY OF NON-FEDERAL MATCHING CONTRIBUTIONS BY U.S. INSTITUTIONS - YEARS 1 (FY 80) THROUGH 7 (FY 86)

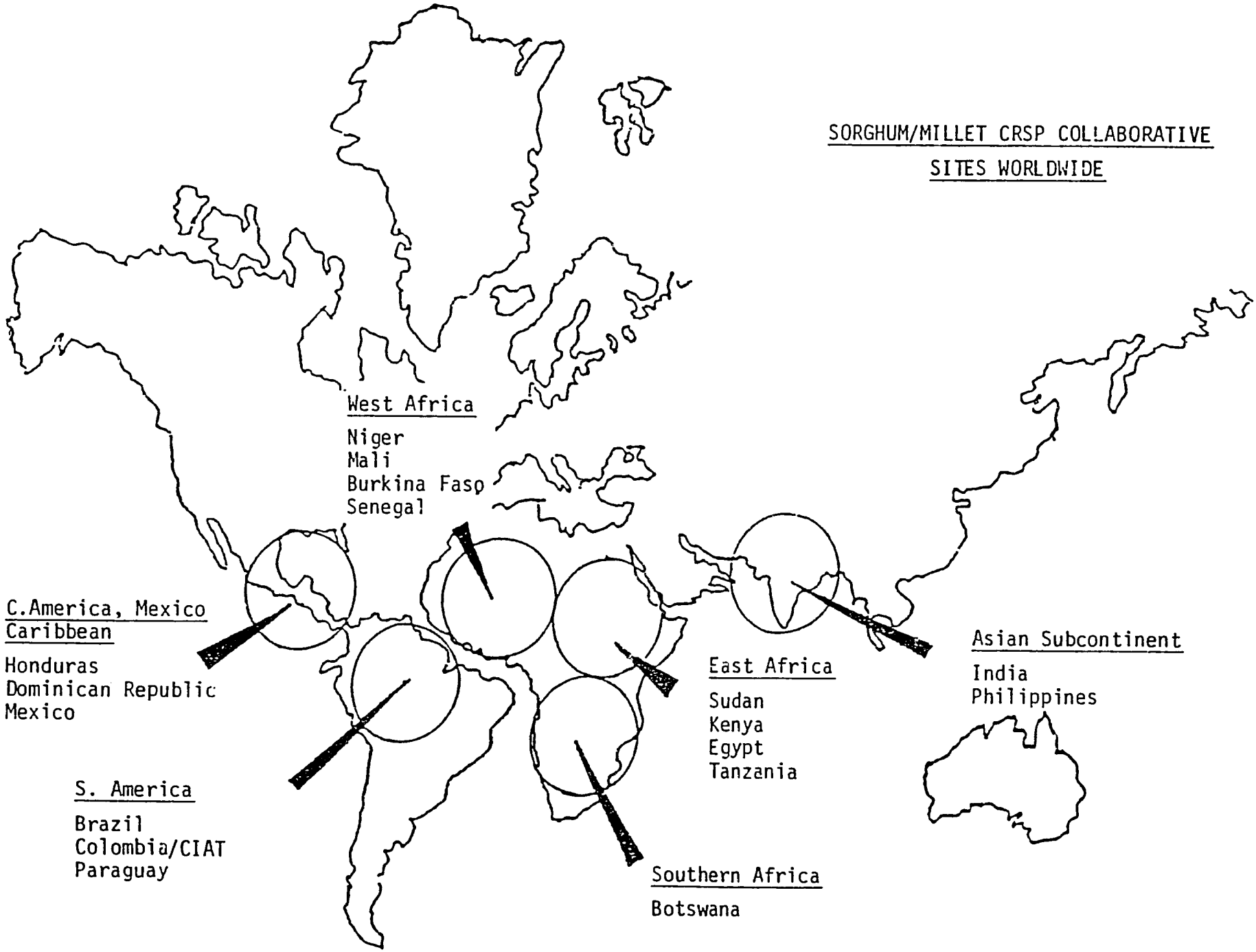
U.S. INSTITUTION	1ST GRANT YEARS (1-6) FY 80-85	YEAR 7 FY 86	YEARS 1-7 TOTALS
University of Arizona	149,310		149,310
Florida A&M University	23,898		23,898
Kansas State University	723,434	146,877	870,311
University of Kentucky	158,702	53,947	212,649
Mississippi State University	604,229	58,875	663,104
University of Nebraska	891,491	143,375	1,034,866
Purdue University	770,815	138,095	908,910
Texas A&M University	1,662,957	204,732	1,867,689
TOTAL	$4,984,836	$745,901	$5,730,737

1986 Project Reports

The Sorghum/Millet CRSP has research linkages in four geographic regions as delineated by AID through the organization of their Regional Bureaus, Africa, Latin America and the Caribbean, Near East and Asia. Depending upon the host country, the range of disciplines covered under collaborative activities between INTSORMIL and the host country varies from one to seven. The more multidisciplinary the country program is the greater the potential for exchange of information on a regional or international basis.

This section of the report describes the research and collaborative activities progress between individual U. S. scientists and their counterparts along disciplinary lines. Research progress has been significant. New varieties and hybrids have been identified which can make a contribution to the improvement of sorghum production in the developing world. A better understanding of insect pests and disease problems in the collaborating countries has been elucidated. Progress in food grain quality has been a major development. This is true for Latin America and Africa. The level of progress in the INTSORMIL program is indicative of the level of interest and commitment that the U. S. and host country collaborators have in the different areas of research. The collaborative mode of interaction has contributed significantly to the development process and has facilitated the administrative process for accomplishing the tasks undertaken by the program.

The annual progress reports were prepared by the U. S. principal investigators. Results presented are from research accomplished by both the U. S. and host country collaborators.


SORGHUM/MILLET CRSP COLLABORATIVE
SITES WORLDWIDE
West Africa
Niger
Mali
Burkina Faso
Senegal
C.America, Mexico
Caribbean
Honduras
Dominican Republic
Mexico
S. America
Brazil
Colombia/CIAT
Paraguay
East Africa
Sudan
Kenya
Egypt
Tanzania
Southern Africa
Botswana
Asian Subcontinent
India
Philippines

Agronomy/Physiology

Executive Summary

In pearl millet research during Year 7, effects of seed quality on germination and stand establishment did not appear to be influenced by high soil temperatures even at temperatures which resulted in 50% reduction in germination. Continued field studies on production of high quality seed under different management regimes of the seed crop showed smaller increases in seed quality and no effect on subsequent grain yield. (KSU-106).

The influence of crop rotation and nitrogen source on sorghum and soybeans is being studied in Nebraska. A consistent yield advantage of crop rotation for both soybeans and sorghum has been obtained. Manure and liquid nitrogen applications increased pH, P, K and micronutrient content of the soil, and the microbial biomass. Soil sampling late in the spring allowed the detection of 50 kg/ha residual soil nitrogen after soybeans grown continuously or in rotation with sorghum.

In Botswana, where rainfall was less than 300mm per season, high grain yields were not necessarily related to high plant densities or to application of residue and manure. However, 98% of the higher fertility treatments resulted in more stover yield and more total biomass. (NU-113)

Despite the erratic, long-delayed and scanty rains in Botswana, a vigorous research program was conducted. Yields in experiments were low, usually less than 500 kg/ha, and variability was great.

Moisture conservation was recognized by ATIP and INTSORMIL personnel as a necessary field of research and some studies were initiated. Efforts will be intensified. (KSU-107)

Fertility trials in the Philippines showed that nitrogen level should be reduced during drier months to increase profitability. Moisture supply and fertility level interacted extensively.

Mycorrhizal research on the effects of different Glomus (VAM) species on growth and mineral element uptake indicated that sorghum plants infected with VAM had 13 to 14 times higher dry matter yields and 26 times as much P uptake from a P deficient soil. There were several interactions with VAM species, soil pH, and temperature. The benefits can be attributed to the fungal hyphae effectively increasing the absorbtion surface areas.

Studies of pearl millet directed at understanding mechanisms of N use efficiency showed that photosynthetic N efficiency alone accounted for

little of genotype N use efficiency. Rather, it was related more to allocation and remobilization of N among plant parts to maintain high C:N ratios. This may be practical in selection for improved mineral use efficiency in sorghum and millet. (NU-114)

Use of a stress screening technique for screening early generation population selections has essentially stopped because of budget reductions. Testing is continuing. Some initial selections dating to 1979 have been stabilized and a few B lines have been sterilized. The first hybrids using these new stress tolerant females will be tested in 1987. Most of them will fit collaborating LDC sites rather than the U.S. Some R lines dating from the initial selections are more appropriate for U.S. agriculture and will be released. A larger portion of the second round of selections (1982-84) are more appropriate for U.S. farmers as well as developing country farmers. A modest number of these are being evaluated in approximately 5,000 University of Nebraska test plots. They will be tested more extensively in 1987 and sterilization of dwarf stress resistant B lines will continue. They appear very promising. Some of both the R and B lines seem to have good stalk strength.

A shortened version of a new tan plant-food grain population is being developed for developing country and U.S. application along with a taller version for developing countries only. (NU-116E)

Progress continued toward identification of characteristics and mechanisms of drought and high temperature resistance of sorghums and pearl millet. Additional selections were made for deep rooting potential by growing and water stressing plants in hydroponic tubes. Generally the sorghums had heavier root growth at 50 to 70 cm depth compared to the pearl millets which had more root growth at 20 to 40 cm depth. The millets also had greater numbers of main roots which appeared to be more efficient at extracting water from the shallower soil depths.

Drought resistant Malian sorghums used less water per unit time than U.S. developed sorghums, and water use efficiency (dry matter/unit water used) of the Malian sorghums was higher. (NU-116S)

In North Kordofan, Sudan, a good farmer:researcher linkage was created by expanding the number of on-farm trials to 28 villages and farmer participants to over 100.

A successful arrangement was made between the USAID Mission to Sudan and the Tenneco Company for multiplication of the Ugandi variety of pearl millet. The seed was distributed to North Kordofan farmers for the 1986-87 season. (KSU-101-1)

Agronomic Research on Sorghum and Millet in
North Kordofan, Sudan
Project KSU-101-1
Tareke Berhe

Principal Investigator

Tareke Berhe (Ph.D.), Agronomist/Breeder, Kansas State University on-site in host country.

Other Researchers

Host Country

Mr. Mirghani Saeed Mohamed (B.Sc.), Research Assistant to INTSORMIL Agronomist

United States

Dr. Richard L. Vanderlip, Agronomist, Kansas State University.

Dr. Jerry Eastin, Agronomist, University of Nebraska

Summary

A few of the significant achievements for KSU-101-1 Sudan project were:

A good farmer:researcher linkage was created by expanding the number of on-farm trials to 28 villages and farmer participants to over one hundred.

A successful arrangement was made between USAID Mission to Sudan and Tenneco Co. for the multiplication of Ugandi variety of pearl millet on 50 acres. The seed was distributed to North Kordofan farmers for the 1986-87 season.

In addition to his own program in North Kordofan, the principal investigator took over and successfully completed an extensive agronomic research program in Kadugli left by the outgoing Washington State University agronomist. A field day was attended by over 200 farmers.

Arrangements were made for the Sudanese counterpart, Mr. Mirghani Saeed Mohamed, to come to the U.S. and study for his Master's degree. Mirghani is now at the University of Nebraska-Lincoln.

Research results have been communicated well in host country and internationally through progress reports, departmental publications and seminars.

Institutions

Collaborating Host Country: USAID/Mission to Sudan, ICRISAT/SUDAN, Regional Ministry of Agriculture and Natural Resources, Kordofan Region and the Western Sudan Agricultural Research Project (WSARP)

U.S.: Kansas State University, University of Nebraska-Lincoln, and Washington State University at Pullman, Washington.

Linkages:

A good working relationship was developed among all host country institutions listed above. Meetings were held at the Western Sudan Agricultural Research Project at the beginning of each season and all research plans discussed and agreed upon. INTSORMIL, ICRISAT, and WSARP carried out the planned research. USAID Mission to Sudan, Washington State University and the Regional Ministry of Agriculture provided the necessary logistic support. Administrative and financial matters were handled by Kansas State University.

Ecogeographic Zones Benefited Most by Research

East and West Africa Regions.

Objectives, Research Procedures, and Production/Utilization Constraints

Year 7 Objectives

INTSORMIL agronomic trials in North Kordofan during the 1985-86 crop season consisted of: (1) on-station trials, (2) on-farm trials.

The objectives of the on-station trials were to identify varieties, lines, cultivars, etc., of sorghum, millet and cowpeas that are:

Adaptable to the area and stable in yield.

Early (70-90 days).

Drought resistant or tolerant.

Pest (especially *Striga hermonthica*) and disease tolerant.

Suitable for inter- or mix-cropping.

The objectives of the on-farm trials were to:

Try best identified genotypes in on-farm trials under farmers' conditions.

Reconfirm good results obtained in previous years.

Try to transfer a proved technology to farmers.

Changes in Objectives from Previous Year

To avoid research overlap, it was agreed that the INTSORMIL project emphasize on-farm trials and WSARP agronomists on-station trials.

Sorghum/Millet Constraints

Some of the major constraints limiting sorghum/millet yields in North Kordofan, Western Sudan are:

Drought -- insufficient rainfall and/or poor distribution.

Pests and diseases.

Poorly adapted genotypes.

Poor soil fertility.

Problems in seedling vigor and seedling establishment.

Inefficient cultural practices.

Research Procedure

Researcher-managed on-station trials were conducted at two sites: sandy soil (Goz) and clay soil (Gardud). Farmer-managed trials were conducted in 28 villages. Over 100 farmers received 1-5 kgs of sorghum and millet seed of promising genotypes.

Problems Regarding Achievement of Objective

- The biggest problem in many villages was insufficient rainfall.
- Some farmers did not follow instructions in planting.
- Some farmers planted our trials late, i.e., after finishing their own planting.

Project Output

Research Findings for Immediate Use

Ugandi variety of pearl millet found to be early and drought resistant. Seed of Ugandi increased on 50 acres for distribution in North Kordofan during 1986-87 crop season.

IS-9830 and SRN-39 genotypes of sorghum confirmed to be tolerant to *Striga hermonthica* prevalent in the area.

P898012 genotype of sorghum found to be drought tolerant and very stable in yield.

More sorghum germplasm collected.

Research Findings for Future Use

Yield and adaptability test results for a promising elite line of pearl millet, bristled population, from the ICRISAT/SUDAN program are available.

P898012 sorghum recommended for release in the near future.

IS-9830 recommended for on-farm trials on the house gardens (Jubrakas) and SRN-39 on the cracking clays (vertisols).

Five entries from the INTSORMIL sorghum germplasm show promise as potential varieties.

Intercropping of groundnut with pearl millet or sorghum at a ratio of 3:1 (6 rows of groundnut to 2 rows of cereal) shows good promise.

Networking Activities

- Workshops

Participated in the International Pearl Millet Workshop held at ICRISAT, India on April 7-11, 1986.

- Research Investigator Exchanges

INTSORMIL experimental sites were visited by host country scientists and scientists from U.S. universities and ICRISAT

- Germplasm and Research Information Exchange

Seed from 95 sorghum collections provided to (1) Western Sudan Agricultural Research Project, El Obeid, (2) Western Sudan Agricultural Research Project, Kadugli, and (3) Dr. Darrell T. Rosenow, Sorghum Breeder, Texas A&M University.

- Assistance to Host Country Researchers

The INTSORMIL office at El Obeid was a source of (a) literature information, (b) sorghum and millet seeds, (c) truck spare parts, and (d) field tools and office equipment for research staff from the Western Sudan Agricultural Research Project and the Regional Ministry of Agriculture.

Travel

International

- Return from Sudan. December 15, 1985. Tareke Berhe returned to Kansas State University to process his American citizenship while writing his reports.

- India. April 4-16, 1986. Tareke Berhe. To attend the International Pearl Millet Workshop held at ICRISAT.

Domestic

- Pullman, Washington. February 1986. Tareke Berhe. Helping Washington State University in the write-up of agronomic results for Kadugli, South Kordofan, Sudan. Washington State University pulled out of Sudan early and as a result Tareke took over the agronomic trials left by the outgoing agronomist.

Publications and Presentations

Publications

Tareke Berhe and Mirghani Saeed Mohamed. 1985. KSU/INTSORMIL Sorghum/Millet Agronomic Research in North Kordofan, Sudan, Africa. Department of Agronomy, Kansas State University, Manhattan, and INTSORMIL, University of Nebraska-Lincoln. 35 pp.

Tareke Berhe and R.P. Jain. 1986. A Pearl Millet Variety for Western Sudan. Agronomy Department Report, Kansas State University, Manhattan. 9 p.

Tareke Berhe. 1986. Notes on rainfall patterns and their influence on sorghum/millet research and production in Kordofan, Western Sudan. Department of Agronomy Report, Kansas State University, Manhattan. 20 p.

Tareke Berhe. 1985. Summary of Kadugli WSARP Station NP Fertilizer Study Results. A three page report prepared for the Director of the Western Sudan Agricultural Research Project.

Tareke Berhe. 1986. KSU/Sudan INTSORMIL Project Agronomic Research in Western Sudan: Summary of achievements. A three page report prepared for INTSORMIL Director.

Tareke Berhe and Tsegazeab Woldetatios. 1986. Recommendations for Agronomic Crops Research Priorities in Kordofan Region of Western Sudan. Office of International Programs, Washington State University, Pullman, Washington. 10 p.

Presentations

Tareke Berhe. Potentials for Pearl Millet Improvement in North Kordofan, Sudan. A seminar presented to ICRISAT Research Staff on April 14, 1986.

Tareke Berhe. Potentials for Sorghum Improvement in Western Sudan. Seminar presented at Purdue University on January 29, 1986, and at Washington State University on February 20, 1986.

Changes in Year 8

With the return of the principal investigator, the KSU-101-1 Project has terminated as of August 1986. Until contract is renewed, agronomic activities will be continued by research staff of the Western Sudan Agricultural Research Project.

Seedling Vigor and Stand Establishment of Pearl Millet

Project KSU-106

R.L. Vanderlip

Kansas State University

Principal Investigator

R.L. Vanderlip, Agronomist, Kansas State University

Other Researchers

Host Country

Tareke Berhe, INTSORMIL Agronomist, El Obeid, Sudan

Elijah Modiakgotla, Department of Agricultural Research, Mahalapye, Botswana

Geoff Heinrichs, Agricultural Technology Improvement Project (ATIP), Francistown, Botswana

Jay Seibert, ATIP Agronomist, Mahalapye, Botswana

Doug Carter, INTSORMIL Agronomist, Sebele Research Station, Gaborone, Botswana

United States

W.D. Stegmeier and Babrak Khaleeq, Fort Hays Branch Experiment Station (KSU-101)

Max Clegg, Agronomist, University of Nebraska (NU-113)

Summary

Effects of seed quality on germination and establishment do not appear to be affected by high soil temperatures even at temperatures which result in 50% reduction in germination. Continued field studies on production of high quality seed with different management of the seed crop showed smaller increases in seed quality and no effect on subsequent grain yield. This is in contrast with the results from Sudan in which increased seed size more than doubled grain yield.

Institutions

Collaborating Host Country: Western Sudan Agricultural Research Project (WSARP), El Obeid, Sudan; Botswana Department of Agricultural Research, Gaborone, Botswana; and Agricultural Technology Improvement Project, Gaborone, Botswana.

U.S. : Fort Hays Branch Experiment Station, Hays, KS; University of Nebraska, Agronomy Department, Lincoln, NE.

Linkages:

Dr. Tareke Berhe, INTSORMIL Agronomist stationed at El Obeid, Sudan tested the effects of management practices developed at Kansas State University for production of high quality seed. This project has since been terminated. Final plans have been made for the 1986-87 cropping season for seed produced with the management practices developed at Kansas State to be tested in ongoing research projects in cooperation with the Department of Agricultural Research and ATIP in Botswana.

Miranda Mortlock, graduate research assistant on KSU-106, will spend the cropping season in Botswana to assist with these projects.

Ecogeographic Zones Benefited Most by Research

Because the program in Sudan has been terminated, the ecogeographic zone most directly affected would be the Southern Africa Zone. However, since the constraints to pearl millet establishment are common to most of the production areas, results could be applicable over a much wider area.

Objectives, Research Procedures and Production/Utilization Constraints

Objectives

1. Improve the stand establishment capability of pearl millet under the stress conditions normally found where pearl millet is grown in the tropics and in Kansas.

2. Determine the seed characteristics which are important in accomplishing objective 1.

3. Manipulate millet seed mechanically through management or in cooperation with the breeders to improve the characteristics identified in objective 2.

Changes in Objectives from Previous Year

Emphasis has been changed from production of seed with improved characteristics to evaluation of seed with these characteristics under controlled and natural environmental conditions.

Sorghum/Millet Constraints

Constraints to productivity include climatic, edaphic, and biological factors. The climate of sorghum and millet producing regions has low and

erratic rainfall which has high within- and between-year variability. The solar radiation is high due to frequent cloudless conditions, and humidity is low resulting in a high potential evapotranspiration (PET) rate. In Botswana the PET exceeds precipitation in every month. The soils are often of low fertility and are prone to crusting, rapid drying, and high soil temperatures which reduce crop establishment. Sorghum and millets are small seeded crops requiring shallow planting. Low yields are the norm in these regions and crop failure is common. Farmers may be unable to produce subsistence grain and seed for the following season. Low yields are a function of the harsh environment which often does not enable an adequate stand to establish.

Research Procedure

Tareke Berhe, El Obeid, Sudan tested the effects of small, medium, and large seed of Ugandi and Baladi millet at planting depths of 6, 9, and 12 cm.

Research in the U.S. was based primarily on seed produced in 1984 with management practices of control, head cut, and spikelet removal. Stan Freyenberger, M.S. student, used seed from each of these sources and separated it into five classes: 1) control (no mechanical seed separation); 2) large (seeds retained on a 0.24 cm sieve); 3) dense (seeds with a density greater than 1.265 g/cc); 4) bold (seeds satisfying both large and dense descriptions); and 5) wet control (as the control, but soaked in the density separation sucrose solution).

Miranda Mortlock, Ph.D. student, used seed from the three management sources to test the effects of elevated soil temperature on stand establishment. Plastic mulch was used to raise soil temperatures. She also separated Senegal bulk seed into three size categories and two density categories for controlled temperature studies.

Problems Regarding Achievement of Objectives

With the closing of the Sudan project, it no longer will be possible to maintain work in this area. Extreme drought conditions in Botswana have made it difficult to produce seed which could be used in subsequent testing. Seed produced in the U.S. was not as affected by management practices as in previous years.

Project Output

Research Findings for Immediate Use

Results in the Sudan indicate that planting medium and large size seeds increased number of seedlings established, number of heads produced, and grain yield (Table 1). This is in agreement with earlier work from the U.S. which was the basis for the work in the Sudan.

Table 1. Effect of seed size on establishment, head number and yield, El Obeid, Sudan.

Seed size	No. seedlings established	No. heads	Plant yield (g)
Small	11	12	77
Medium	14	20	166
Large	17	22	181

Research at Kansas State University by Elijah Modiakgotla (Botswana) and Miranda Mortlock (United Kingdom) have shown no interaction between temperature and seed characteristics in their effects on germination and stand establishment. Therefore, we would not expect the effects previously reported for increases in stand establishment and yield due to seed characteristics to be negated by high soil temperatures.

Stan Freyenberger (U.S.) found that even when the establishment was affected by seed characteristics, yield was not necessarily increased (Table 2). This indicates that under certain environmental conditions, the effects on yields previously reported may not occur.

Table 2. Effect of crop management and separation on subsequent seedling establishment and grain yield of millet, Freyenberger, 1985.

Treatment	St. John		Manhattan	
	% Establishment	Yield kg/ha	% Establishment	Yield kg/ha
Control	30.6 ab*	2592 a	28.0 a	2832 ab
Spikelet removal	32.8 a	2294 b	27.4 a	2753 b
Head cut	29.6 b	2626 a	27.3 a	2927 a
L.S.D. (p = 0.05)	2.5	258	2.3	155
Control	30.2 b	2421 ab	25.6 b	2857 ab
Large	29.9 b	2543 ab	28.9 a	2851 ab
Dense	33.7 a	2690 a	28.4 ab	2799 ab
Bold	32.0 ab	2512 ab	28.7 a	2941 a
Wet control	29.3 b	2353 b	26.2 ab	2738 b
L.S.D. (p = 0.05)	3.2	333	2.9	200

* Means with the same letter within a site are not significantly different (p = 0.05).

Other Research Results

Increased emphasis has been placed on relating germination and emergence to temperature. Figure 1 shows the temperatures attained by using a plastic mulch in the field. Under the conditions here, the higher temperatures resulted in increased establishment with 23% establishment under the plastic and 10% on the bare soil. There were, however, no significant interactions between plastic cover (soil temperature) and source of seed from the control, head cut, and spikelet removal treatments. In growth chamber experiments, both high density seed and large seed increased emergence, both at high and low temperatures, again with no interaction.

Germination response to temperature has been studied using a thermal gradient plate and preliminary results are shown in Figure 2. These results suggest that at the high soil temperatures frequently encountered in the tropics, percent germination might be reduced to roughly 50% of that under ideal temperature conditions. This work is being continued, looking at effects of seed size and density, both on pearl millet and grain sorghum. This work is also being expanded to use the screening technique developed by ICRISAT where high intensity lamps are used over pots in the greenhouse. It

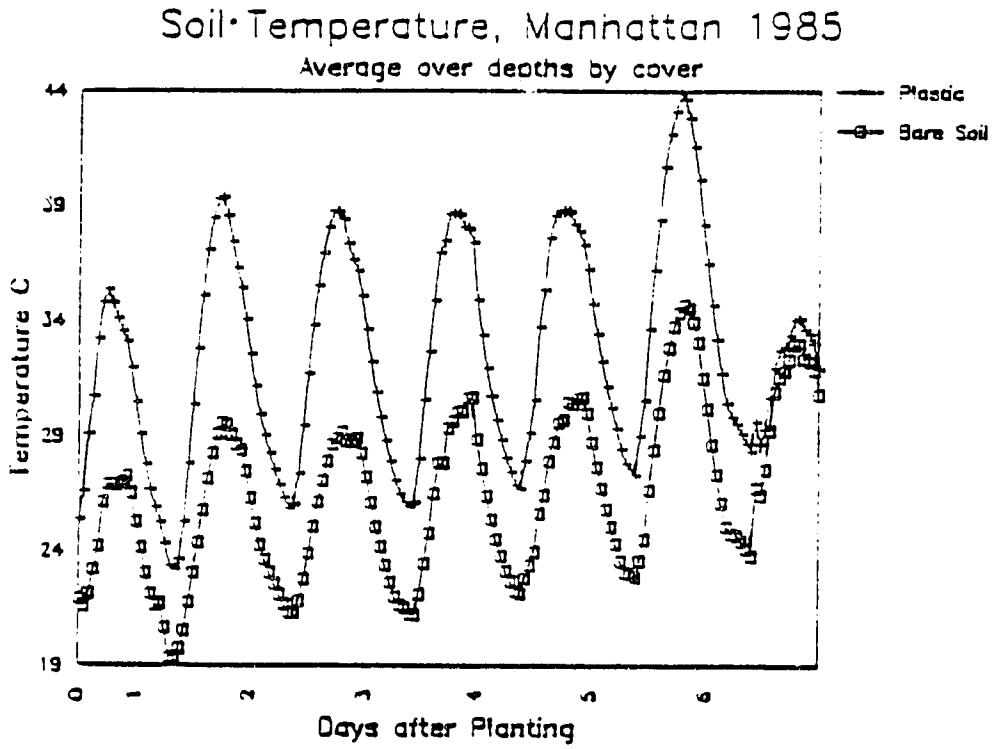


Figure 1. Effects of plastic mulch on soil temperature, Manhattan, 1985.

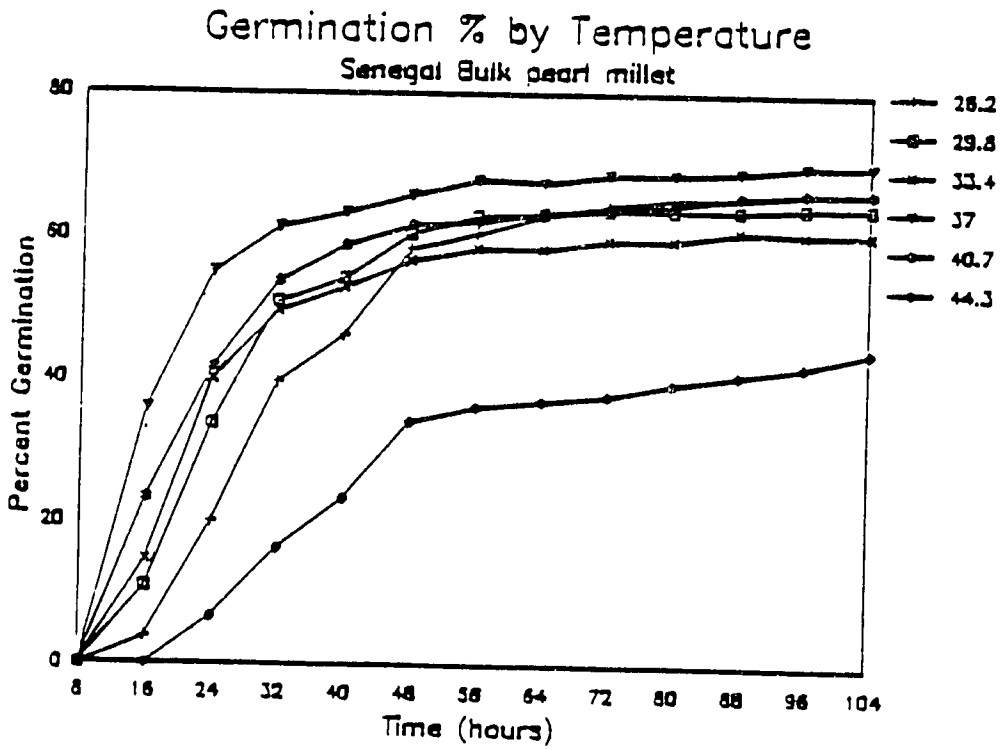


Figure 2. Effects of constant temperatures on rate and percent germination.

appears that maximum soil temperatures can easily be elevated to 45° to 48°C and effects of seed characteristics are being studied under these conditions.

Networking Activities

Discussion with researchers in Botswana in January of 1986, and with many of the researchers who visited Kansas State University later this year, have resulted in on-farm trials of improved seed quality on farmers' fields in each of the areas in Botswana where the ATIP program is active.

Travel

- Chicago, Illinois. December 1-5, 1985. R.L. Vanderlip. Attend ASA national meetings and recruit graduate research assistant for INTSORMIL project.
- Gaborone, Mahalapye, and Francistown, Botswana. January 6-20, 1986. R.L. Vanderlip. Coordinate seed production and make plans for 1986-87 field experiment.

Publications and Presentations

Okonkwo, J.C. and R.L. Vanderlip. 1985. Effect of cultural treatment on quality and subsequent performance of pearl millet seed. Field Crops Res. 11:161-170.

Freyenberger, Stanley G. 1986. Emergence, yield, and yield components responses to size and density separations of pearl millet seed produced by three management practices. M.S. Thesis Abstract.

Mwageni, G.J. and R.L. Vanderlip. 1986. Seed vigor measurements for predicting field establishment of pearl millet. Trans. KS Acad. Sci. 89:57-61.

Changes in Year 8

Increased emphasis on the direct effects of high temperature and moisture stress on germination and seedling establishment. This will continue to be related to seed characteristics of seed size and seed density.

Field evaluations of seed of various "quality" under a broader range of conditions, particularly utilizing extremely low plant populations which would more closely approximate LDC conditions.

Water Use Efficiency, Intercropping with Legumes, Tillage and Other Cultural Practices for Sorghum and Millet in Botswana

Project KSU-107

L.V. Withee

Kansas State University

Researchers in Host Country

Dr. Douglas Carter, Senior Scientist

Mr. Wayne Youngquist, Junior Scientist

Ms. Joan Youngquist, Research Assistant, University of Nebraska. Sponsored by NU-113 project and collaborating with KSU-107.

Collaborating staff of Department of Agricultural Research.

Researchers in U.S.

Dr. L.V. Withee, Principal Investigator and Campus Coordinator at Kansas State University

Dr. Richard Vanderlip, Principal Investigator, KSU-106, Kansas State University

Dr. Edward Kanemasu, Director ET Laboratory, Kansas State University Experiment Station

Dr. Max Clegg, Principal Investigator, NU-113, University of Nebraska

Dr. Geoffrey Heinrichs, Agricultural Technology Improvement Project (ATIP), Collaborating Agronomist

Dr. Jay Siebert, ATIP, Collaborating Agronomist

Summary

Year 7 was the second for Project KSU-107. It was a drought year in Botswana, as have been the last five: however, a vigorous research program was conducted despite the erratic, long-delayed, and scanty rains. As would be expected, yields in experiments were low, usually less than 500 kg/ha and the variability was great.

Wayne and Joan Youngquist completed their two year assignment and returned, having given good service to the project. Wayne was particularly effective in helping establish the computer capability of the project and in advising other officers of DAR and of ATIP in use of the computers available.

Moisture conservation was recognized by ATIP and INTSORMIL personnel as a necessary field of research and some studies were initiated. Efforts will

be intensified. Arrangements were made to establish a second position at Sebele for someone with soil physics training and experience to deal with problems such as crusting, infiltration, runoff, land shaping, and water harvesting - all related to moisture conservation and increased production of sorghum and millet.

Institutions

Collaborating Host Country: Department of Agricultural Research, Agricultural Research Station at Sebele, Botswana.

U.S.: Kansas State University

Linkages:

Project personnel work within the Division of Arable Crops Research in the Department of Agricultural Research at the Agricultural Research Station at Sebele and collaborate with officers and staff of the Station. There are DAR substations at Goodhope, Mahalapye and Maun with staff to assist with research. Also in Botswana is a farming systems research project called Agricultural Technology Improvement Project, a MIAC project with Kansas State University as the lead institution. ATIP personnel include two agronomists, one at Francistown and the other at Mahalapye, with whom excellent opportunities for exchange of information, observations, and experience are possible and with whom there is collaboration.

Ecogeographic Zones Benefited Most by Research

Southern Africa, especially where rainfall is marginal.

Objectives, Research Procedures, and Production/Utilization Constraints

Year 7 Objectives

Same as previously.

Reduce risk associated with sorghum and millet production in Botswana by identifying practices that will stabilize yields. Support existing sorghum and millet genetic improvement program. Identify areas of collaboration where INTSORMIL resources can be directed.

The objectives of the project are quite broad and allow a wide range of investigations; however, during the year investigations were initiated in tillage and land shaping for moisture conservation, some of this in collaboration with ATIP agronomists.

Sorghum/Millet Constraints

The climatic constraint to production is the low and highly variable rainfall - variable from year to year and with time of onset and ending and frequency within the growing season. Soil constraints include crusting, low infiltration rates, excessive runoff even with low rainfall, low fertility, low water holding capacity and low pH in some areas. Economic and social constraints are the traditional methods of crop production with minimum resources and the relative importance of cattle production which adsorbs capital because cattle production is less risky than crop production. It should be recognized that years in which rainfall is between 250 mm and 400 mm are frequent, five to seven years out of ten. Consequently crop failures will be frequent. Strategies to deal with drought must be sought.

Research procedures

Field experimental techniques are used to establish treatments and measure growth and yield. Laboratory techniques are used to determine nutrient uptake in the case of some experiments. Computer equipment and software have been provided for statistical analysis. Soil moisture is determined by use of a neutron probe.

Problems Regarding Achievement of Objectives

During the first two years of the project rainfall has been limited; consequently crop production has been at a very low level. Yields have been low and coefficients of variability have been large in experiments; nevertheless some general results have been obtained that are useful in refining experimental designs and technique and suggesting strategies.

One vehicle was purchased by INTSORMIL for the project and this was inadequate when there were three researchers there. Facilities for analyzing soil and plant samples are limited and long delays in obtaining results may occur.

Project Output

The variable results obtained during two years of drought are insufficient; however, some generalizations may be made from the data.

Applications of manure and/or crop residue (stover), which influence the intake of rainfall and availability of soil water, increased yields. Manure by itself was effective and in combination with stover was more effective than when used alone.

Under moisture stress conditions, studies of dates of planting and of plant populations gave erratic results.

Short season varieties of sorghum appeared to be advantageous.

A popular local variety, Segaolane, gave larger yields than other varieties and demonstrated drought tolerance. It may be an important variety in the breeding program for years to come.

With deficient soil moisture the effects of rotation were negligible but with improved growing conditions, i.e., higher average yields, the beneficial effects of rotation were measured. The same was true for response to nitrogen fertilizer.

During favorable years, those with median or better rainfall, there exist techniques which if applied would increase production; however for years of deficient rainfall new strategies and techniques are necessary. More effort should be directed to identifying the most productive portions of fields and those practices that conserve moisture - practices that modify the soil surface and the microtopography in order to control or direct runoff.

Networking Activities

- Workshops

A workshop in Bulawayo, Zimbabwe for Southern Africa is planned for April 1987. The workshop will deal with soil properties and soil management as they affect sorghum and millet production and breeding. The workshop will be cosponsored by INTSORMIL, ICRISAT, and SACCAR.

- Germplasm and Research Information Exchange

Dr. Carter has received germplasm from Dr. Stegmeier, Kansas Agricultural Experiment Station, Dr. D. Rosenow, Texas A&M, and ICRISAT. Research information is exchanged with ATIP personnel and in some cases of collaboration the information is jointly produced.

Travel

- Return from Botswana. April 1986. Mr. and Mrs. Wayne Youngquist. Completed their two year assignment and returned to Lincoln and the University of Nebraska. Their return was paid for by INTSORMIL.
- Home leave from Botswana. Part of July and August. Dr. Douglas Carter and family. Dr. Carter made a one day visit to Kansas State University. Home leave expenses were paid by ATIP.

- Chicago, Illinois. December 1-5, 1985. Dr. L.V. Withee. Attended the American Society of Agronomy annual meeting.
- Gaborone, Botswana and Bulawayo, Zimbabwe. June 1-14, 1986. Dr. L.V. Withee. To negotiate a new memorandum of understanding for a second position at Sebele and to consult with Dr. Martin Kyomo, Director of SACCAR, and Dr. Lee House, Director of ICRISAT station at Matopos, Zimbabwe, regarding a joint workshop sponsored by INTSORMIL, ICRISAT and SACCAR.

Publications and Presentations

Publications

Wayne Youngquist wrote an end-of-tour report; Dr. Carter has written one annual report and the draft of a second report. Dr. Withee has written one trip report and with Drs. Vanderlip, Kanemasu and Clegg another trip report.

Three papers will be presented at the national meeting of the American Society of Agronomy in December 1986, two by Wayne Youngquist and one by Max Clegg for Joan Youngquist. These will be reported in Year 8.

Presentations

Wayne Youngquist gave a seminar to the Department of Agronomy, Kansas State University, upon his return from Botswana.

Changes in Year 8

In June 1986 a new agreement was made with USAID Mission, Botswana, ATIP and the Department of Agricultural Research for a second INTSORMIL position. It is expected that the person in the second position will direct his/her research to areas of moisture conservation and factors influencing availability of water for crops such as soil crusting, infiltration rates, run off reduction, land shaping and water harvesting. Crop production in Botswana is on marginal rainfall and moisture conservation is an important consideration in plans to increase or stabilize grain production.

During Year 7 there was collaboration with ATIP in the investigation of effects of tillage and land shaping and this work will continue and be expanded.

Agronomy and Cropping Systems

Project NU-113

Max D. Clegg and Stephen Mason

University of Nebraska

Principal Investigators

Max D. Clegg, Associate Professor, University of Nebraska

Stephen Mason, Assistant Professor, University of Nebraska

Other Researchers

Douglas Carter, Agronomist, INTSORMIL, Botswana

J.D. Fastin, Professor, University of Nebraska

Lucas Gakale, Senior Research Officer, Botswana

J.W. Maranville, Professor, University of Nebraska

Mohamad S. Mostafa, Sorghum Breeding, Egypt

C. Reddy, Agronomist, NCRP/Niger

I. Soumana, Director General of INRAN, Niger

R. Vanderlip, Professor, Kansas State University

Summary

This is one of the few projects involving agronomy and cropping system research. The studies are usually long term. At present, legume-sorghum/millet rotations, plant density and residue studies are in progress. Our approach allows for both practical and basic agronomic studies and the training of scientists of developing countries in research which can be directly applied upon their return.

Lucas Gakale, Peter Odo, and Samy Mostafa completed their Ph.D's and have returned to their countries. Dr. Gakale's research was only partially completed in his country because of the drought. Complementary research was completed at Nebraska.

The influence of crop rotation and nitrogen source on sorghum and soybeans is being studied in Nebraska. A consistent yield advantage of crop rotation for both soybeans and sorghum has been obtained. Manure and liquid nitrogen applications resulted in similar yields, although manure applications increased pH, P, K and micronutrient content of the soil, and the microbial biomass. Soil sampling late in the spring allowed the detection of 50 kg/ha residual soil nitrogen after soybeans grown continuously or in rotation with sorghum.

Where rainfall was less than 300mm per season (Botswana), high grain yields were not necessarily related to high plant densities or to application of residue and manure. However, 98% of the higher fertility treatments resulted in more stover yield and more total biomass.

Institutions

Collaborating Host Countries: Botswana, Niger, Philippines, and Sudan.

U.S.: Kansas State University.

Linkages:

Botswana: Lucas Gakale has completed a Ph.D. and returned to Botswana. Dr. Gakale will be continuing research in the area of legume nitrogen for a following cereal crop. Problems are being evaluated for collaborative research. We will continue to deal with sorghum as a grain crop and possibly introduce forage sorghums in relation to legumes for animal use. The adaptability of short maturing varieties to be planted late in the growing season will be evaluated.

Niger: Dr. Idrissa Soumana, Director General of INRAN, visited the University of Nebraska May 10-1 . Discussions were held to explore areas of work and mechanisms to establish collaborative research. It was decided that a proposal should be prepared on the nitrogen contribution of legumes to millet and sorghum in cooperation with Dr. Chandra Reddy, Niger Cereal Research Project, and then submitted to INRAN. This proposal has been prepared and is being translated into French. Present plans are for Dr. Mason to visit Niger in March to finalize the collaborative project, so field research can start during the 1987 growing season.

Sudan: Mr. Mirghani Mohamed has enrolled in the University of Nebraska to pursue a M.S. degree in Agronomy. He has been assigned the millet-soybean rotation project which was established in Year 7. This study will determine the nitrogen contribution of soybeans to millet and its influence on water use efficiency.

Philippines: Mr. Alex Soriano is completing his research relating to plant height of sorghum intercropped with soybeans.

Kansas State University: Agronomic studies deal with factors influencing stand establishment.

Ecogeographic Zones Benefited Most by Research

West and Southern Africa

Objectives, Research Procedures, and Production/Utilization Constraints

Year 7 Objectives

Explore the soil fertility relationships in intercropping and rotations of sorghum or millets with grain legumes under temperate and tropical conditions.

Evaluate the effects of cereal and legume genotypes in contributing to the effectiveness of intercropping and rotation schemes, the efficient use of nitrogen in these schemes, and the alternatives available for meeting fertility needs on the farm.

Determine the genotype X cropping interactions in the cereal/legume systems, and the potential for genetic improvement for adaptation to these systems.

Develop new germplasm and cropping practices for testing in conditions of fertility deficit, where rotations and multiple cropping patterns are a part of currently used systems.

Determine the influence of environmental factors on nitrogen release and the mechanisms involved before, during and after cropping with cereal/legumes.

Integrate the component research on intercropping and nitrogen relations with ongoing farming systems research in several outreach projects in the national programs.

Sorghum/Millet Constraints

High variability of environmental and soil factors are major constraints for crop production. Long term research projects are needed to obtain results.

Lack of trained scientist on-site.

Distance and time available for principal investigators on-site, because of the long term nature of projects and lack of on-site scientists.

Research Procedures

Sorghum/soybean and millet/soybean rotations are in progress in Nebraska. Various microbial and physical measurements are being made on soils from these systems as well as growth and development and biochemical measurements on plants from the different treatments.

Sorghum/legume (cowpea and groundnut) rotations have been maintained the last two years by Wayne Youngquist, as an INTSORMIL Agronomist in

Botswana. Agronomic and soil data were being measured. Yield stability and residue studies were continued this year and are now being summarized (J. Youngquist).

Project NU-116 is involved with water use and sorghum/legume rotations in Sudan.

Project Output

Research Findings for Immediate Use

The influence of crop rotation and nitrogen source to grain sorghum and soybeans is being studied in an experiment established in Nebraska in 1980. INTSORMIL supported graduate student Walter Roder has determined grain yield, residue production, plant nutrient status and physical, chemical, and microbial properties of soil during the past two growing seasons. In addition, during the 1986 cropping season, rooting patterns of the crop are being determined. The first six-year results show a consistent yield advantage of crop rotation for both grain sorghum and soybeans. Manure and liquid nitrogen applications resulted in similar yields, although the manure applications increased pH, P, K and micronutrient contents of the soil, and the microbial biomass.

The equivalent of approximately 50 kg/ha N has been estimated as being supplied by legumes based on crop yield and plant uptake in Botswana and Nebraska but not on chemical analysis of the soil. In Nebraska (1985), estimates of residual soil N (as nitrate) of 50 kg/ha were obtained after soybeans grown continuously or in rotation with sorghum. Sampling was done late in the spring which allowed the measurement of mineralized N from the organic matter supplied by the soybeans. Thus, cereal/legume rotations can provide an amount of nitrogen at a level recommended for crop production in many developing countries (L. Gakale, Botswana).

Plant density by environment studies by Joan Youngquist in Botswana (1984-1986) where rainfall was less than 300mm per season showed that high grain yields were not necessarily related to high plant densities. Yields of 2.37-3.09 Mg/ha [Mega grams per hectare (Mg/ha) is equal to one metric ton per hectare (Mt/ha)] were obtained at Goodhope in 1984-85 with plant densities of 17,800 to 19,800 plants/ha. In 1985-86 yields were 0.38-0.78 Mg/ha with plant densities of 32,700-35,800 plants/ha. Application of residue and manure did not always result in higher grain yields. Of 28 environments, 58% yielded more because of the higher fertility. However,

98% of the higher fertility (residue/manure) applications yielded more stover resulting in more total biomass (grain + stover). This indicated a better use of the moisture received. In Botswana, the higher stover production could be used for animal production of which beef is a primary agricultural product.

Eighty-eight grain sorghum hybrids with five commercial hybrids as checks were tested by Samy Mostafa to evaluate their performance as a function of their male parent selection. The male parents were early maturing because of selection in cool short season locations or because of late planting in a sorghum growing area. Significant female, male and female x male interactions were found for 50% bloom, plant height, grain yield, lodging, seeds per square meter, 100-seed weight and test weight. The male groups had a major effect on the performance of the genotypes in all the different environments. Seed number and seed size were found to be the most important components of yield for all the genotypes over all the environments.

Research Progress for Future Use

Collaborative research on the nitrogen contribution of cowpeas to pearl millet in various intercropping systems used in Niger hopefully will be initiated. Initial evaluation of the nitrogen contribution during the cropping system will be possible in 1987, while residual nitrogen contributions can be measured in 1988.

Research on sorghum-soybean crop rotations in Nebraska will continue with the goal of better understanding the "rotation effect". Emphasis at present is being given to rooting patterns, physical properties and microbial activities in the soil. During 1987 it is hoped to evaluate the rooting patterns of the crops under continuous and rotational systems, and if possible relate this to yield, plant growth and development, and soil water extraction.

Early maturing varieties and hybrids are being evaluated for agronomic characteristics. These materials will then be used in row spacing and date of planting studies in Nebraska, Botswana, Sudan, and Egypt to determine their potential when water is limiting or when rain is delayed.

Residue management studies in Botswana are being summarized and the results will be available shortly. Also, Proso millet is being evaluated for possible use in management schemes.

Networking Activities

Professionalism and International Involvement, faculty development workshop sponsored by the International Programs Office, University of Nebraska, December 10, 1985.

Travel

- Kansas State University. October 13-15, 1985. M.D. Clegg. Attended the Farming Systems Research and Extension Management and Methodology Symposium.
- Chicago, Illinois. December 1-5, 1985. M.D. Clegg and S.C. Mason. Attended the American Society of Agronomy meetings.
- Botswana. January 6-17, 1986. M.D. Clegg and R.L. Vanderlip, KSU-106. To review INTSORMIL projects (part of which are for Joan Youngquist's thesis research), to develop a project for an agronomist position, and to review other collaborative research.

Publications and Presentations

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Gakale, L.P. 1986. Complementary effects of grain legumes to sorghum [Sorghum bicolor (L.) Moench] yields, nitrogen nutrition and residual soil mineral nitrogen accumulation in rotation systems. Ph.D. dissertation, University of Nebraska, Lincoln.

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Mostafa, M.S. 1986. Agronomic performance of grain sorghum hybrids [Sorghum bicolor (L.) Moench] under several environments as a function of their male parent selection. Ph.D. dissertation, University of Nebraska, Lincoln.

Odo, P.E., M.D. Clegg, and J.W. Maranville. 1985. Yield evaluation in sorghum-legume mixed cropping system. Agron. Absts. p. 102.

Saeed, M., C.A. Francis, and M.D. Clegg. 1986. Yield component analysis in grain sorghum. Crop Sci. 26:346-351.

Schepers, J.S., J.R. Santos, and M.D. Clegg. 1985. Effect of fertilizer N on potentially mineralizable N under a sorghum-soybean rotation. Agron. Absts. p. 183.

Changes in Year 8

The objectives were modified somewhat to conform with the procedures of the Agricultural Research Division, Institute of Agriculture and Natural Resources, University of Nebraska.

Mineral Element Uptake, Use, Efficiency, and Tolerance in Sorghum and Millet

Project NU-114

Ralph E. Clark (USDA/ARS) and Jerry W. Maranville
University of Nebraska

Principal Investigators

Dr. Ralph B. Clark, Research Plant Physiologist, USDA/ARS, University of Nebraska

Dr. Jerry W. Maranville, Professor of Agronomy, University of Nebraska

Other Researchers

Alagarswamy, G., Millet Physiologist, India (ICRISAT)
Andrews, D., Sorghum/Millet Breeder, USA (Nebraska)
Borgonovi, R., Sorghum Breeder, Brazil (deceased)
Duncan, R.R., Sorghum Breeder, USA (Georgia)
Flores, C., Sorghum Breeder, Colombia (INTSORMIL)
Furlani, A.M.C., Plant Physiologist, Brazil
Furlani, P.R., Plant Physiologist, Brazil
Gourley, L.M., Sorghum Breeder, USA (Mississippi)
Knudsen, D., Professor, USA (Nebraska)
Pitta, G., Soil Scientist, Brazil
Oliva, L., Agronomist, Philippines
Rosario, D.A. del, Professor, Philippines
Ross, W.M., Sorghum Breeder, USA (Nebraska) retired
Seetharama, N., Sorghum Physiologist, India (ICRISAT)
Solomon, D., Agronomist, Botswana

Summary

Soil fertility is a major constraint to satisfactory sorghum and pearl millet production world wide. Research by project NU-114 was directed primarily at understanding how these two crops react to conditions of water and mineral stress environments. Fertility trials in the Philippines showed that nitrogen level should be reduced during drier months to increase profitability. Moisture supply and fertility level interacted extensively.

Mycorrhizal research on the effects of different Glomus (VAM) species on growth and mineral element uptake indicated that sorghum plants infected with VAM had 13 to 14 times higher dry matter yields and 26 times as much P

uptake from a P deficient soil. There were several interactions with VAM species, soil pH, and temperature. The benefits can be attributed to the fungal hyphae effectively increasing the absorbtion surface areas.

It was found that silicon added to the growth medium partially alleviated Al and Mn toxicity in sorghum. This has important implications regarding acid soil problems which occur extensively in sorghum producing areas.

Studies in pearl millet directed at understanding mechanisms of N use efficiency showed that photosynthetic N efficiency (CO_2 fixed/unit N) alone accounted for little of genotype N use efficiency. Rather, it was related more to allocation and remobilization of N among plant parts to maintain high C:N ratios. This may be practical in selection for improved mineral use efficiency in sorghum and millet.

Institutions

Collaborating Host Country: IPB, Los Banos, Philippines; SMARC, USM, Kabacan, Philippines; CIAT, Cali, Colombia; EMBRAPA, Campinas and Sete Lagoas, Brazil; ICRISAT, Hyderabad, India.

U.S.: Department of Agronomy, University of Nebraska; Department of Agronomy, Mississippi State University and Department of Agronomy, Georgia (Experiment).

Linkages:

Working arrangements with CIAT, Colombia on chemical analyses and germplasm exchange.

Cooperative research in screening and understanding sorghum/millet growth in acid toxic (Al) and mineral deficient soils at CIAT.

Formally linked with PCARRD in the Philippines and work with SMARC/USM in the "on-farm" demonstration research trials for nitrogen and phosphorus fertility in sorghum.

Ecogeographic Zones Benefited Most by Research

Asian Subcontinent and South America.

Objectives, Research Procedures, and Production/Utilization Constraints

Objectives

Identify and evaluate sorghum/millet germplasm for capabilities to produce high quantity and quality grain and forage under mineral stress conditions, especially in countries collaborating with INTSORMIL programs.

Determine effects of environment, production practices, and management conditions in these countries on mineral element interactions as well as efficiency, tolerance, and use of mineral elements by sorghum/millet.

Determine physiological and chemical mechanisms for uptake, translocation, accumulation, distribution, balance and use of mineral elements by plants grown under mineral, moisture, and temperature stresses.

Train, orient, and assist INTSORMIL participating country scientists (including students) to identify and assess mineral stress problems, screen and evaluate genotypes for mineral stress efficiencies and tolerances, and perform appropriate procedures in conducting experiments pertinent to mineral stress problems.

Sorghum/Millet Constraints

One of the most marked production constraints in the LDC's is lack of adequate soil fertility. This constraint very often is greater than that of drought in the sense that it consistently occurs. Soil fertility also interacts with moisture supply so that without adequate fertility, crops like sorghum or millet cannot fully express their potentials to avoid or tolerate low moisture supply. Lack of major nutrients such as N and P cause plants to lose vigor, the degree dependent upon the magnitude of deficiency. Also, soil disorders that occur under acid conditions or Al toxicity inpair root development, causing disruption in normal mineral and water uptake. Project NU-114 is the only INTSORMIL project addressing these issues from a standpoint of physiological solutions to mineral nutrition problems. NU-114 links well with the programs NU-116 and NU-123 (moisture stress research), NU-113 (cropping systems research), NU-115 (sorghum and millet breeding), TAM-121 (sorghum breeding for productivity), and MSU-111 (sorghum and millet breeding for acid soils).

Research Procedures

Soil fertility research in the Philippines. This research is being conducted as "on-farm" trials. It serves both research and extension components and provides data for economic analysis. Major nutrients N and P are being applied to promising sorghum genotypes at different rates to determine optimum economic returns from fertilization. The procedures are standard for agronomic trials.

Mycorrhizae research. The objectives are to determine the effects of soil phosphorus and other environmental factors affecting sorghum plant infection with different species of VAM for plants grown in a greenhouse or growth chamber. Roots are examined under a microscope for VAM infection by a gridline intersect method. Changes in biomass production and mineral element uptake (especially P) are used to assess the influence of the VAM.

Manganese and aluminum toxicity research. Sorghum is grown in nutrient solutions at varied Al, Mn, and Si levels in a growth chamber to determine the effects of Si for alleviating Al and Mn toxicities. Visual symptoms, dry matter yields, and mineral element concentrations and contents are used to evaluate the effects of Si.

Acid soil research. Several hundred plant samples have been received from CIAT for mineral analyses at UNL (EDXRF) as a part of the ongoing acid soil research linked with INTSORMIL and NU-114. Sorghum germplasm from CIAT is being tested in controlled conditions for mineral use efficiency and tolerance to acid media. Field testing is conducted at CIAT.

Research on mechanisms of mineral use and efficiency. Genotypes identified as producing high biomass and grain per unit of mineral element (N or P) are contrasted with less efficient genotypes relative to root morphology and function and several biochemical/physiological processes. Similar genotype contrasts are being made under controlled conditions for acid soil response. Many of the genotypes are from LDC country programs or from INTSORMIL breeding programs both domestic and abroad.

Problems Regarding Achievement of Objectives

Budgetary constraints have necessitated reduction or elimination of direct INTSORMIL inputs into several countries. Present emphasis is to conduct research in Africa. NU-114 has no direct linkage with African programs (at present linkages are with South America and Asia), and it may take time to establish linkages in other prime site countries. NU-114 is generally the only mineral nutrition program and it could contribute to several INTSORMIL projects which have been established in the LDCs. More assistance from individual country coordinators is needed to help NU-114 establish important collaborative links before the project can effectively meet its objectives in Africa.

Project Output

Research Findings for Immediate Use

The "on-farm" fertility trials in the Philippines showed that of the eight levels tested, three were economically feasible. The 60-20-0 NPK kg/ha level was most profitable for the January-April season. However, for the drier March-June cycle, the lower 40-20-0 NPK kg/ha level showed better profitability and yield. It was obvious that the moisture supply and fertility level interacted extensively.

Research Progress for Future Use

Much of the research in Year 7 for NU-114 was directed toward understanding reasons sorghum or millet react to conditions of water and mineral stress environments. Several experiments tested potential solutions to overcome mineral stress problems. These were conducted primarily at the University of Nebraska - Lincoln under controlled conditions.

Effects of different Glomus (VAM) species on sorghum growth and mineral element uptake from soils with different P levels, pH values, and temperatures were determined. Sorghum plants infected with VAM in a low P soil had 14 times higher shoot, 13 times higher root dry matter yields, and 26 times higher shoot P contents than uninfected plants. Higher P uptake of VAM infected plants was attributed to larger absorption surface areas because of root proliferation and VAM hyphae external to the root. A VAM x sorghum genotype P-efficiency interaction was observed. Mycorrhizal infection had no effect on sorghum grown at a soil pH 4.13, but the sorghum growth and P uptake increased extensively when the soil pH was 4.49. A soil temperature x VAM fungi species interaction affected sorghum growth and P uptake. The beneficial effects of Glomus macrocarpum on sorghum growth and P uptake were considerably greater than for those of Glomus fasciculatum and Glomus deserticolum.

Silicon fertilization has been shown to alleviate Mn and Al toxicities in some plants. Growth chamber studies were conducted to better assess the role of Si in the alleviation of Mn and Al toxicity symptoms, and to determine the Si effects on dry matter yields and mineral element composition of sorghum grown in nutrient solutions with toxic levels of Mn and Al. Silicon alone at the lowest concentration tested did not alter plant growth, but dry matter production was reduced at higher

concentrations. Silicon added to the growth medium partially alleviated Al and Mn toxicity symptoms and dry matter yield reductions.

The mineral element analyses by (EDXRF) indicated that toxic Mn levels decreased P, K, Ca, Mg, Si, S, Fe, Cu, Zn, and Cl contents in shoots and roots, and increased Mn contents and concentrations in both plant parts. Addition of Si reduced Mn accumulations at moderate Mn levels, but did not cause any change at higher Mn levels. The reduction of Si uptake at high Mn levels in solution might have accounted for the incomplete Si effect. High Al concentrations in solution decreased Mg, K, Ca, S, Mn, Fe, Cu, Zn, Cl, and Si contents. Addition of high Si levels reduced the accumulation of Al, P, and Ca in roots. Silicon was unable to completely overcome severe Mn and Al toxic effects in sorghum.

Search for physiological mechanisms allowing differences in N efficiency has been ongoing with sorghum and millet. Pearl millet genotypes identified in the field for extremes in N efficiency at ICRISAT were studied in controlled environments at UNL with the objective of separating efficiency contributed by photosynthesis from that contributed by N uptake, partitioning, and remobilization. Although one of the N-inefficient genotypes required 10 to 15% more leaf N to achieve similar photosynthetic rates as the other genotypes, photosynthetic N efficiency alone accounted for little of the genotype N efficiency. Nitrogen efficiency was related more to the N allocated among plant parts with the most efficient genotypes maintaining high C:N ratios, regardless of the level of N nutrition. These results are pertinent to understanding the physiological functions that might be practical for the selection of improved mineral use efficiency in sorghum and millet.

Networking Activities

- Workshops

Dr. Clark attended "Factors affecting the rhizosphere and their effects on mineral uptake by plants", January, 1986. Braunschweig, W. Germany.

- Research Investigator Exchanges

Dr. Maranville traveled to the Philippines during May and early June, 1986 to collaborate on agronomic and fertility trials with sorghum. Dr. Clark traveled throughout West Germany discussing mineral nutrition problems with scientists (May to July, 1986).

- Germplasm Exchange

Several sorghum genotypes were received from CIAT for testing for N use efficiency and acid soil tolerance.

Travel

- Chicago, Illinois. October 2-3, 1985. Jerry Maranville. INTSORMIL TC meeting.
- Kansas City, Missouri. January 13-15 and March 18-29, 1986. Jerry Maranville. INTSORMIL TC meetings.
- Philippines. May 12-21, 1986. Jerry Maranville. To collaborate with Philippine scientists on agronomic trials. Primary persons concerned were Drs. Lydia Oliva (SMARC), D.A. del Rosario (IPB), and Artemio Salazar (IPB sorghum breeder).

Publications and Presentations

Publications

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Changes in Year 8

Establish new linkages in Africa (possibly in Niger, Mali, Botswana, and/or Zambia).

Water and Temperature Effects on Sorghum and Millet as Related to Grain Production and Breeding

Project NU-116E

Jerry D. Fastin

University of Nebraska

Principal Investigators

Dr. Saeed Farah, Agricultural Research Center Water Scientist, Sudan

Dr. Chandra Reddy, INRAN Production Scientist, Niger

Dr. Idrissa Soumana, INRAN Director General (Physiologist), Niger

Mr. Ouendeba Botorou, INRAN Millet Breeder, Niger

Dr. Jerry D. Fastin, Physiologist, University of Nebraska

Dr. Charles Y. Sullivan, Physiologist, University of Nebraska

Other Researchers

Dr. N. Seetharama, Dr. John Peacock, Physiologists, ICRISAT

Mr. Louis Mazhani, Breeder, Botswana

Mr. David Andrews, Breeder; Drs. Jerry Maranville, Max Clegg, Steve Mason, Production-Physiology, University of Nebraska

Drs. Mendoza, Gonzalez, Hernandez, Physiology-Breeders, Mexico

Commercial breeders from Funks, DeKalb-Pfizer, NC+ and Pioneer

Summary

Use of our stress screening technique for screening early generation population selections has essentially stopped because of budget reductions. Testing is continuing. Some of our initial selections dating to 1979 have been stabilized and a few B lines have been sterilized. The first hybrids using these new stress tolerant females will be tested in 1987. Most of them will fit overseas rather than the U.S. scene. Some R lines dating from the initial selections are more appropriate for U.S. agriculture and will be released. A larger portion of the second round of selections (1982-84) are more appropriate for U.S. farmers as well as developing country farmers. A modest number of these are being evaluated in approximately 5000 UNL test plots. They will be tested more extensively in 1987 and sterilization of dwarf stress resistant B lines will continue. They appear very promising. Some of both the R and B lines seem to have good stalk strength.

A shortened version of a new tan plant - food grain population is being developed for developing country and U.S. application along with a taller version for developing country areas only.

Seasonal water use efficiency results as influenced by tillage system and rotations for high elevation, cool areas will be reviewed in 1987. The same is true for carbon balance studies and instantaneous water use efficiency measurements. Likewise, anatomical work detailing the sites in the floret where stress damage causes a reduction in seed number will be reviewed. Work has been initiated attempting to learn about the mechanisms leading to the damage and those conferring resistance. Most questions relating to improved stress resistance and efficient use of water (and nutrients) are complex. These require long term experimental efforts to assure progress which is currently encouraging.

Institutions

Collaborating Host Countries: Sudan - Agricultural Research Center, Niger - INRAN, India - ICRISAT, and Mexico - Chapingo University.

U.S.: University of Nebraska, Purdue University, University of Georgia and Texas A&M University.

Linkages:

Sudan. Research is in progress on 1) evaluating row spacing/plant density effects on farm field yields, 2) evaluating nitrogen use efficiency, 3) limited screening for water use and stress resistance and 4) testing stress resistant sorghums. Items 1-3 are cooperative with Dr. Saeed Farah and 4 was cooperative with Dr. T. Berhe. Hopefully, future experiments can be conducted with Dr. Farah on water use efficiency (WUE) in legume-sorghum rotations.

Niger. Cooperative experiments have been proposed and tentatively agreed on with Drs. Chandra Reddy, Steve Mason and Jerry Maranville covering millet/legume intercropping, residue management to maximize yield and minimize wind and water erosion, stand establishment and seedling screening, and fertility x water interactions for yield and WUE. An instantaneous WUE - carbon balance - seasonal water use study has been tentatively planned with Drs. Soumana and Reddy to determine seasonal and instantaneous WUE in millet and cowpea sole cropped and intercropped. We suspect the legume uses more water than millet which could influence how the legume can be most

effectively handled in an intercropping system to maximize both millet and cowpea yields. A preliminary water stress millet screening program has been planned with Mr. O Botorou to see if our sorghum screening technique will work. Sorghum experiments have yet to be planned.

Mexico. Currently a science information exchange only on water and temperature stresses.

Germplasm exchange with ICRISAT, Niger, Philippines, Senegal, Sudan, Dominican Republic, Botswana, Zimbabwe.

Ecogeographic Zones Benefited Most by Research

Zones where work is most applicable in West Africa (Niger and Mali) and Sudan for high temperature and water stress; Kenya and Niger for low temperature and water stress.

Objectives, Research Procedures, and Production/Utilization Constraints

Year 7 Project Objectives

Continue stress screening and development of breeder stress screening techniques.

Measure water use, seasonal and instantaneous WUE, and canopy carbon balance in relation to yield.

Evaluate energy costs associated with root activity.

Attempt seedling stress screening.

Changes in Objectives from Previous Year

Application of our field stress screening technique to breeder materials is reduced because of budget constraints.

Cool temperature seedling stress research will be reduced drastically and some high temperature research initiated.

Sorghum/Millet Constraints

The constraints addressed are combined deleterious yield effects of one or more of the following: low temperature and/or high temperature stresses, water stress, erosion and nutrient stresses.

Research Procedures

Field stress screening involves imposing water stress from panicle initiation to bloom and subsequently determining stability in grain yield, seeds m^{-2} and seed weight compared to irrigated plots.

Seasonal water use is measured with soil neutron probes. Instantaneous water use and WUE is measured with a LICOR 6000.

Energy costs (respiration is measured with CO_2 and O_2 analyzers).

Seedling stress screening is done with early field planting and growth rooms.

Problems Regarding Achievement of Objectives

These are primarily budgetary. Budget reductions (over 40% in three years) are seriously hampering U.S. stress screening applicable to both developing country and U.S. farmers. This research cannot be completely carried out in developing countries. Results are encouraging and commercial companies have picked up some of the reduction but this research cannot continue much longer without added support. Cool temperature research pertinent to off season production in Niger, Senegal and Mali and to normal season production in Kenya, Uganda, and highlands of Mexico and other Central and South American countries is being reduced substantially.

Cooperative experiments that ICRISAT/INTSORMIL initiated with Drs. Seetharama and Peacock on stalk rot problems will have to be delayed since travel funds are not available. We can loan ICRISAT equipment for off season research but they need help in learning to run it. The research problem outlined was similar to a high priority "Research Needs" statement issued collectively by some 40 scientists at the 1983 Bellagio Stalk Rot Conference. PSTC funds may be available at a later date to resume this cooperative effort.

Project Output

Research Findings for Immediate Use

Stress screening techniques

Eighty-one sorghum genotypes were tested for drought resistance in western Kansas by imposing water stress from panicle initiation to anthesis (GS_2) and comparing grain yields and yield components to irrigated plots. An attempt was also made to develop a physiologically sound yet practical screening technique to complement grain yield comparisons under stress. The complementary measurement made was the canopy-air temperature differential which was correlated with grain yield. Canopy-air temperature was chosen because it is assumed that at least some of the major drought resistance mechanisms in the plant must contribute to maintaining enough turgidity to

usually sustain some transpiration even under severe stress. Since transpiration has a cooling effect, this would be reflected in reducing the temperature of the canopy compared to air temperature. Possible stress resistance mechanisms contributing to maintaining turgidity and transpiration could be extensive root exploration and osmoregulation to maintain water flow in various plant parts as soil water is exhausted. Certainly these are not all of the stress resistance mechanisms operating but may be major ones.

Genotypes used included 30 hybrids and 11 lines from our program, 25 entries from Texas programs, and five checks. Ten hybrids from Nebraska ranked higher than the best commercial check under irrigation. Of the 27 genotypes that outranked the highest yielding check under stress, 25 were from Nebraska and two were from Texas (82C495 and Tx623 x Tx430).

Canopy temperature measurements were made during late GS_2 stage when seed number potential was being set. Canopy-air temperature was moderately correlated with grain yield ($r = -0.56$) under stress. However, when the effect due to genotypes was isolated and factored out, the grain yield showed a rather strong association with canopy-air temperature ($r = -0.81$). This shows a strong relationship between grain yield and canopy-air temperature *per se*. About 66% of the variability in yield was associated with variability in canopy-air temperature. The moderate overall association ($r = -0.56$) was, therefore, also reflecting the differential response of genotypes to drought. This suggests that genetic variability existed for this differential response to stress, as measured by canopy-air temperature, which could be exploited to increase the efficiency of selection in drought resistance breeding programs. There was a strong genotype x irrigation interaction for canopy-air temperature. Consequently, there was almost no rank correlation between the canopy-air temperatures in irrigated and stressed treatments ($r = 0.08$). Therefore, canopy-air temperature under irrigated conditions appears to be of little value. However, the rank correlation between wet and dry for grain yield was 0.71 indicating that canopy-air temperature measurements under stress may complement grain yield data to sharpen field selection for stress resistance mechanisms. This measurement may be particularly useful in a breeding program since it is made prior to anthesis so that desired crosses and the measurement can still be made the same season.

The field stress technique mentioned earlier can be used immediately. The canopy-air temperature measurement appears encouraging but is less well tested.

Germplasm release

Some population germplasm derived using field stress screening technique will be released in 1987.

Cool temperature screening

Depending on the world location, cool temperature problems arise at planting (germination and emergence), development from emergence to anthesis, and during grain fill. This research relates to development problems from emergence to anthesis common to the high elevation tropics where night temperatures in the 8-12 C range inhibit development and the crop can get caught by frost before maturing (Mexico, Uganda, Kenya, etc.). Breeding germplasm to hasten development is, therefore, critical. Such germplasm was introduced by Dr. Elmer Johnson some 20 years ago at Chapingo, Mexico (2240 m elevation where 8 C nights are common) in the form of early milos. Thirty-eight day milo (M 38) was crossed with late high elevation Uganda lines (Nyando and others) capable of setting seed under 8 C nights to get earlier lines which would set seed (M 38 will not set seed at Chapingo). The approach was successful but F_2 segregates tended to reflect either parent more than one might suspect (suggesting high linkages) and yielded a less diversified array of progeny than hoped for. Therefore, a decision was made to better quantify plant responses to temperature to see if such an approach is worth continuing. Nyando x M 38, 2 temperate sorghums and one corn hybrid were subjected to 22/35 and 8/27 night/day temperatures and tested for growing degree days (GDD) required to reach panicle initiation and anthesis. M 38 and corn actually required fewer GDD to get to both PI (tassel differentiation for corn) and anthesis under cool conditions (8/27C) compared to warm (22/35). Nyando and Nyando x M 38 derivatives required generally from 10 to 30% more GDD under cool conditions to reach those stages. By contrast the temperate sorghums required about 70% more GDD to reach PI and anthesis. M 38 has not been used much recently in breeding for early cool tolerant genotypes. Probably it should be considered again despite its apparent linkages which reduce the expected amount of segregation in the F_2.

Research Progress for Future Use

Release of cool tolerant R lines. Some are stress resistant.

Release of stress tolerant A and B line pairs.

Use of instantaneous WUE measurements on legumes and millets to sharpen intercropping approaches.

Networking Activities

International Plant Physiology Congress Planning Committee (Delhi) for application of physiology to crop improvement.

- Research Investigator Exchanges

ICRISAT India (Seetharama, Peacock, several plant breeders); Niger INRAN scientists (Soumana, Reddy, Botorou); ICRISAT, Niger (Fussell, Sivakumar, Serafini).

- Germplasm Exchanges

See Linkages. Stress resistant germplasm performed well in heavy soils in Sudan (T. Berhe tests) and did poorly in acid soils of Niger.

- Research Equipment and other Support

Repaired neutron probes and did CO_2 exchange training for Sudanese. Loaned CO_2 exchange equipment and helped train ICRISAT scientists. Demonstrated CO_2 exchange and WUE equipment for Nigeriens - 1987 experiments are being set up.

Travel

International

- Hyderabad, India. January. ICRISAT stalk rot-gas exchange consulting for two weeks.
- Australia. February. Presented stress paper at Australian Sorghum Conference - mostly other funds.
- Niger. July 14-27, 1986. Presented INRAN-ICRISAT Niger seminar and plan for 1987 INRAN experiments.
- Shenyang, China. August 18-September 4, 1986. Presentation at the Liaoning Academy Sorghum Conference - no INTSORMIL funds.

Domestic

- Sublette, Kansas. June, August, September and October. Stress testing.

- Chicago, Illinois. December. Verma presented ASA paper on stress.

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Changes in Year 8

Continue germplasm screening at a reduced level because of budget reductions.

Produce hybrids using new A lines developed.

Do more WUE - production research.

Initiate stress induced protein research.

Water and Temperature Effects on Sorghum and Millet as Related to Grain Production and Breeding

Project NU-116S

C.Y. Sullivan

Principal Investigators

Dr. C.Y. Sullivan, University of Nebraska

Dr. J.D. Eastin, University of Nebraska

Other Researchers

Moussa Traore, Mali

Summary

Progress continued toward identification of characteristics and mechanisms of drought and high temperature resistance of sorghums and pearl millet. Additional selections were made for deep rooting potential by growing and water stressing plants in hydroponic tubes. Generally the sorghums had heavier root growth at 50 to 70 cm. depth compared to the pearl millets which had more root growth at 20 to 40 cm. depth. The millets also had greater numbers of main roots which appeared to function as more efficient at extracting water from the shallower soil depths.

Drought resistant Malian sorghums used less water per unit time than U.S. developed sorghums, and the water use efficiency (dry matter/unit water used) of the Malian sorghums was higher.

Abscisic acid (ABA) appears to be a major biochemical substance in drought resistance. When ABA was exogenously applied to seeds or leaves, and the plants subsequently drought stressed, germination increased, root growth was stimulated, desiccation tolerance markedly increased, and yield increased - mainly due to increased seed numbers. The effect of ABA was greatest on drought susceptible sorghums and generally less on the more drought resistant Malian genotypes. Plans and equipment purchases were made for development of a more extensive collaborative plant physiology program in Mali.

Institutions

Collaborating Host Country: Republic of Mali, Ministry of Agriculture, Institute of Rural Economy.

U.S.: University of Nebraska and USDA-Agricultural Research Service, Lincoln, Nebraska.

Linkage:

Moussa Traore completed his Ph.D. degree in December 1985 and returned to Mali where he was appointed coordinator of the Malian INTSORMIL program. Prior to leaving Nebraska, plans were made for development of a cooperative plant physiology research program on several aspects of heat and drought resistance of sorghums and pearl millet in the sub-Saharan environment.

Ecogeographic Zones Benefited Most by Research

West Africa will benefit most directly, but also East Africa and all zones where drought stress is a problem should benefit from the basic physiological information on behavior of sorghums and pearl millet in stressful environments.

Objectives, Research Procedures, and Constraints

Objectives

Characterize the effects of temperature extremes and water deficits on developmental processes which limit the grain size and grain number components of yield. Use results to develop cropping systems and agronomic practices which maximize and/or stabilize yields.

Define physiological characteristics which are affected most by heat and drought stress, and identify both tolerance and avoidance mechanisms which may improve stress resistance.

Evaluate temperature and water effects on metabolic or production efficiency with emphasis on essential physiological processes as they relate to plant development and components of grain yield.

Develop and implement practical techniques of screening for drought and heat stress resistance.

Changes in Objectives from Previous Year

The objectives remained essentially the same. However, with a trained plant physiologist (Traore) on site in the collaborating country for half of the year, planning and initiation of research in the host country was realized.

Constraints

A major constraint has been the lack of trained personnel who could manage and conduct cooperative physiological research in the host country. Also, the lack of necessary physiological equipment in the host country has

been a constraint, and finally, the absence of rapid communications means between U.S. and host country personnel often slows progress. With the completion of the Ph.D. program by M. Traore and his return to Mali and purchase of several pieces of equipment from NU-116S funds for physiological research, the first two constraints are being corrected. Dr. Yohe is assisting with investigations into the feasibility of an electronic mail and data communications hook-up with IER-Bamako, through the IBM-PC system purchased by NU-116S, which should help communications tremendously.

Research Procedures

Research continued toward gaining a better basic understanding of inherent stress resistance mechanisms of both native sub-Saharan and U.S. sorghum and millet selections. The results are useful in both developing countries and U.S. crop improvement programs. Plants were grown in greenhouses, growth chambers, under rain shelters, and in the field. Controlled environments were necessary for some experiments because of the naturally variable climate which often would not permit stress at the desired time of development. Hydroponic cultures were used for study of root systems growth and development, water use and water use efficiency. Selection for deep rooting potential with the ability to utilize deep, available water continued. Experiments also continued on the involvement of abscisic acid (ABA) in drought resistance. Seeds were soaked in dilute ABA solutions and dried prior to planting or leaves were sprayed with the solutions. An assessment was made of the effects of ABA on germination, seedling root growth, desiccation tolerance, photosynthate partitioning, and grain yield.

Problems Regarding Achievement of Objectives

Budget reductions have caused reduced field research which is more expensive with high labor requirements. Priority given to equipment needs in the host country has delayed additional graduate research assistance.

Project Output

Research Findings

Selection for deep rooting potential continued in hydroponic tubes. When drought stressed, third generation selections had an increased rooting at 100-120 cm. depth of 82% greater than the check Martin and 68% greater than the check RS 610 (on a dry wt. basis).

In comparative studies of sorghum and pearl millet, the pearl millet had a greater number of adventitious roots than the sorghums, but the potential rooting depth of the millets was less than the sorghums when drought stressed. The millets transpired less water that the sorghums when stressed, but used the same amount when well watered. Generally, water use efficiency was negatively correlated with total water use.

Presoaking seed in dilute abscisic acid (ABA) solutions before planting resulted in increased rooting depth of RS 671 by 15% compared to untreated controls, whereas, in the drought resistant Malian sorghum SC 90, rooting depth was slightly decreased by the ABA treatment.

When seed harvested from plants grown from ABA treated seed was germinated, there was a 10% increase in germination over untreated controls of RS 671, while SC 90 was unaffected by the treatment and SC 283 was decreased 13% in germination by the ABA treatment.

Stressed sorghum plants sprayed with ABA solutions during early panicle development had higher yields, compared to controls, due to increased seed numbers. Plants did not respond to ABA applied at mid-panicle development. Gibberellic acid and kinetin sprays counteracted the effects of ABA.

Seedling desiccation tolerance was dramatically increased by presoaking seeds in ABA solutions.

Desiccation tolerance tests and osmotic potentials, both determined on leaf discs, agreed well with visual seedling desiccation tolerance ratings.

The rooting intensity (dry wts.) of millets was greater at 20-40 cm. depth, compared to sorghums which had more roots at 50-70 cm. depth. The millets appeared to be more efficient at utilizing shallower water.

Drought resistant sorghums from Mali had lower water use and higher water use efficiency than U.S. sorghums tested.

Research Progress

Identification of rooting patterns and water use characteristics of the more productive Malian genotypes when drought stressed, together with an implemented screening program for natural ABA levels, and antagonistic growth substances, is expected to give results useful in both management decisions and genotype selection.

Networking Activities

March 25 to 29, 1985 Sullivan represented INTSORMIL at the annual meetings of the Commision Technique Specialisee des Productions Vivrieres et Oleagineuses under the auspices of the National Committee for Agronomic Research, Ministry of Agriculture, Bamako, Republic of Mali. Discussions included INTSORMIL/Mali collaborative research. M. Traore presented the INTSORMIL/Mali plant physiology program proposed for FY 87.

- Research Investigator Exchanges

M. Traore, J. Scheuring, and C. Sullivan planned and outlined a cooperative physiology program and the needs to conduct the program. A proposal was written and submitted to USAID-Science and Technology Cooperation Program in order to supplement the INTSORMIL physiology program in Mali. The three year program was approved and will be of great assistance to our program.

- Assistance to Host Country Researchers

Assistance was given to M. Konate, Mali Sorghum Breeder, in locating a laboratory where treatment of seeds would be performed for possible mutations. It was desired to change the dark testa to a light, more desirable one without loss of other desirable characteristics of the plants.

The following equipment items were purchased from NU-116S funds (Sullivan) to aid in establishment of a plant physiology program in Mali: An IBM-PC system with expanded memory, color monitor, two disk drives, Epson FX-85 printer, Constant voltage transformer, power surge controller, and all needed interfaces, extra diskettes and case of printer paper, Data Base Manager and MSTAT computer software programs, A Mettler electronic balance, B & L stereozoom microscope, Cassette Tape Recorder and leads, and a Cassette Tape Reader for use with the IBM-PC, a Kodak Ektagraphic slide projector with case and 12 extra bulbs, Pressure chamber for water potentials, and a Thermocouple Psychrometer with Digital Meter, Infrared Thermometer, 2 cases of Petri dishes, some chemicals and books.

Travel

- Bamako, Mali. March 25-30, 1986. C. Sullivan. To attend Commision Technique meetings, consult on collaborative INTSORMIL research, and obtain a draft copy of the Third Amendment to the Research Convention between the Institute of Rural Economy and INTSORMIL.

Publications and Presentations

Publications

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Blum, A. and C.Y. Sullivan. 1986. The comparative drought resistance of land races of sorghum and millet from dry and humid regions. Annals of Botany 57:835-846.

Presentations

Traore, M. 1986. Programme d'Agrophysiologie (the Mali plant physiology program). Annual Meetings of the National Committee for Agronomic Research, March 28, Bamako, Mali.

Changes in Year 8

Project NU-116 with J.D. Eastin and C.Y. Sullivan as principal investigators has been split with each heading separate projects. The new project with C.Y. Sullivan as P.I. is titled "Mechanisms of Drought and High Temperature Resistance in Sorghum and Pearl Millet", Project NU-123. Project objectives are similar to those previously incorporated in NU-116, with emphasis on defining mechanisms of stress resistance, root growth and development, and the collaborative Mali program, with Moussa Traore as principal investigator. Selections from the Collection of Sorghums and Millets of Mali will be grown at three sites in Mali with different rainfall levels including some introduced selections. The effects of ABA will be further investigated, particularly with reference to seedling establishment and desiccation tolerance. Quantitative analyses for endogenous levels of ABA in sorghums and millets under stress will be conducted.

Plant Breeding

Executive Summary

Several pearl millet production constraints that are amenable to breeding efforts and that pose problems in many areas of the dry tropics are being addressed. Population, F_2 families and inbred lines possessing early maturity, drought tolerance, and high yield potential have been sent to several countries. Nurseries sent to Kenya, Botswana, and Zimbabwe in the fall of 1986 contain F_2 families that will segregate for lodging resistance and improved stand establishment characteristics.

A larger proportion of project KSU-101 material placed in nurseries for use in lesser developed countries are populations and segregating F_2 families which provide an opportunity to select for disease resistance and adaptation before these characteristics become fixed in advanced inbred generations. Experience in northern Senegal in 1984 and 1985 indicates these early maturing materials have a good potential for use in areas of low rainfall, and short duration of the rainy season. (KSU-101)

The main thrust of project NU-115 was to further develop sorghum breeding populations from crosses between widely adapted stocks recently developed in the tropics and leading U.S. lines of notable value, e.g., parents of outstanding hybrids. This will form the basis for material for collaboration, and selection in the U.S. in future years.

In some cases tropical stocks used were outstanding local varieties, such as Segaolane, from Botswana. The first series of 65 crosses, made in 1984, have been carried through to the selection of F_3 families. F_2 populations and some F_3 families were sent to Botswana for exploitation by the collaborating breeder. A further 170 hand crosses were made during the year. (NU-115)

Activities in project NU-118 in Year 7 were (1) advancing material from crosses between tropically adapted pearl millet breeding lines and early maturing U.S. stocks, (2) exploiting existing program material by selection per se and in test crosses, the main criteria being yield, seed set, and lodging resistance, and (3) testing a modified type of mass selection, as an appropriate breeding method to recommend to pearl millet breeders with limited resources to allocate to recurrent selection. The method is being used to improve a dwarf population for performance. (NU-118)

Extensive evaluation of sorghum lines and hybrids from project TAM-121 was completed in Honduras, Niger, Sudan, Paraguay, Mexico and other sites. In addition, breeding materials derived from elite x identified sources of resistance to stresses and sources of yield or quality were distributed, selected and used in collaborating countries.

A synthetic with proven high yield, excellent food quality, vitreous endosperm and agronomically desirable characteristics was released and has been widely distributed. Two inbred lines possessing desirable food and agronomic traits were also released for distribution. Several superior lines and hybrids were identified in trials.

A total of 2,859 germplasm items were distributed as well as 71 evaluation trials. These materials were deployed to strengthen host country breeding efforts and to determine ranges of adaptation and yield expression.

Glossy lines may have internal mechanisms which allow them to maintain growth under soil water stress. Glossy does not appear to be associated with major differences in root type. (TAM-121)

A dual purpose sorghum variety called SureMo was released in Honduras in 1985. It possesses high grain yield potential, white, food-type grain with excellent quality for tortillas and atole and grain which has resistance to grain mold, weathering, and to the maize weevil. It has good resistance to downy mildew and several leaf diseases.

The new "stay-green" male sterile line, A35, performed extremely well in hybrid combination in the U.S. and lesser developed countries, and has been distributed for immediate testing. Hybrids with this line possess excellent post-flowering drought tolerance and are very resistant to post-flowering lodging and charcoal rot.

New drought tolerant B lines with excellent pre- and post-flowering drought tolerance have been identified, sterilized, and tested in experimental hybrids. Seed of the A and B lines and experimental hybrids has been sent to Sudan and other countries for testing. (TAM-122)

We have found that sorghum genotypes differ in translocation of nitrogen from roots to the shoots. This coupled with a previous determination that sorghums differ in their ability to remove nitrogen from the soil may explain why: (1) greenhouse solution culture techniques are inadequate for use in screening for nitrogen use efficiency, (2) sorghum genotypes differ in grain production per unit of nitrogen supply, and (3)

sorghum genotypes differ in their response to fertilizer nitrogen. We have suggested a modified definition for nitrogen use efficiency based upon these results.

An investigation of yield components has revealed that grain production at high nitrogen levels is strongly related to nitrogen in the grain and at low nitrogen level to total biomass at black layer. (TAM-123)

Plant breeding work in Kenya has been directed initially at determining what kinds of germplasm fit the various ecological zones within the country, and with developing the capability of the Ministry to conduct meaningful sorghum and millet research. The last year has been successful in both regards.

Trials in five locations have provided very good data on both the basic ecozones in Kenya, and what types of germplasm will fit those areas. In general we have found that three different zones exist, and that three different types of sorghum will be needed to fit these areas. Those types grown in the wetter areas of the west are most different in both adaptation and quality factors, and will require the most work. (TAM-132)

Progress has been made in identifying sorghum lines with increased levels of drought resistance, some of which are currently being incorporated into breeding programs both in Niger and Sudan, and in the U.S. Sorghum germplasm with superior grain mold resistance has also been identified and the physic-chemical basis of this resistance characterized.

Collaborative research on Striga resistance mechanism in sorghum has led to the identification of a chemical exudate associated with sorghum root hairs with capacity for the stimulation of Striga germination and haustorial initiation. The behavior of root growth and patterns of root distribution in some Striga resistant sorghum varieties has been associated with a possible avoidance mechanism of host-parasite interaction. (PRF-107)

The primary research objective in project MSU-104 is to evaluate sorghum and pearl millet germplasm for tolerance to infertile, acid soils of the tropics.

Four aluminum-tolerant seed parents (A-lines) and their maintainer (B-lines) have been released as germplasm by the Mississippi Agricultural and Forestry Experiment Station from breeding research conducted in this

project. All U.S. public and ICRISAT seed parent lines of hybrids evaluated have been found to be susceptible to aluminum toxicity. The ultimate goal of the breeding effort is development of aluminum-tolerant hybrids.

Our studies have shown that root mass of aluminum-tolerant hybrids growing in acid soil is nearly always superior to that of the most aluminum-tolerant parent. The aluminum-tolerant seed parents released will provide sources of tester females and aluminum-tolerant genes for the production of commercial aluminum-tolerant hybrids. (MSU-104)

The need to develop crops with tolerance and adaptability to soil acidity has increased recently in many South and Central American countries. However, methods and approaches to accomplish this objective are either not available to scientists in the region or not well defined because of lack of research in the area.

The development of a reliable field screening technique to screen for Al tolerance has resulted in the selection of several hundred Al-tolerant sorghum lines. About 50 promising lines have been identified with potential grain yield of 3 tons per hectare under acid soil conditions with minimum fertilization practices. National programs of Colombia, Peru, Venezuela, Panama and Honduras are extensively testing the best Al-tolerant selections from project MSU-111. Private institutions and other national programs in the region are using our Al-tolerant germplasm as a breeding base in their sorghum breeding programs.

Pearl millet has excellent adaptation to acid soils even under low phosphorus conditions. Several pearl millet varieties, synthetics, and populations have potential grain yields of 2 to 3 tons per hectare under conditions where Al-tolerant sorghums could hardly produce grain. Pearl millet tolerates a much higher level of Al toxicity than sorghum. (MSU-111)

The major focus of project PRF-103A is to develop high yielding sorghum varieties with acceptable food quality and good nutritional value for use in developing countries. A great deal of progress has been made in two areas.

We now understand many of the factors necessary for improving the nutritional value of sorghum through local village processing. Sorghum flour is less digestible than most cereal flours unless it is processed using local village procedures that have evolved over hundreds of years. We now understand the scientific reasons why processing is important. This

knowledge will help us modify and improve the traditional processing methods and develop improved processing methods for use in other countries where sorghum is used as a feed or food grain.

New knowledge has been gained about utilization of sorghum populations in breeding programs. Traits such as heritability of grain hardness and heritability of seedling cold tolerance are important for both the U.S. and developing countries. Selection methods for improving these important traits have been developed. (PRF-103A)

Pearl Millet Breeding

Project KSU-101

W.D. Stegmeier

Kansas State University

Principal Investigators

W.D. Stegmeier, Millet Breeder, Fort Hays Branch Experiment Station

Babrak Khaleeq, Millet Breeder, Fort Hays Branch Experiment Station

T.L. Harvey, Entomologist, Fort Hays Branch Experiment Station

Other Researchers

J.R. Witcombe, Millet Breeder, ICRISAT, Patancheru, India

K.N. Rai, Millet Breeder, ICRISAT, Patancheru, India

S.C. Gupta, ICRISAT, Zimbabwe

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F.L. M'Ragwa, Millet Breeder, Katumani Station, Kenya

R. Mills, Entomologist, Department of Entomology, Kansas State University

L. Mazhani, Sorghum/Millet Breeder, Botswana

A.T. N'Doye, Millet Breeder, CNRA, Senegal

J. Mann, Breeder, Texas A&M University

D. Meckenstock, Sorghum Breeder, Texas A&M University

Summary

Several pearl millet production constraints that are amenable to breeding efforts and that pose problems in many areas of the dry tropics are being addressed. Population, F_2 families and inbred lines possessing early maturity, drought tolerance, and high yield potential have been sent to several countries. Nurseries being sent to Kenya, Botswana, and Zimbabwe in the fall of 1986 contain F_2 families that will segregate for lodging resistance and improved stand establishment characteristics. A larger

proportion of KSU-101 material placed in nurseries for LDC use are populations and segregating F_2 families which provide an opportunity to select for disease resistance and adaptation before these characteristics become fixed in advanced inbred generations. Experience in northern Senegal in 1984 and 1985 indicates these early maturing materials have a good potential for use in areas of low rainfall, and short duration of the rainy season.

Several lines selected for increased length of mesocotyl and coleoptile structures show improved stand establishment capability. Lodging resistant inbred lines have produced high yielding hybrid combinations that remained standing four months after physiological maturity. Five occurrences of air temperature below 13.9°C in 1985 allowed selection within populations, lines, and segregating families for low temperature tolerant materials showing good seed set.

Work with a pollen collecting device attached to a miniature vacuum cleaner indicates it will be a useful tool in breeding. One of these units is being evaluated as a spore collector by Dr. King, ICRISAT pathologist.

Institutions

Collaborating Host Countries: India, Sudan, Zimbabwe, via ICRISAT, Botswana, and Senegal.

U.S.: University of Nebraska, Mississippi State University, and Texas A&M University.

Linkages:

KSU-101 has informal linkages with India, Senegal, and Zimbabwe and the SADCC countries through ICRISAT millet breeders in those countries.

India - collaboration and germplasm exchanges continue with the ICRISAT millet breeding project under the direction of Dr. J.R. Witcombe and his staff. KSU-101 lines have been released to Indian breeding programs by ICRISAT.

Senegal - Dr. S.C. Gupta, ICRISAT, had evaluated Kansas materials at two locations in Senegal and since his transfer to Zimbabwe he has been evaluating the best lines from the Senegal program plus additional Kansas materials in Zimbabwe. Following his departure from Senegal, KSU-101 and NU-118 millet populations are being tested in Senegal at Louga and Bambey by Madame A.T. N'Ndoye. CNRA.

Sudan - Millet lines, populations and hybrids of KSU-101 and ICRISAT parental lines are evaluated by T. Berhe, KSU-101-1 and R.P. Jain, millet breeder, ICRISAT. A satisfactory arrangement has not been achieved to continue the Sudan work with the impending departure of Dr. Jain and the termination of Dr. Berhe's project.

Kenya and Botswana - Discussions with F.L. M'Ragwa, millet breeder, Kenya, and L. Mazhani, sorghum breeder, Botswana, will result in exchanges of germplasm and evaluation of KSU-101 materials. Mr. M'Ragwa has visited Kansas and selected materials that he thought would be useful in Kenya. KSU-101 materials are used by Dr. Carter, KSU-107, in stand establishment and photoperiod response studies.

Cooperative work with U.S. institutions includes the exchange of germplasm and lines with NU-114 and testing of materials from each project in both Kansas and Nebraska. An array of materials is being increased for screening under acid soil conditions by MSU-111 and to include in nurseries for Latin America and Paraguay by TAM-131 and TAM-121. Evaluation and screening of KSU-101 materials is conducted by KSU-104 and KSU-106.

Objectives, Research Procedures, and Production/Utilization Constraints

Year 7 Project Objectives

To develop widely adapted, early maturing pearl millet populations, lines, and hybrids with a) improved drought tolerance, seed size and density, seedling stand establishment, lodging resistance, and grain yield; b) insect, disease, bird and *Striga* resistance; and c) good food quality characteristics.

To select and evaluate materials developed in this program under a wide range of environments and farming systems in the developing countries.

Changes in Objectives from Previous Year

Additional emphasis has been placed on screening and stabilizing lines for increased length of seedling mesocotyl and coleoptile structures, and determining the effect of this increased length on stand establishment capability. Machinery is being modified and developed to allow precise depth of planting adjustments and to refine soil crusting procedures to enhance screening of lines for improved stand establishment capability. Work has started to determine if light transmittance through seed (opaque to translucent) is associated with seed and seedling characteristics of

economic value and if the procedure can be effectively used as a breeding tool to select within populations of seeds.

Millet Constraints

Numerous constraints to successful pearl millet production exist throughout the dry tropics. Each constraint varies in importance and/or severity in different ecogeographic zones and in the ease and degree of success by which plant breeding efforts influence it. Drought and heat stress are the primary constraints in much of the dry tropics since millet is grown in areas receiving limited amounts and erratic patterns of precipitation. Drought and heat stress are involved with poor seedling establishment when associated with factors such as reduced speed and vigor of germination and seedling growth, shallow planting depths, and rapid surface soil drying that interrupts germination. Seed and seedling characteristics are also involved in the capability of a seedling to penetrate and emerge through crusted soils. The need for adequate levels of resistance or tolerance to several insects, diseases such as downy mildew, ergot, smut, rust and diseases affecting stalk and grain quality is a continuing constraint as many of these organisms readily mutate to forms that overcome plant resistance. Bird depredation is common and the incidence of Striga is becoming more severe as fields remain in cultivation for a longer time between periods of fallow. Several constraints and problems are associated with the use of the crop, ranging from stalk characteristics needed for construction and forage to the apparent food quality of the grain in regard to nutritional value, ease of processing, and consumer acceptability.

Research Procedure

Standard breeding procedures for open-pollinated plants are used. The pedigree breeding method is used for the early development of nearly all materials entering the program, the advancement of elite lines, and lines extracted from populations undergoing recurrent selection. Population improvement is carried forward using the following selection methods: mass selection, gridded mass selection, and the S_1 and S_2 progeny performance testing methods. Screening and evaluation is conducted at several Kansas, Nebraska, and LDC locations.

Problems Regarding Achievement of Objectives

Adverse weather conditions have continued to impose serious constraints on the types of materials and seed quantity and quality available for use in LDC's. Freezing temperatures have occurred in September in each of the years from 1983 to 1985 in Kansas. This has caused a shift to an earlier than desired maturity range in much of our breeding materials and populations and greatly reduced seed germination. This, in turn, has eliminated most of our materials from consideration for inclusion in nurseries to be sent to overseas cooperators. Medium-late and late-maturing materials have been advanced in the greenhouse at the cost of reduced selection pressure on several desirable characteristics.

Project Output

Research Findings for Immediate Use

The two pairs of pearl millet cytoplasmic male-sterile and maintainer lines that had been released to Indian breeders have been incorporated into many of the Indian breeding programs and are being crossed to a wide array of Indian materials. The large seed, drought tolerance, and early maturity of these lines are filling a need in developing materials having improved stand establishment characteristics and maturities that fit into cropping sequences used in many areas of India. An array of materials will be sent to Dr. S.C. Gupta in Zimbabwe as F_2 segregating families because it is not possible to screen these materials for resistance to diseases such as downy mildew in the United States. Grain yields of some of these materials as F_1 hybrids exceeded 4000 kg/ha in 1985.

Performance testing of Kansas, Nebraska, and Senegalese populations at Louga in northern Senegal indicates early maturing U.S. populations will yield more grain than the Senegalese materials under conditions of low rainfall (216 mm) and limited downy mildew disease pressure. However, at Bambey the results were reversed due to high levels of infection by downy mildew. Four KSU-101 populations will undergo selection for adaptation and disease resistance at these locations in 1986.

Screening of more than 500 lines for length of mesocotyl, coleoptile, total seedling, and radical lengths has identified several that have excellent stand establishment capability in both field and greenhouse tests. Some of these lines are being included in nurseries sent to LDC's.

Performance tests of experimental F_1 hybrids continue to demonstrate that the grain yield potential of pearl millet is equal to the yield of sorghum grown at this location. Three sorghum and four pearl millet hybrids with similar maturities produced average grain yields of 4800 kg/ha, however, this group of millets lodged 73% compared to sorghum lodging of 1%.

Research Progress for Future Use

Although progress has been made over the last 10 years in selecting lines and populations for resistance to lodging, we had been unable to develop millet materials possessing 90 to 100 percent seed set and high grain yield coupled with lodging resistance approaching the resistance found in improved sorghum materials. Lodging in millet can be due to several factors: stalk diseases, poor root penetration in clay or hard pan soils, reduced secondary and brace root development, thin stalk rind, an abscission layer in the nodes, and disintegration of the stalk pith in the internodal stalk areas when the plant is drought-stressed at physiological maturity. Progress has been made in reducing or eliminating lodging due to charcoal rot, poor root development characteristics, and breakage at the node, but until 1984 we had been unable to identify lines resisting disintegration of the pith or lines with sufficient rind thickness.

Disintegration of the pith appears to be associated with drought stress during the later seed-fill period and lodging occurs at or shortly after the seeds reach physiological maturity. At this stage there appears to be a shriveling of the pith tissues above the node, the tissues pull away from the stalk rind, and a cavity is formed. Since most millets have a relatively thin rind, the stalk will buckle or break at the point where the cavity appears. Cavitation within the stem can occur within any internode but most frequently occurs in the peduncle, just above the peduncle node, allowing the head to break over.

Work is continuing to transfer lodging resistance into populations and cytoplasmic male-sterile maintainer lines. Crosses have been made and additional crosses are planned to transfer lodging resistance and long seedling mesocotyl into an array of lines that are large-seeded, drought tolerant, and have good grain yield potential. F_2 families of these materials are being included in nurseries sent to cooperating LDC breeders. In 1985, six of 53 F_1 hybrids with lodging resistance and 100% seed set had lodging of less than 20% four months after physiological maturity.

Ambient air temperatures of 11.1 to 13.9°C (the threshold temperature at which disruption of meiosis occurs resulting in sterility) occurred five times between August 10 and 27, 1985. A large proportion of the materials in the breeding nurseries had plants and late tillers undergoing meiosis during that time and good differentials within and between materials were observed. Selection for low temperature tolerance appeared to be particularly effective within three populations in S_1 recurrent selection programs and in the breeding nursery containing advanced inbred lines.

More than 500 inbred lines and selections from populations have been germinated and measured for length of radical, mesocotyl and coleoptile structures, and total seedling length. Variation in length ranged from 98 to 250, 38 to 172, 14 to 33, and 52 to 205 mm, respectively. Field and greenhouse plantings at depths to 100 mm identified several long mesocotyl lines possessing the capacity to emerge to good stands through a dense overburden of soil. Total seedling emergence and stand establishment were significantly influenced by increased length of mesocotyl and total seedling length. Future work will determine if these lines have improved emergence under conditions of soil crusting. Attempts to induce soil crusting in 1985 and 1986 to screen for ability of seedlings to penetrate a crust failed because of frequent rains.

Collection of pollen using a battery-powered miniature vacuum cleaner equipped with air controls and a collection chamber appears to be feasible. Several variations in chamber size and configuration of baffles within the chamber are being evaluated. Pollen characteristics of pearl millet lines vary and a considerable difference is seen in the amount of agitation and abrasion that pollen from different lines will survive before cell walls rupture. Therefore, the length of time the machine runs and the number of heads from which pollen is removed will have an influence on the degree and amount of cell wall damage that occurs. One of these units was given to Dr. Stan King, ICRISAT pathologist, to be evaluated as a spore collector.

Networking Activities

- Workshops

April 7-11, 1986. Stegmeier participated in the International Pearl Millet Workshop at ICRISAT, Patancheru, India.

- Research Investigator Exchanges

July 19-22, 1985. Peter Stuart, pearl millet breeder, Pacific Seeds, Ltd. Toowoomba, Australia. Review millet breeding program and arranged exchange of materials.

August 21-22, 1985. Dr. S.C. Gupta, pearl millet breeder, ICRISAT, Zimbabwe and SADCC countries. Reviewed millet breeding program, selected materials to be sent to Zimbabwe, and discussed millet breeding problems.

August 21-22, 1985. Prof. D.J. Andrews, pearl millet breeder, University of Nebraska. Reviewed the millet program and selected materials to incorporate into the Nebraska program.

September 23-26, 1985. Mr. Lawrence M'Ragwa, pearl millet breeder, Kenya. Purpose: studied and observed Fort Hays Branch Experiment Station millet breeding program and methods and selected Kansas materials to incorporate into the Kenya national breeding program.

September 24-25, 1985. Mr. Moriba Kanote, sorghum/millet breeder and Research Coordinator of the Institute of Rural Economy, Mali. Purpose: observed Fort Hays Branch Experiment Station millet program and materials. Requests will be made at a later date for breeding materials.

October 2, 1985. Mr. Yakim Ntau, Governor of Northern Province, Cameroon. Toured pearl millet and sorghum research programs.

- Germplasm Exchange

During the pearl millet workshop at Patancheru, India, arrangements were made to send millet materials to the countries and workers listed below.

Senegal, Mde A.T. N'Doye, CNRA, four populations to be grown at Louga and Bambey.

Zimbabwe, Dr. S.C. Gupta, ICRISAT, lines, F_2 families, and populations.

India, Drs. Witcombe and K.N. Rai, ICRISAT, A - B lines and two populations.

Botswana, Mr. L. Mazhani, inbred lines, F_2 families, varieties and populations.

Kenya, Mr. F.L. M'Ragwa, inbred lines, varieties, and populations.

Travel

International

- Patancheru, India. April 7-13, 1986. W.D. Stegmeier. Participated in the International Pearl Millet Workshop and reviewed the ICRISAT pearl millet field trials, breeding nurseries, and Kansas materials growing at Patancheru.

Domestic

- University of Nebraska and the Agricultural Research and Development Center at Mead, Nebraska. September 4-5, 1985. W.D. Stegmeier. Observed the UN/INTSORMIL pearl millet breeding program and evaluated the KSU-101 materials being grown there.
- Miami, Florida. December 7-12, 1985. T.L. Harvey. Attended the Entomological Society of America Annual Convention.
- Manhattan, Kansas. March 17-20, 1986. T.L. Harvey. Participated in the Plant Resistance to Insects Workshop.
- Molokai Island, Hawaii (return trip from India). April 14-19, 1986. W.D. Stegmeier. Evaluate and harvest pearl millet winter nurseries.

Publications and Presentations

Andrews, D.J., and W.D. Stegmeier. 1985. Pearl Millet Breeding in INTSORMIL. A paper presented at the Sorghum and Millet Workshop, INRAN/INTSORMIL/NCRF, Niamey, Niger, October 14-17, 1985.

Stegmeier, W.D., B. Khalegg, and T.L. Harvey. 1986. The Potential of Pearl Millet as a Crop in the Central Great Plains of the United States. Abstract of a paper presented at the International Pearl Millet Workshop, Patancheru, Andhra Pradesh, India, April 7-11, 1986.

Changes in Year 8

Minor changes will be made in some areas of the program where beneficial progress appears imminent. Increased emphasis will be placed on selection for long mesocotyl lines with improved stand establishment capability, determining the effects of seed opaque/translucent characters on seed quality, seedling characteristics, and seed storage insect activity and the selection of lodging resistant materials.

Sorghum Host-Plant Resistance and Genotype Evaluation

Project MSU-104

Lynn M. Gourley

Mississippi State University

Principal Investigators

Host Country

South American Ecogeographic Zone

Dr. Catalino I. Flores, Plant Breeder and MSU-111 PI, Cali, Colombia

Dr. Hernan Gaviria, Sorghum Coordinator, ICA, Nataima, Colombia

Dr. Robert Schaffert, Sorghum Breeder, EMBRAPA, Sete Lagoas, Brazil

Dr. Gilson Pitta, Soil Scientist, EMBRAPA, Sete Lagoas, Brazil

Mr. Hector Mena, Director of Cereal Research, CENIAP FONAIAP Maracay, Venezuela

Dr. Dale Bardy, North Carolina State University Mission/INIPA and TROPSOILS, Lima, Peru

Southern Africa Ecogeographic Zone

Dr. Bhola Nath Verma, Sorghum Breeder, SIDA-Mt. Makulu Exp. Sta., Zambia

Dr. Lee House, ICRISAT/SADCC Project Leader, Matopos, Zimbabwe

United States

Dr. Lynn M. Gourley, Sorghum Breeder and MSU-104 PI, Mississippi State University

Dr. Henry Pitre, Entomologist and MSU-105 PI, Mississippi State University

Drs. Ralph Clark and Jerry Maranville, Plant Nutritionists and NU-114 PI's, University of Nebraska

Mr. David Andrews, Sorghum and Pearl Millet Breeder and NU-115 PI, University of Nebraska

Dr. John Axtell, Sorghum Breeder and PRF-103 PI, Purdue University

Mr. W.M. Stegmeier, Pearl Millet Breeder and KSU-101 PI, Kansas State University

Other Researchers

Other Host Country and U.S. Researchers

Dr. Eric Owen, Soil Scientist, ICA La Libertad

Dr. Antonio Pinchinat, Research Specialist, IICA, Lima

Dr. Pedro Sanchez, Soil Scientist and TROPSOILS Coordinator, North Carolina State University

Ms. S. Ann Rogers, MSU-104 Graduate Research Assistant

Mr. Guillermo Munoz, MSU-104 Graduate Research Assistant

Mr. Muhammad J. Yakub, MSU-104 Graduate Research Assistant

Mr. Cesar Ruiz, MSU-104 Graduate Research Assistant

Mrs. Libby Montgomery, MSU-104 Technician and Graduate Research Assistant

Mrs. Mahmuda Haroon, MSU-104 Graduate Research Assistant

Summary

The primary objective of the research in this project is to evaluate sorghum and pearl millet germplasm for tolerance to infertile, acid soils of the tropics. Most of these soils reduce the availability of or tie-up phosphorus fertilizer, have toxic levels of aluminum and some, toxic levels of manganese in the soil solution.

Four aluminum-tolerant seed parents (A-lines) and their maintainer (B-lines) have been released as germplasm by the Mississippi Agricultural and Forestry Experiment Station from breeding research conducted in this project. All U.S. public and ICRISAT seed parent lines of hybrids evaluated have been found to be susceptible to aluminum toxicity. The ultimate goal of the breeding effort is the development of aluminum-tolerant hybrids. Our studies have shown that root mass of aluminum-tolerant hybrids growing in acid soil is nearly always superior to that of the most aluminum-tolerant parent. The aluminum-tolerant seed parents released will provide sources of tester females and aluminum-tolerant genes for the production of commercial aluminum-tolerant hybrids. Improved aluminum-tolerant seed and pollen parent lines are also being developed.

Future research efforts will include the evaluation of aluminum-tolerant lines for phosphorus efficiency in laboratory studies at Mississippi State University and in the field in Colombia. These same lines will be evaluated for tolerance to manganese toxicity in the acid soils of Zambia.

Institutions

Collaborating Host Country: ICA Colombia, INIPA Peru, EMBRAPA Brazil, FONAIAP Venezuela, SIDA Zambia and ICRISAT/SADCC Zimbabwe.

U.S.: Mississippi State University MSU-104 and MSU-111, University of Nebraska NU-114 and NU-115, Purdue University PRF-103, Kansas State University KSU-101 and North Carolina State University TROPSOILS.

Linkages:

Collaborative research linkages have been established with the National Programs ICA-Colombia, EMBRAPA-Brazil, FONAIAP-Venezuela and INIPA-Peru in the major acid soils areas in South America. The linkage with ICA-Colombia, prime site country for South America, is still a strong informal cooperative research effort, but a formal ICA-INTSORMIL MOA will be sought next year. The linkage with EMBRAPA is a strong formal collaborative research effort and other linkages with two Brazilian universities have also been signed. The linkages with FONAIAP and INIPA are informal and in the nature of germplasm exchanges and in collaborating in Al-tolerant regional yield trials.

The collaborative linkage with SIDA at the Mt. Makulu Experiment Station, Zambia is informal but strong mainly via the ICRISAT/SADCC agreement with INTSORMIL.

Cooperation with TROPSOILS, CIAT, and soil scientists working in Africa extends INTSORMIL's limited resources and experience in acid soils areas to many countries of the world.

Ecogeographic Zones Most Benefited by Research

Since sorghum and pearl millet are generally planted on marginal land in most countries, those countries with large land areas of acid soils will benefit most from this research. The primary zone of benefit is South America and the secondary zone of benefit is Southern Africa. Many other countries in all six ecogeographic zones will benefit from the Al-tolerant genotypes developed in this project.

Objectives, Research Procedures, and Production/Utilization Constraints

Year 7 Project Objectives

Screen and evaluate sorghum and pearl millet germplasm in the laboratory and field for sources of tolerance to low phosphorus and aluminum and manganese toxicities.

Incorporate new sources of tolerance to aluminum and manganese toxicities into elite U.S. and LDC sorghum germplasm.

Develop armyworm tolerant sorghum genotypes for entomology evaluation (MSU-105).

Train selected U.S. and LDC personnel.

Changes in Objectives from Previous Year

The major change in objectives is the 20% commitment of screening and evaluation of pearl millet for acid soil tolerance. The second change is the screening of Al-tolerant sorghums for phosphorus uptake efficiency. A third change from Year 6 objectives is the 10% commitment to the Southern Africa Ecogeographic Zone. Through the SADCC-ICRISAT Cooperative Program with SIDA in Zambia, Al-tolerant sorghum and pearl millet germplasm are evaluated for tolerance to toxic levels of manganese.

Sorghum/Millet Constraints

One of the major constraints to sorghum production in South America and Africa is aluminum and manganese toxic acid soils. Al-tolerant germplasm will increase sorghum and pearl millet production in acid soil areas by requiring fewer soil amendment inputs.

Manganese toxicity appears to be more of an academic problem in Latin America, but one which occupies a very large land area in Zambia and possibly other countries in Africa.

Armyworms are another major constraint to sorghum production throughout the world, but especially in the Southeastern U.S., Central and South America.

Many of the sorghum diseases found in Mississippi are also common throughout many tropical LDC countries. Every breeding project must maintain disease resistance as a breeding goal, or after accomplishing the primary breeding objective the material can be rendered worthless by a destructive plant pathogen.

Research Procedure

In a field screening technique using a high level of soluble aluminum saturating the soil exchangeable cation exchange capacity (60-65%), susceptible sorghum genotypes die and the remaining genotypes range from severely stunted to nearly normal healthy plants. Additional screening of the available world sorghum and pearl millet germplasm is essential to determine the extent of the genetic variability for Al tolerance. Soil analysis at planting and harvest are necessary to insure that no element falls below its critical level. Soil acidity of the screening plots established at Quilichao, Colombia is about pH 4.5.

Genetic control of several factors, such as sensitivity to aluminum, extensive root system, phosphorus efficiency and drought tolerance all appear to influence the variability observed as aluminum tolerance in the field. Inheritance studies of some of these factors are underway. B-line and R-line diallel crosses among susceptible and Al-tolerant lines are being evaluated. Four Al-tolerant exotic B-lines have been sterilized and are being used as tester females with Al-tolerant R-lines to evaluate different sources of Al tolerance.

After determination of restorer reaction, the best Al-tolerant sources are being incorporated into either B-line or R-line random-mating populations containing the ms 1 genetic male sterility gene. These populations are cycled on soils of 60-65% Al saturation in preparation for release.

The most Al-tolerant cultivars, with a potential to be used directly in grain production, are being evaluated in regional yield trials throughout Latin America. These and other Al tolerant genotypes are being evaluated in Mali, Niger, Zambia and Zimbabwe.

Phosphorus efficiency of Al-tolerant sorghums is being evaluated in the laboratory at Mississippi State University and in the field in Colombia. Pearl millet has been shown to tolerate a lower soil level of phosphorus and to withstand a higher level of Al saturation with additional phosphorus than Al-tolerant sorghums.

Winter and seed increase nurseries are conducted at CIAT-Palmira in cooperation with Flores (MSU-111) and Axtell (PRF-103).

Project Output

Research Findings for Immediate Use

Eleven pairs of A (male sterile) and B (maintainer) lines of sorghum with the brown-midrib characteristics were released as germplasm. These pairs of lines represent sources of three non-allelic brown-midrib genes with lignin reduction of as much as 40%.

Four pairs of Al-tolerant exotic A and B-lines have been approved for release as germplasm. These lines can be used as Al-tolerant tester female and as germplasm sources of Al tolerance to improve commercial seed parents. One constraint to Al-tolerant hybrids is the lack of photoperiod insensitive seed parents.

Research Findings for Future Use

National and other INTSORMIL programs in Latin America, Asia, West and Southern Africa are evaluating Al-tolerant genotypes from this project. The National Program of Colombia, ICA, plans to release the first Al-tolerant variety in that country in the near future. Other releases are expected.

Two Al tolerant random-mating sorghum populations, B-line and R-line, are being characterized for release in Year 8. These temperate adapted bulks will be made available to commercial and public sorghum breeders throughout the world.

Sources of Al-tolerant sorghum genotypes with tolerance to toxic levels of manganese will be available in the future. Information concerning the genetic variability for phosphorus efficiency of these Al-tolerant varieties will also soon be available.

Networking Activities

- Workshops

PI was invited to present a paper "Breeding Al-Tolerant Sorghums for Low-Input Systems" at an American Society of Agronomy Symposium on Sustainable Low Input Farming Systems.

- Research Investigator Exchanges

Two Brazilian scientists from EMBRAPA, Carlos Casela and Renato Borgonovi, were brought to the U.S. for meetings and short-term training.

- Germplasm and Research Information Exchange

Australia:	Dr. Peter Stuart, Pacific Seeds
Cameroon:	Mr. Allan Brown, Save the Children
England:	Ms. Judith Appleton, Save the Children
West Germany:	Mr. Thomas Bergmann, Nutrition and Food Scientist
Honduras:	Ms. Therese Lebeut, CARE
Kenya:	Mr. M.D.W. Kerre, PfP
Peru:	Dr. Alexander Grobman, Gentec
Philippines:	Mr. Francisco P. Cayco, Technobank
Puerto Rico:	Dr. Antonio Sotomayor, USDA
U.S.A.:	Mrs. Sharon Tobing, ADRA
	Mr. Ken Crane, ADRA
	Ms. Maryel Barry, Nutrition Planning
	Dr. Martin L. Price, ECHO
	Dr. Pedro Sanchez, TROPSOILS
	Mr. James Osborne, NC+ Hybrids
	Dr. Richard Atkins, Iowa State University
	Dr. James Allison, Taylor-Evans Seed Co.
	Dr. Gene Dalton, Pioneer Hi-Bred Inter., Inc.
	Dr. Ralph Finkner, New Mexico State University
	Dr. John Axtell, Purdue University
	Dr. Darrell Rosenow, Texas A&M University
	Mr. Terry Hill, Triumph Seed Co., Inc.
	Dr. B.R. McGehee, Asgrow Seed Co.
	Dr. Fred Miller, Texas A&M University
	Dr. Norman Wilson, Funk Seeds International
	Dr. D.W. Gorbet, University of Florida
	Dr. Charles Berry, Cargill
	Dr. Dale Weibel, Oklahoma State University
	Mr. Tom Prest, Northrup King & Co.
	Dr. Robert Voigt, University of Arizona
Zimbabwe:	Dr. A.C. Mosha, SADCC Food Security
	Project Teams

- Assistance to Host Country Researchers

  Chemicals have been provided to EMBRAPA-Brazil.

Travel

- Colombia, Brazil. July 9-10, 1985. L.M. Gourley. Zone Planning
- Kansas City, Missouri. August 15, 1985. L.M. Gourley. EZC Meeting.
- Chicago, Illinois. October 2-3, 1985. L.M. Gourley. TC Meeting.
- Starkville, Mississippi. October 16, 1985. Ruiz. M.S. Training.
- Chicago, Illinois. December 1-6, 1985. Gourley/Rogers. ASA Meetings.
- Kansas City, Missouri. January 14-15, 1986. Gourley. TC and EZC Meetings.
- Kansas City, Missouri. March 2-3, 1986. Gourley. Board Meeting.
- Colombia. March 6-18, 1986. Gourley. Winter Nursery.
- Kansas City, Missouri. March 18-20, 1986. Gourley. TC and EZC Meetings.
- Colombia. April 23-May 9, 1986. Gourley. Winter Nursery.
- Kansas City, Missouri. May 13, 1986. Gourley. EZC Meeting.

Publications and Presentations

Publications

Gourley, L.M. 1985. A comparative perspective on sorghum and millet-based farming systems--Andean region. p. 107-114. In C.L. Paul and B.R. DeWalt (Eds.) Sorghum Farming Systems in Latin America. CIMMYT (International Center for Maize and Wheat Improvement), El Batan, Mexico. (Span.)

Trevathan, L.E., J.A. Cuarezma-Teran and L.M. Gourley. 1985. Relationship of Plant Nematodes and Edaphic Factors in Colombian Grain Sorghum Production. Nematropica 15:145-153.

Gourley, L.M., S.A. Rogers, C. Fisher, G. Stevens, N.W. Buehring, M.A. Blaine, C.H. Hovermale, T.G. Sanders, N.C. Edwards and H. Bloodworth. 1986. 1985 Grain Sorghum Performance Trials. MAFES Info. Bul. 80.

Galvez, L., R.B. Clark, L.M. Gourley, J.W. Maranville and W.M. Ross. 1985. Manganese and aluminum toxicity interactions with silicon in sorghum. In Proc. 14th Grain Sorghum Res. Util. Conf., Lubbock, Texas.

Rogers, S.A., and L.M. Gourley. 1985. Genetic Components of Aluminum Tolerance in Sorghum. Agronomy Abstracts 77:68.

Gourley, L.M. 1985. The Brown-Midrib Genes in Sorghum. Agronomy Abstracts 77:54.

Gourley, L.M. and C.I. Flores. 1985. Breeding Al-tolerant sorghum for low-input systems. Agronomy Abstracts 77:35.

CIAT. 1985. The sorghum alternative for acid soils. CIAT International 4:7-10.

Anonymous. 1986. New-found sorghum varieties benefit Latin America and Africa. L.I.F.E. Newsletter 19(1):45.

Anonymous. 1986. Seeking aluminum-tolerant sorghums. MAFES Research Highlights 47:7.

Presentations

Gourley, L.M. and C.I. Flores. 1985. Breeding Al-tolerant sorghum for low-input systems. Presented at the National ASA Meetings, Chicago, IL.

Gourley, L.M. 1985. The brown-midrib genes in sorghum. Presented at the National ASA Meetings, Chicago, IL.

Changes in Year 8

Two changes in research plans have been made for Project MSU-104. A portion of the acid soil research will evaluate Al tolerance with different levels of phosphorus using a laboratory technique. Phosphorus "efficient" genotypes will then be tested in the field under low levels of phosphorus fertility in Colombia. The second change will involve a shift in time spent doing collaborative research between the South American and Southern Africa Zones. This project has been requested by ICRISAT to increase research efforts on acid soil constraints in Zambia. Aluminum-tolerant sorghum genotypes will be screened for tolerance to manganese toxicity in the high rainfall area of Zambia.

Adaptation of Sorghum and Pearl Millet to Highly Acid Tropical Soils

Project MSU-111

Catalino I. Flores

Mississippi State University

Host Country Researchers

South American Ecogeographic Zone

Dr. Hernan Gaviria E., National Sorghum Research Coordinator, ICA-Nataima, Colombia

Dr. Eric Owen, Soil Scientist, ICA-La Libertad, Colombia

Mr. Cesar Ruiz (on study leave at MSU), Breeder, ICA-La Libertad, Colombia

Ms. Cecira de Martinez, Head, Corn and Sorghum Section, ICA-La Libertad, Colombia

Mr. Hector Hernandez, Technical Director for Lowland Environments, FENALCE-Bogota, Colombia

Dr. Gabriel Alves Maciel, Breeder, EUP-IPA, Serra Talhada, Brazil

Mr. Renato Borgonovi (deceased), National Sorghum Research Coordinator, EMBRAPA-Sete Lagoas, Brazil

Dr. Robert Schaffert, Breeder, EMBRAPA-Sete Lagoas, Brazil

Dr. Gilson Pitta, Soil Scientist, EMBRAPA-Sete Lagoas, Brazil

Mr. Paulo Motta Ribas, Breeder, AGROCERES-Capinopolis, Brazil

Mr. Hector Mena, Director of Cereal Research, CENIAP-FONAIAP-Maracay, Venezuela

Dr. Mauricio Riccelli M., Professor of Genetics, Central University of Venezuela and Head of Breeding Program, Protinal, C.A., Valencia, Venezuela

Mr. Hugo Acosta V., Agricultural Director, Management of Agricultural Development, Maracaibo, Venezuela

Mr. Pedro Carrasco, Leader of INIPA's Selva Program, INIPA, Yurimaguas, Peru

Mr. Carlos Egoavil, Soil Scientist, INIPA-Mayobamba, Peru

Mr. Federico Scheuch, Breeder and Co-leader National Maize Program, INIPA-Tarrapoto, Peru

Dr. Antonio Pinchinat, Research Specialist, IICA-Lima, Peru

Dr. Dale Bandy, NCS University Mission/INIPA and TROPSOILS, Peru

Central America and Caribbean Ecogeographic Zone

Mr. Justiniano Diaz M., Breeder, Natural Resources Station, La Esperanza, Intibuca, Honduras

Mr. Benjamin Name, Soil Scientist and Leader of Acid Soil Program, IDIAP-Santiago de Veraguas, Panama

Mr. Alfonso Alvarado, Head of Corn and Sorghum Section, IDIAP-Panama

South African Ecogeographic Zone

Dr. Bhola Nath Verma, Breeder, SIDA, Zambia

Dr. L.R. House, Project Leader, ICRISAT/SADCC, Zimbabwe

U.S. Researchers

Dr. Catalino I. Flores, Plant Breeder and MSU-111 PI (CIAT, Colombia), Mississippi State University (Principal Investigator)

Dr. Lynn M. Gourley, Plant Breeder and MSU-104 PI, Mississippi State University

Dr. Henry Pitre, Entomologist and MSU-105 PI, Mississippi State University

Drs. Ralph B. Clark and Jerry Maranville, Plant Nutritionist and NU-114 PI, University of Nebraska

Mr. Dave Andrews, Plant Breeder and NU-115 PI, University of Nebraska

Dr. John Axtell, Plant Breeder and PRF-103A PI, Purdue University

Dr. Douglas J. Lathwell, TROPSOILS, Cornell University, Coordinator for Brazil

Summary

The need to develop crops with tolerance and adaptability to soil acidity has increased recently in many South and Central American countries. However, methods and approaches to accomplish this objective are either not available to scientists in the region or not well defined because of lack of research in the area. The development of a reliable field screening technique to screen for Al tolerance has resulted in the selection of several hundred Al-tolerant sorghum lines. About 50 promising lines have been identified with potential grain yield of 3 tons per hectare under acid soil conditions with minimum fertilization practices. National programs of Colombia, Peru, Venezuela, Panama, and Honduras are extensively testing the best Al-tolerant selections from this project. Private institutions and

other national programs in the region are using our Al-tolerant germplasm as a breeding base in their sorghum breeding programs.

Sorghum hybrids will probably be the final product of breeding work in this project. Our studies showed that hybrids have better agronomic characteristics than their tolerant parents in addition to high yield potential and high tolerance on acid soils. Apparently aluminum tolerance is dominant over susceptibility. This would permit the use of susceptible females with superior agronomic characteristics in combination with agronomically inferior but tolerant males in hybrid production.

Sorghum adapts to soil acidity by slowing growth, reducing leaf and stalk production and delaying maturity with no or small yield reduction.

Pearl millet has excellent adaptation to acid soils even under low phosphorus conditions. Several pearl millet varieties, synthetics, and populations have potential grain yields of 2-3 tons per hectare under conditions where Al-tolerant sorghums could hardly produce grain. Pearl millet tolerates a much higher level of Al toxicity than sorghum.

Institutions

Collaborating Host Country: ICA-Colombia, CIAT-South America, EMBRAPA-Brazil, FONAIAP-Venezuela, INIPA/IICA-Peru, IDIAP-Panama, Recursos Naturales-Honduras, ICRISAT/SADCC-Zimbabwe and SIDA-Zambia.

U.S.: Mississippi State University MSU-104 and MSU-105, University of Nebraska NU-114 and NU-115, Purdue University PRF-103A and TROPSOILS.

Linkages:

This project is informally linked with many countries in South and Central America in which CIAT conducts research. We have cooperative research linkages established with the national programs of ICA-Colombia, EMBRAPA-Brazil, FONAIAP-Venezuela, and INIPA-Peru in the major acid soil areas. The linkage with ICA is a strong informal collaborative research agreement. ICA has provided land, facilities, personnel and administrative support at the national level and at the La Libertad and Carimagua stations in the Llanos. The linkage with EMBRAPA is strong and formal. The main request of EMBRAPA from INTSORMIL is mainly germplasm, technical assistance and graduate training of their young staff. The linkage with Venezuela, Peru, Honduras and Panama are in the nature of germplasm supply and

conducting regional trials. Cooperation with TROPSOILS and CIAT soil scientists is mainly in technical consultations.

The main breeding and selection work is accomplished at CIAT-Palmira and CIAT-Quilichao by the INTSORMIL PI and collaboratively at ICA-La Libertad and ICA-Carimagua.

Regional trials of the best aluminum-tolerant selections are being conducted at the following locations:

Colombia:	Quilichao - INTSORMIL
	La Libertad - ICA/INTSORMIL
	Villavicencio - Semillano
Brazil:	Sete Lagoas - EMBRAPA
	Capinopolis - AGROCERES
	Serra Talhada - Pernambuco - IPA
Venezuela:	Aragua-Flor de Aragua, C.A.
	Guarico - FONAIAP
	El Sombrero-Gerencia de Desarrollo Agricola
Peru:	Iquitos - INIPA
	Yurimaguas - INIPA
Panama:	Santiago de Veraguas - IDIAP
	Canita - Chepo - IDIAP
Honduras:	La Esperanza, Intibuca - Recursos Naturales
Guyana:	East Coast, Demerara

Ecogeographic Zones Benefited Most by Research

The impact of our research output will undoubtedly be in major acid soil areas of South and Central America and Africa. The availability of sorghum and millet cultivars with tolerance to Al and Mn toxicities and P deficiency will stimulate agricultural production in many unproductive marginal lands. As farm inputs are always expensive, many national and private institutions in Latin America are interested in our Al-tolerant sorghum germplasm for minimum input farming systems.

Objectives, Research Procedures and Production/Utilization Constraints

Year 7 Project Objectives

To establish a regional program for the development of sorghum and pearl millet germplasm with tolerance to low pH tropical soils with phytotoxic levels of aluminum.

To screen and evaluate a large portion of the world sorghum and pearl millet collections for tolerance to aluminum and manganese toxicities, and phosphorus deficiency stress.

To incorporate sources of tolerance to aluminum and manganese toxicities, and phosphorus stress into elite U.S. and tropical sorghum germplasm.

To develop minimum-input technology strategies for the evaluation of Al-tolerant lines grown on tropical savanna soils.

To distribute sorghum and pearl millet germplasm developed from INTSORMIL projects and ICRISAT to national programs in Latin America and Africa.

To train and assist Latin American and African scientists in the use of effective breeding and screening methods for the adaptation of sorghum and pearl millet to acid soils.

To give technical assistance to national and private institutions to promote sorghum production and utilization in the region.

Sorghum/Millet Constraints

The most important constraint of sorghum and millet in South America is soil acidity. South America has the largest acid soil areas in the world. These unproductive acid soils contain enough toxic levels of Al to inhibit the growth of major cereal crops. In addition, they are characterized by low phosphorus content and availability due to high chemical fixation and deficiency of various plant nutrients. The second most important constraint of sorghum and millet is bird pests. It is almost impossible to avoid bird damage because there are no sorghum or millet cultivars which are bird-proof. Tannins in sorghum grains and long bristles on pearl millet panicles do not guarantee protection from birds. As a consequence, high-tannin or brown sorghum varieties or hybrids are preferred in South America. Farmers sacrificed grain quality in exchange for some bird protection due to tannins in the grain.

Soil acidity is also a major constraint in some Central and South African countries. Manganese toxicity is in some cases more important than Al toxicity. Tolerant sorghum and millet cultivars coupled with minimum input technology will encourage agricultural production in many food-deficient countries of Africa.

Research Procedures

A field screening nursery has been developed and established at CIAT-Quilichao, Colombia. The saturation level of Al has been maintained at 60-63%. At this stress level susceptible genotypes die or produce little or no grain at all while tolerant genotypes grow and produce good yields. Phosphorus is probably the second most critical element in acid soils. At least 10 ppm P should be available in soils with 65% Al saturation. Otherwise tolerant genotypes react as if they were susceptible. Monitoring the levels of different nutrient elements is done through soil analyses at planting and harvest time.

The stress level being used in sorghum is not useful to differentiate susceptible from tolerant genotypes in pearl millet. This crop can tolerate much higher Al stress than sorghum. Its response is quantitative and there is high Al and P interaction. Appropriate field screening technique for pearl millet is being developed.

Most of the Al-tolerant sorghum lines with high yield potential have poor agronomic characteristics. They are tall, flower late and are sensitive to day length variation. They are crossed to Al-susceptible and short elite genotypes from U.S.A. and ICRISAT to develop tolerant progenies with good agronomic characteristics. Segregating progenies are handled through the pedigree method. Selection is based on tolerance, short height, earliness, yield potential and grain color. White or yellow selections are not useful for South America but they are kept for areas like Africa and Central America where food grain types are important.

Tolerance to Al is a very complex trait. Morphological traits which may be related to Al tolerance have been found. The presence of numerous adventitious roots is probably one of the keys to Al tolerance in sorghum. Al-tolerant lines with numerous and extensive adventitious roots were crossed to elite and susceptible lines. Segregating progenies were screened for tolerance and root masses examined.

The inheritance of Al tolerance is complex. However tolerance is probably governed by many dominant or overdominant genes. Progenies from susceptible and tolerant parents are always more tolerant than their susceptible parents. Susceptible and tolerant males were crossed to a common susceptible female. The hybrids were evaluated at 40 and 60% Al saturations at CIAT-Quilichao. Hybrids from tolerant x tolerant and

tolerant x susceptible parents were also produced. Tolerant B-lines were sterilized to develop tolerant A-lines. New tolerant A-lines are used in hybrid production with susceptible but agronomically superior R-lines.

New tolerant R-lines or B-lines are being incorporated in appropriate sorghum populations. Two new populations with 50% tolerant germplasm are now being recombined in fertile field isolations. Recombination in fertile or amended soil is necessary to increase the chance of getting tolerant recombinants with high yield potential and good agronomic characteristics. Mass selection and S_1 family evaluation are being used to improve tolerance, yield potential, and agronomic traits.

More sorghum and pearl millet collections from germplasm banks in U.S.A., ICRISAT, and Brazil were acquired. They were increased first at CIAT-Palmira before testing at CIAT-Quilichao. Al-tolerant lines developed from this project are being distributed for yield trials to national and private institutions in South and Central America.

The morphological and physiological bases of Al tolerance are being examined in cooperation with Dr. R.B. Clark. Tolerant and susceptible genotypes are tested to determine the major effects of Al on phenology, dry matter production and harvest index. Mineral analyses are done by Dr. Clark (NU-114) and Dr. J. Salinas (CIAT).

Pearl millets are being screened for Al and low P tolerance using the technique for sorghum. Being a cross-pollinated species, pearl millet is genetically heterogenous. Varieties, inbreds, and populations are increased by selfing and S_1 families are screened for Al and low-P tolerance.

Winter and seed increase nurseries are conducted in cooperation with Gourley MSU-104 and Axtell PRF-103A at CIAT-Palmira.

Problems Regarding Achievement of Objectives

Movement of germplasm to different national programs in Latin America has been slow because of strict plant quarantine and importation requirements. In spite of full cooperation of our collaborators germplasm often does not arrive on time for the desired planting season.

Project Output

Research Findings for Immediate Use

Using an acid field screening technique, several hundred world collection sorghum lines and breeding selections with high Al tolerance have

been identified. These lines represent a wide range of agroclimatic adaptation based on their country of origin. Most of them are useful only as breeding materials because of poor agronomic characteristics and low yield potential. However, about 50 promising lines have been identified with potential grain yield of 3 tons per hectare under acid soil conditions at minimum fertilization practices.

To overcome the agronomic inferiority of Al-tolerant lines, they are used as pollen parents in hybrid production using Al-susceptible but agronomically superior females. Some hybrids from specific combinations of susceptible and tolerant parents have excellent agronomic acceptability in addition to good yielding ability on acid soils. Apparently tolerance is dominant over susceptibility. All hybrids from susceptible and tolerant parents are more tolerant than their susceptible parents. Several non-restorer selections (B-lines) with good tolerance have been male sterilized to be used as females (A-lines) in hybrid development. Four pairs of tolerant A and B lines will be released by MAFES in early 1987.

Four random-mating populations with Al-tolerant germplasm have been developed. Two of these populations have excellent tolerance, but yield potential is low. The other two populations are still being recombined in fertile field isolations to obtain a high frequency of recombinants with tolerance, high yield potential and good agronomic characteristics.

Phosphorus is the second most critical element in acid soils. Variability for low-phosphorus tolerance has been observed among Al--tolerant selections. Even at 50% Al saturation, tolerant lines reacted as if they were susceptible if P is very low in the soil. However, sorghum can tolerate up to 75% Al saturation provided P is adequately available (at least 80 kg P_2O_5 per ha).

The contribution of varietal tolerance to yield stability of sorghum on acid soils was studied. Tolerant lines were less affected by Al and there was no genotype x Al level interaction effects for grain yield. Yield reduction ranged from 1.3 to 13.2% and 46 to 80% for tolerant and susceptible lines, respectively. Tolerant genotypes adapt to Al toxicity conditions by reducing vegetative growth and delaying maturity with no or small yield reduction. As a consequence the harvest index of tolerant genotypes increased in response to high Al stress.

Several pearl millet varieties, synthetics, and populations introduced from ICRISAT, Brazil, and the U.S. have excellent adaptability to Colombian acid soils. Pearl millet grain yield potential ranges from 2 to 3 tons per hectare under conditions where Al-tolerant sorghum could hardly produce grain. ICA of Colombia will test some of this pearl millet germplasm not only in acid soil areas but also in hot and dry areas on the Colombian Atlantic coast.

Research Findings for Future Use

National programs in South and Central America are testing Al-tolerant selections from this project. Additional Al-tolerant selections are being distributed in the region. ICA of Colombia plans to release the first Al-tolerant sorghum variety of the country in one or two years. National and private agencies in Brazil, Colombia, Peru, Venezuela, Honduras, and Panama are using our Al-tolerant germplasm as a breeding base in their sorghum breeding programs.

Networking Activities

- Workshops

PI coordinated the selection of participants from South America for the Sorghum Seed Production Workshop for Latin America, held October 1985. PI attended this workshop at CIMMYT Mexico.

PI was a resource speaker for the First Advanced Course on the Quality and Control of Seed-Transmitted Diseases, held October 21-November 22, 1985 at CIAT.

PI was a resource speaker for a course on Research and Production of Corn and Sorghum sponsored by CIMMYT and FENALCE, held January 13-18, 1986 at CIAT.

PI was a resource speaker for the Intensive Course on Seed Production and Technology, held April 1-May 23, 1986 at CIAT.

- Research Investigator Exchanges

Sorghum researchers from national institutions and private seed companies in Colombia have visited our acid field screening nursery at CIAT-Quilichao.

- Germplasm and Research Information Exchange

Researchers who received Al-tolerant and other sorghum germplasm:

Colombia:	Dr. Heman Gaviria, ICA-Nataima
	Ms. Maria Cecira de Martinez, ICA-La Libertad
	Mr. Hector Hernandez, FENALCE-Bogota
	Mr. Luis Mario Barrios, Semillas de Occidente, Cartago
	Mr. Eduardo Villota, Semillano, Villavicencio
	Dr. Carlos Sere, CIAT
	Dr. Judy Nolt, CIAT
	Dr. Rosemary Bradley, CIAT
	Ms. Irene Koumen, CIAT-Rothamsted
Venezuela:	Mr. Carlos Agudelo, Fundacion Polar
	Mr. Wilier Diaz, Flor de Aragua, Aragua
	Mr. Hugo Acosta, Management of Agricultural Development, Maracaibo
	Mr. Pedro Solorzano, Protinal, C.A., Valencia
	Mr. Osman Gutierrez, FONAIAP, Guarico
Brazil:	Mr. Paulo Motta Ribas, AGROCERES
	Dr. Gabriel Alves Maciel, IPA
	Mr. Renato Borgonovi, EMBRAPA
Peru:	Mr. Juan Manuel Ramirez, IIAP-Iquitos
	Dr. Antonio M. Pinchinat, IICA-Lima
	Mr. Federico Scheuch, INIAP-Tarrapoto
Panama:	Mr. Alfonso Alvarado, IDIAP-Panama City
	Mr. Benjamin Name, IDIAP-Veraguas
Honduras:	Mr. Justiniano Diaz, Recursos Naturales
Mexico:	Dr. Vartan Guiragossian, ICRISAT-Mexico
Guyana:	Mr. Randall Gibbons
Philippines:	Dr. Artemio Salazar, IPB, University of the Philippines at Los Baños
U.S.A.:	Dr. Jerry Maranville, University of Nebraska
	Dr. Dale Ritchey, USDA, Virginia

New sorghum and millet germplasm has been acquired from Brazil, ICRISAT, Georgia, Purdue, Nebraska and Mississippi.

- Assistance to Host Country Researchers

MSU-111 supported travel of Colombian scientists to CIAT for short term training. The project also donated 20 bags of fertilizer to ICA-La Libertad station.

Travel

- Brazil. July 19-August 2, 1985. C.I. Flores. Meeting with EMBRAPA scientists and evaluation of acid soil problems.
- Carimagua and Villavicencio. October 1-9, 1985. C.I. Flores. Planted research plots.
- CIMMYT, Mexico. October 13-19, 1985. C.I. Flores. Attended Sorghum Seed Production Workshop.
- Panama. October 20-22, 1985. C.I. Flores. Meeting with IDIAP scientists and assessment of soil acidity problems.
- Carimagua. November 13-15, 1985. C.I. Flores. Applied fertilizers and collected soil samples.
- Villavicencio. November 21-23, 1985. C.I. Flores. Applied fertilizers and collected soil samples.
- Philippines, Nebraska and Mississippi. December 7, 1985-January 9, 1986. C.I. Flores. Vacation in the Philippines and meeting with INTSORMIL and MSU staff.
- Carimagua and Villavicencio. February 4-9, 1986. C.I. Flores. Harvested research plots.
- Bogota. April 8, 1986. C.I. Flores. Meeting and consultation with FENALCE staff.

Publications

Flores, C.I., W.M. Ross, and J.W. Maranville. 1986. Quantitative genetics of agronomic and nutritional traits in related grain sorghum random-mating populations as affected by selection. Crop Science 26:9-14.

Flores, C.I., W.M. Ross, C.E. Walker, P.J. Mattern, and J.W. Maranville. 1985. Genetic variation for starch gel consistency and seed density in sorghum populations. Cereal Res. Communication 13:433-439.

Gourley, L.M., and C.I. Flores. 1985. Breeding Al-tolerant sorghum for low-input systems. Agronomy Abstracts 77:35.

Anonymous. 1986. Sorghum tolerant to aluminum. The Republic Newspaper, Medellin, Colombia. May 26 Issue (In Spanish).

CIAT. 1985. The sorghum alternative for acid soils. CIAT International. 4:7-10.

Anonymous. 1986. New-found sorghum varieties benefit Latin America and Africa. L.I.F.E. Newsletter 19(1):45.

Anonymous. 1986. Seeking aluminum-tolerant sorghums. MAFES Research Highlights 49:7.

Changes in Year 8

In Year 8, Al-tolerant lines will be screened for low-phosphorus tolerance. Preliminary experiments showed that Al-tolerant sorghum lines behaved as if they were Al-susceptible when P is very low. Experiments to determine the appropriate field screening technique for pearl millet will be initiated. It is not possible to distinguish tolerant from susceptible millet using the sorghum screening technique.

Breeding Sorghum for Developing Countries

Project NU-115

David J. Andrews

University of Nebraska

Principal Investigators

Mr. Louis Mazhani, sorghum/millet breeder, Botswana

Dr. Raphael Duverge, sorghum breeder, Dominican Republic

Dr. Joanne Logan, sorghum agroclimatologist, NU-121, Dominican Republic

Dr. Jerry Eastin, sorghum physiologist, NU-116, University of Nebraska

Mr. David Andrews, sorghum/millet breeder, NU-115, University of Nebraska

Others Researchers

Dr. T. Obilana, sorghum breeder, Bulawayo, Zimbabwe

Dr. Jerry Maranville, cereal physiologist, NU-114/121, University of Nebraska

Summary

The main thrust of this project at this stage was to further develop breeding populations from crosses between widely adapted stocks recently developed in the tropics (mainly by ICRISAT) and leading U.S. lines of notable value, e.g., parents of outstanding hybrids. This will form the basis for material for collaboration, and selection in the U.S. in future years. In some cases, tropical stocks used were outstanding local varieties, such as Segeolane, from Botswana. The first series of 65 crosses, made in 1984, have been carried through to the selection of F_3 families. F_2 populations and some F_3 families were sent to Botswana for exploitation by the collaborating breeder. A further 170 hand crosses were made during the year.

Institutions

Collaborating Host Countries: Ministry of Agriculture, Sebele, Gaborone, Botswana; CESDA, San Cristobal, Dominican Republic; ICRISAT, Bulawayo, Zimbabwe

U.S.: Kansas State University

Linkages:

Mainly consist of collaborative work with breeders in host countries either in cooperatively testing NU-115 material, or through discussion of breeding procedures appropriate to existing host country material. Seed requests are met for these and other countries.

Ecogeographic Zones Benefited Most by Research

Southern Africa and Central America (potentially Asia).

Objectives, Research Procedures, and Production/Utilization Constraints

Project Objectives

To develop higher yielding sorghum varieties and hybrid parents through crosses with existing U.S. parents and new tropical stocks.

Use appropriate parts of this variability to support breeding projects in collaborating countries, and in the U.S. to develop higher yielding stocks.

Collaborate on testing for drought and heat stress tolerance.

Study selection methods, generate genetic information and student thesis material.

Changes in Objectives from Previous Year

The overall objectives have not changed but new tropical sources of material have been introduced and emphasis has shifted to make the maximum use of these to quickly develop segregating populations and lines suitable for collaborative breeding.

Sorghum Constraints

Constraints to sorghum production are both genetic and physical factors in the growing environment. Many existing landrace varieties, though they are well adapted to low moisture and fertility situations and to numerous pests and diseases, are not efficient in converting the dry matter they produce into grain. Their harvest index (HI) efficiency is poor. There are breeding stocks which are twice as efficient in this process but they generally perform poorly in African conditions because they have little adaptation or pest/disease resistance. A combination of traits conferring adaptation and grain production efficiency is required through breeding, as well as further improvement in the basic breeding stocks (particularly seed parents) for grain yield potential *per se*. Combinations (lines/plants) with

good adaptation qualities can only be identified *in situ* in developing countries. Thus, segregating material generated from crosses with stocks known to perform well in the region concerned, in crosses with selected high HI lines, are supplied for selection in collaborative projects.

Research procedures:

Introduce exotic stocks, hand cross with U.S. stocks, put into breeding populations, and select in individual crosses.

Winter nurseries will be used to more quickly advance material.

Early generation products of crosses will be sent to cooperative sites for evaluation and selection, which will involve grain quality considerations.

Products should be tested with established check varieties both under current LDC farming conditions and with projected improved cultivation practices.

Selection will also be conducted in Nebraska in two contrasting locations (Lincoln and Sidney), under drought stress, and under controlled and natural high and low temperature conditions.

Project Output

Research Findings for Immediate Use

Tropical introductions were increased and evaluated for *per se* performance and in testcrosses, and for suitability as breeding parents. F_1's and F_2's, mostly of crosses between tropical and U.S. B-lines were grown and selected. Half-sib, full-sib, and S_1 progenies from a high altitude ICRISAT/CIMMYT population were evaluated for seedling cold tolerance both in growth chamber and in the field and responses correlated. B- and R-line nurseries of inbreds generated from random-mating populations by earlier genetic studies in the project were evaluated at Mead and Sidney, Nebraska, principally for *per se* performance, grain weathering and lodging resistance. Testcrosses were made to determine their hybrid potential. One hundred and seventy further cross combinations were made by emasculation in the winter greenhouse. A winter nursery, conducted in the Dominican Republic in conjunction with NU-121 and CESDA, was used for generation increase, testcross production and backcrossing. CESDA staff were trained in testcrossing, emasculation and selection. They generated/selected their own seed for a hybrid trial and a selection nursery. F_2 populations and F_3

lines of crosses made specifically to Segaolane were sent for collaborative selection in Botswana primarily for B-line production where some 36 selections were made out of 119 families sent.

Research Progress for Future Use

The main thrust of the breeding, to develop segregating populations from which varieties/B-lines can be selected, will come on stream after the 1986 crop season. Stocks of tropical varieties, and hybrids for collaborative tests will also be ready then. The breeding project will become more involved with NU-116 to evaluate drought and heat stress tolerance in materials being developed.

Networking Activities

- Workshops

NCRP/INRAN cereals workshop, Niamey, Niger, October 1985, paper presented.

- Research Investigator Exchange

Visits to Botswana and Zimbabwe in March to see collaborative nurseries and to network with ICRISAT activities in the SACCAR region.

- Germplasm Exchange

Germplasm sent to Botswana, Dominican Republic, and Kansas.

Germplasm received from India, China, Kansas, Texas, and Purdue.

- Assistance to Host Country Researchers

NU-115 purchased (via KSU-7) irrigation equipment for growing off-season nursery and germplasm maintenance for the sorghum and millet breeding program at Sebele, Botswana. Single-head thresher parts and selfing bags were supplied to CESDA, Dominican Republic.

Travel:

International

- Niger. October 11-19, 1985. D.J. Andrews. NCRP Cereals Conference.
- Dominican Republic. February 6-22, 1986. D.J. Andrews. Winter Nursery.
- Botswana, Zambia, and Zimbabwe. March 28-April 5, 1986. D.J. Andrews.

Discussion with breeders on collaborative material.

Domestic

- Kansas City. MO. August 15, 1986. D.J. Andrews. INTSORMIL EZC meeting.
- Hays, KS. August 20-23, 1986. D.J. Andrews. To see sorghum and millet program.
- Chicago, IL. Nov. 30-Dec. 7, 1986. D.J. Andrews. Attended ASA annual meetings.
- Kansas City, MO. March 20, 1986. D.J. Andrews. INTSORMIL EZC meeting.

Publications

Andrews, D. J. 1986. Current results and prospects in sorghum and pearl millet breeding. In Proc. Sixth Agricultural Sector Symposium: Development of Rainfed Agriculture Under Arid and Semi-Arid Conditions. World Bank, Washington, DC.

Ross, W.M. 1985. A unique combine-height sorghum genotype. Proc. Grain Sorghum Bien. Res. and Util. Conf., Lubbock, TX 14:90-91.

Tiffany, G.D., and W.M. Ross. 1985. Mass selection for seed size and seed number in sorghum. Proc. Grain Sorghum Bien. Res. and Util. Conf., Lubbock, TX 14:100-101.

Williams, E.P., W.M. Ross, R.B. Clark, G.M. Herron, and M.D. Witt. 1985. Variability for iron chlorosis in S_1 progenies from a sorghum random-mating population. Proc. Grain Sorghum Bien. Res. and Util. Conf., Lubbock, TX. 14:82.

Galvez, L., R.B. Clark, L.M. Gourley, J.W. Maranville, and W.M. Ross. 1985. Manganese and aluminum toxicity interactions with sorghum. Proc. Grain Sorghum Bien. Res. and Util. Conf., Lubbock, TX. 14:57.

Ross, W.M. 1986. Improving plants for tolerance to iron deficiency and other mineral nutrition problems: breeding and genetic points of view. Third International Symposium on Iron Nutrition and Interaction in Plants. Lincoln, NE, June 1985. J. Plant Nutr. 9:309-333.

Williams, E.P., W.M. Ross, R.B. Clark, G.M. Herron, and M.D. Witt. 1986. Heritability of iron-deficiency chlorosis and its effect on agronomic traits in a sorghum population. Third International Symposium on Iron Nutrition and Interaction in Plants. Lincoln, NE, June 1985. J. Plant Nutr. 9:423-433.

Breeding Pearl Millet for Developing Countries

Project NU-118

David J. Andrews

University of Nebraska

Principal Investigators

Mr. Louis Mazhani, sorghum/millet breeder, Botswana

Mr. A. T. N'Doye, millet breeder, Senegal

Mr. Nieno Jika, millet breeder, Niger

Mr. Botoru Oendeba, millet breeder, Niger

Dr. Chuck Walker, food scientist, NU-119, University of Nebraska

Ms. Janet Buck, food scientist, NU-119, University of Nebraska

Dr. Jerry Eastin, physiologist, NU-116, University of Nebraska

Mr. David Andrews, sorghum/millet breeder, NU-115, University of Nebraska

Other Researchers

Mr. Amadu Fofana, millet breeder, CNRA, Bambey, Senegal

Dr. J. R. Witcombe, millet breeder, ICRISAT, India

Dr. S. C. Gupta, millet breeder, Bulawayo, Zimbabwe

Mr. W. M. Stegmeier, millet breeder, KSU-101, Hays, Kansas

Dr. R. R. Duncan, breeder, University of Georgia, Griffin, Georgia

Dr. Lynn Gourley, breeder, MSU-111, University of Mississippi

Dr. Jerry Maranville, cereal physiologist, NU-114/121, University of Nebraska

Summary

There are three principal activities in the project in 1985/86:

Advancing material from crosses between tropically adapted breeding lines (mostly from ICRISAT) and early maturing U.S. stocks. This will form the bulk of the project material to support collaboration, and for exploitation in the U.S. in future years. F_3 families from the initial wave of 130 crosses were evaluated in 1985.

Exploiting existing program material by selection per se and in testcrosses, the main criteria being yield, seed set, and lodging resistance.

Testing a modified type of mass selection, as an appropriate breeding method to recommend to pearl millet breeders (with implications for other

species) with limited resources to allocate to recurrent selection. The method is being used to improve a dwarf population for performance.

Institutions

Cooperating Host Countries: CNRA, Bambey, Senegal; INRAN, Niger; Ministry of Agriculture, Sebele, Gaborone, Botswana; ICRISAT, Hyderabad, India; ICRISAT, Bulawayo, Zimbabwe.

U.S.: Kansas State University, Hays, KS; Mississippi State University, Misssissippi State, MS; and University of Georgia, Griffin, GA

Linkages:

Linkages consist mainly of collaborative work with breeders in host countries either in cooperatively testing NU-117 material, or through discussion of breeding procedures appropriate to existing host country material. Seed requests are met for these and other countries. Germplasm has been supplied to other institutions (Kansas and Mississippi) and to University of Georgia for testing on acid soils.

Ecogeographic Zones Benefited Most by Research

West and Southern Africa (potentially Asia).

Objectives, Research Procedures and Production/Utilization Constraints

Project Objectives

To develop higher yielding pearl millet varieties and hybrid parents through crosses with existing U.S. parents and new tropical stocks.

Use appropriate parts of this variability to support breeding projects in collaborating countries, and in the U.S. to develop higher yielding stocks.

Collaborate on testing for drought and heat stress tolerance.

Study selection methods, generate genetic information and student thesis material.

Changes in Objectives from Previous Year

The overall objectives have not changed but new tropical sources of material have been introduced and emphasis has shifted to make the maximum use of these to quickly develop segregating populations and lines suitable for collaborative breeding. Studies on recurrent selection still continue on pearl millet.

Millet Constraints

Constraints to pearl millet production are both genetic and physical factors in the growing environment. Many existing landrace varieties, though they are well adapted to low moisture and fertility situations and to numerous pests and diseases, are not efficient in converting the dry matter they produce into grain. Their harvest index (HI) efficiency is poor. There are breeding stocks which are twice as efficient in this process but they generally perform poorly in African conditions because they have little adaptation or pest/disease resistance. A combination of traits conferring adaptation and grain production efficiency is acquired through breeding, as well as further improvement in basic breeding stocks (particularly seed parents) for grain yield potential per se. Combinations (lines/plants) with good adaptation qualities can only be identified in situ in developing countries. Thus, segregating material generated from crosses with stocks known to perform well in the region concerned, in crosses with selected high HI lines, are supplied for selection in collaborative projects.

Research Procedures

Introduce exotic stocks, select directly or hand cross with U.S. stocks, put into breeding populations, and select in individual crosses.

Winter nurseries will be used to more quickly advance material.

Early generation products of crosses will be sent to cooperative sites for evaluation and selection, which will involve grain quality considerations.

Products should be tested with established check varieties both under current LDC farming conditions and with projected improved cultivation practices.

Selection will also be conducted in Nebraska in two contrasting locations (Lincoln and Sidney), under drought stress, and under controlled and natural high and low temperature conditions.

Project Output

Research Findings for Immediate Use

Modifications of mass selection recurrent selection procedures were devised (Andrews and Stegmeier, 1985) and presented at the Niger Cereals Conference in Niamey, 1985. The method is being tested operationally on a dwarf millet population in Nebraska and at ICRISAT and on sorghum at the

ICRISAT/SADCC Center in Bulawayo. A few further introductions were introduced through winter greenhouse quarantine. A soil tube/hydroponic procedure was developed which enables 200 plants to be grown per m^2 of bench space in winter greenhouse, thereby enabling random-mating generations to be obtained when space is limiting. A large amount of material generated from crosses with introduced tropical stocks was moved from F_2 to F_3 and from F_3 to F_4, 700 testcrosses were evaluated at Mead and Sidney, Nebraska, and older program material screened for seed set and combining ability. Varieties were sent from KSU-101 and this project for test in north Senegal where downy mildew is not a problem. Effective rainfall was 215 mm. Semi-tall KSU varieties yielded best, NU-115 dwarf material equaled yield of local check but was earliest and half the height--which is preferred for intercropping.

Research Progress for Future Use

Single cross and topcross hybrids will be tested in 1986 and 1987, identifying the best for wider testing. New dwarf varieties will be tested during the same period. Potential seed parents will be ready for testing in two years. The major grain types being used in breeding will be characterized for their attributes in making principal types of millet food products.

Networking Activities

- Workshops

NCRP/INRAN cereals workshop, Niamey, Niger, October 1985, paper presented.

International Pearl Millet Workshop, ICRISAT/INTSORMIL, April 1986, Hyderabad, India. Chairman/breeding panel coordinator.

- Research Investigator Exchanges

Visits to Botswana and Zimbabwe in March to see collaborative nurseries and to network with ICRISAT activities in the SACCAR region.

- Germplasm Exchange

Germplasm sent to Senegal, Botswana, Honduras, Kansas and Mississippi (for Colombia). Germplasm received from India and Kansas.

Travel

International

- Niger. October 11-19, 1985. D.J. Andrews. NCRP Cereals Conference.
- Botswana, Zambia, and Zimbabwe. March 28-April 5, 1986. D.J. Andrews. Discussion with breeders on collaborative material.
- New Delhi, India. April 6-17, 1986. D.J. Andrews. Participated in International Pearl Millet Workshop, discussed INTSORMIL India/Pakistan collaboration with AID/Delhi.

Domestic

- Kansas City, MO. August 15, 1986. D.J. Andrews. Attended INTSORMIL EZC meeting.
- Hays, KS. August 20-23, 1986. D.J. Andrews. To see sorghum and millet program.
- Kansas City, MO. January 13-15, 1986. D.J. Andrews. Attended INTSORMIL EZC meeting.
- Kansas City, MO. May 12-13, 1986. D.J. Andrews. Attended INTSORMIL EZC meeting.

Publications

Andrews, D. J. 1986. Current results and prospects in sorghum and pearl millet breeding. In T. Davis (ed.) Proc. Sixth Agricultural Sector Symposium: Development of Rainfed Agriculture Under Arid and Semi-Arid Conditions. World Bank, Washington, DC.

Andrews, D. J., S. C. Gupta, and P. Singh. 1985. Registration of ICMV-1 pearl millet. Crop Sci. 25:199-200.

Andrews, D. J., K. N. Rai, and S. D. Singh. 1985. A single dominant gene for rust resistance in pearl millet. Crop Sci. 25:565-566.

Andrews, D. J., and W. M. Stegmeier. 1986. Pearl millet breeding in INTSORMIL. In Sorghum and Millet Workshop, INRAN/INTSORMIL, NCRP, Niamey, Niger, Oct. 14-17, 1985 (in press).

Krishna, K. R., P. J. Dart, and D. J. Andrews. 1985. Genotype dependent variation in mycorrhizal colonization and response to inoculation of pearl millet. Plant & Soil 86:113-125.

Rai, K. N., D. J. Andrews, and A. S. Rao. 1985. Hybrid potential of 81A--a dwarf male sterile line of pearl millet. Ind. J. Plant Breed and Genetics (in press).

Development of Agronomically Superior Germplasm Including Varieties, Hybrids and Populations Which Have Improved Nutritional Value and Good "Evident" Grain Quality

Project PRF-103A

John D. Axtell

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Principal Investigators

John D. Axtell, Project Leader, Sorghum Breeder

Edwin T. Mertz, Nutritionist

Gebisa Ejeta, Sorghum Breeder

John Clark, INRAN/NCRP Sorghum Breeder

Lee House, SADCC/ICRISAT Project Manager

Sam Mukuru, ICRISAT Sorghum Breeder

Mousa Adamou, INRAN Sorghum Breeder

Other Researchers

Allen W. Kirleis, Cereal Chemistry

Larry Butler, Biochemist

Mohamed Hassen, Purdue Laboratory Analyst

Terry Lemming, Purdue Field Technician

Tom Tyler, Purdue Graduate Research Assistant

Emmanel Monyo, Purdue Graduate Research Assistant

Nora Mason, Purdue Graduate Research Assistant

Osman Ibrahim, ARC/Sudan Sorghum Breeder

R. Jambunathan, ICRISAT Biochemist

Vartan Guiragossian, ICRISAT Sorghum Breeder for East Africa

Lynn Gourley, Mississippi State/CIAT Sorghum Breeder

David Andrews, Nebraska Millet Breeder

T. Obiliana, SADCC/ICRISAT Sorghum Breeder

Kay Porter, Pioneer Sorghum Breeder

Joseph Mushonga, Zimbabwe Sorghum Breeder

George Graham, Nutritionist/Johns Hopkins University

Bruce Hamaker, Nutritionist/Institute of Nutrition, Lima, Peru

Summary

The major focus of this project is to develop high yielding sorghum varieties with acceptable food quality and good nutritional value for

utilization in developing countries. A great deal of progress has been made in two areas.

We now understand many of the factors necessary for improving the nutritional value of sorghum through local village processing. Sorghum flour is less digestible than most cereal flours unless it is processed using local village procedures that have evolved over hundreds of years. We now understand the scientific reasons why processing is important. This knowledge will help us modify and improve the traditional processing methods and develop improved processing methods for utilization in other countries where sorghum is used as a feed or food grain.

Relatively little is known about sorghum breeding and genetics in comparison to other major staple cereals. Genetic studies contribute to the development of improved breeding methodologies for sorghum improvement. New knowledge has been gained by this project about utilization of sorghum populations in breeding programs. Traits such as heritability of grain hardness and heritability of seedling cold tolerance are important for both the U.S. and developing countries. Selection methods for improving these important traits have been developed.

Institutions

Collaborating Host Countries: Niger - Niger/INRAN and Purdue Niger Cereals Research Project; Sudan - Agricultural Research Corporation (ARC); Zimbabwe - ICRISAT/SADCC Sorghum and Millet Improvement Program and Zimbabwe National Sorghum Research Program; India - ICRISAT.

U.S.: Purdue University, Mississippi State University, University of Nebraska, Texas A&M University, Johns Hopkins University, DeKalb/Pfizer Genetics, Pioneer Seed Corporation, Cargill/PAG Seed Company and Asgrow Seed Company.

Linkages:

The primary linkages of PRF-3A are with Niger, Sudan and SADCC. Collaborative research programs are in progress with INRAN in Niger, ARC in Sudan and the Sorghum and Millet Improvement Program in Southern Africa (SADCC).

More of the breeding activities will be conducted in developing countries. Much of the breeding will be conducted in Niger, Sudan and is developing with the ICRISAT Southern Africa and East Africa regional centers

with Vartan. Gebisa will continue his collaboration with the Sudan on Striga tolerance and drought tolerance. He and Axtell plan to spend considerable time and effort working with Sudanese scientists on grain quality using pedigree breeding as well as population and hybrid development. A major effort will be made to develop A and B lines with good grain quality, Striga tolerance, and drought tolerance which are adapted to Sudan and Niger.

Axtell will continue breeding for good grain quality in elite sorghum cultivars which also have African adaptability, good yield potential and other needed agronomic traits. Characteristics such as kernel hardness have now been identified which will facilitate breeding for grain quality. This program also will be carried out jointly with Niger and Sudan. Much of the breeding work will be done in Niger with backup using laboratory facilities at Purdue and Purdue winter nursery facilities. Screening and trials will be conducted at three locations in Niger as well as in Sudan.

Secondary research linkages have been developed with ICRISAT, SADCC, Mississippi State University and Texas A&M University.

Ecogeographic Zones Benefited Most by Research

West Africa - Niger; SUDANO - East Africa - Sudan; and Southern Africa/ SADCC.

Objectives, Research Procedures, and Production/Utilization Constraints

Sorghum/Millet Constraints

The major constraint in Niger and Sudan is the development of well adapted varieties and hybrids which will tolerate drought and produce grain which is acceptable for the local food products in these countries. The interaction between variety, methods of food processing and nutritional value are major objectives of this project. The recent results discussed under Project Output illustrate the importance of local processing on nutritional value of local sorghum food products. In these studies with children in Peru, sorghum flour cooked as a thick gruel gave nitrogen digestibility values of 46% but when prepared as the traditional Sudanese sorghum food, nasha, the nitrogen digestibility increased to 74%. This suggests that thin fermented porridges which are widely used in East and Southern Africa are very important for obtaining the maximum digestible protein and energy from sorghum grain.

An intensive laboratory effort by Joe Mushonga from Zimbabwe has resulted in improvement of techniques to measure diastatic power in sorghum grain. Much of the sorghum produced in Southern Africa is utilized as a thin fermented porridge (local beer). Special varieties are being developed by the SADCC Program for this purpose which requires laboratory screening procedures developed by Joe Mushonga.

Dr. Sam Mukuru is exploring local processing technologies used in East Africa by people who treat high tannin sorghums with wood ash to reduce the antinutritional effects of tannin and to improve digestibility. Dr. Mukuru, who is on sabbatical leave at Purdue for one year, has uncovered some very interesting results on the value of local processing in East Africa.

Project Objectives

Identify, develop and evaluate sorghum lines or mutants with improved nutritional quality and superior food grain quality using both chemical and biological methods.

Develop agronomically elite sorghum lines for Niger and Sudan with good adaptability, good grain quality, good drought and *Striga* tolerance, and improved yield potential.

Develop improved B-lines for adaptation in Niger and Sudan. These can provide a genetic base for future hybrid production in these countries.

Investigate the potential for developing varieties of sorghum with high nutritional value and good food properties for potential use as nutritional foods for young children, pregnant women and nursing mothers.

Train LDC personnel in plant breeding and genetics.

Change in Objectives

The major focus for Year 8 will continue to be ascertainment of the nutritional value of thin fermented porridges as used in East and Southern Africa and also to determine what genetic characteristics are necessary in a new variety to successfully prepare these porridges. For example, it is generally known that local varieties have a high diastatic power which is essential for fermentation with either yeast or lactobacillious. Many improved sorghum varieties lack this characteristic and this factor may be responsible for low adoption rate of improved varieties. Joe Mushonga has developed rapid assays for diastatic power and studying inheritance of diastatic activity in sorghum cultivars. Joe has screened breeding material

from Lee House's program in Bulawayo and will be studying the inheritance of diastatic power for his Ph.D. thesis research at the University of Zimbabwe. Dr. Sam Mukuru from ICRISAT has joined us for a one year leave to study these problems. He has great expertise in sorghum breeding and also in local processing information from his home village in Uganda. These studies will be combined with the ongoing program to develop well adapted, high yielding sorghum varieties.

Research Procedures

PRF-3A has developed extensive expertise in laboratory facilities, field facilities and staff expertise to study interdisciplinary problems in collaboration with scientists in Niger, Sudan and Zimbabwe.

Problems Regarding Achievement of Objectives

The major obstacle is coordination of laboratory and field experiments at Purdue with local food processing technologies available in Africa and to study the inheritance of these traits. These have been largely overcome by developing solid collaborative relationships in Niger, Sudan and Zimbabwe, and by bringing African collaborators like Joe Mushonga and Sam Mukuru to Purdue to learn the laboratory and field techniques prior to the conduct of their incountry research programs in Africa.

Project Output

Research Findings for Immediate Use

Nasha is a satisfactory weaning food when supplemented with relatively small amounts of lysine-rich foods such as milk, fish or legumes. ("Digestibility and utilization of protein and energy from nasha, a traditional Sudanese fermented weaning food" by G.G. Graham, W.C. MacLean, E. Morales, B.R. Hamaker, A.W. Kirleis, E.T. Mertz and J.D. Axtell. J. Nutrition 116:978-984, 1985). Digestibility of sorghum nasha was 74 percent in infants compared with 82 percent from wheat, 72 percent from maize and only 47 percent from cooked unprocessed sorghum. Thus, conversion of sorghum to nasha raised the digestibility from 47 to 74 percent and makes sorghum a satisfactory cereal for infants.

Normal sorghum and high lysine sorghum are good sources of tryptophan ["Tryptophan Levels in Normal and High Lysine Sorghums" by M.M. Hassen, E.T. Mertz, A.W. Kirleis, G. Ejeta, J.D. Axtell and E. Villegas. Cereal

Chemistry 63: (2):175-176, 1985.] Normal sorghum proteins contain 0.8 gram of tryptophan per 100 grams of protein (this is the FAO recommended level for infants) and high lysine sorghum proteins contain 1.2 grams or 50% more than the recommended level. The extra tryptophan in high lysine sorghum can be converted by the child to niacin, a vitamin often deficient in the diets of children in developing countries.

"Improving the in vitro digestibility of sorghum with reducing agents." B.R. Hamaker, A.W. Kirleis, L.G. Butler, J.D. Axtell and E.T. Mertz. Proceedings of the National Academy of Science, USA (In press). We have shown in previous reports that cooked sorghum protein is less digestible than other cooked cereal proteins. The pepsin indigestible proteins in sorghum were found to be mainly prolamin proteins. Cooking sorghum in the presence of 2-mercaptoethanol increased protein digestibility (in vitro using pepsin or trypsin/chymotrypsin) to a level comparable with other cereals. At a concentration of 100 mM other reducing agents (dithiothreitol, sodium bisulfite and L-cysteine) were equally effective in improving sorghum digestibility. When maize was cooked in the presence of 2-mercaptoethanol protein digestibility increased 5% compared to 25% for sorghum. Cooking barley, rice and wheat with 2-mercaptoethanol had no significant effect on protein digestibility. The addition of reducing agents appears to prevent the formation of protein polymers linked by disulfide bonds.

"Effect of cooking on the protein profiles and in vitro digestibility of sorghum and maize." Bruce R. Hamaker, Allen W. Kirleis, Edwin T. Mertz and John D. Axtell. J. Agric. Food Chem. 34:647-649. Uncooked sorghum was almost as digestible as uncooked maize, when assayed in vitro with pepsin and/or a trypsin-chymotrypsin mixture. However, after cooking, sorghum protein digestibility was significantly decreased. In contrast, cooking maize had no effect on pepsin digestibility and increased trypsin-chymotrypsin and pepsin-trypsin-chymotrypsin digestibility. After cooking, sorghum prolamins, measured by the Landry-Moureaux procedure and SDS-PAGE, became much less soluble and less pepsin digestible than maize prolamins. These findings demonstrate that sorghum and maize proteins behave differently when cooked and may explain why cooked sorghum has a lower digestibility than maize, wheat, and rice in children.

"Selection for seedling cold tolerance in grain sorghum." R.K. Bacon, R.P. Cantrell, and J.D. Axtell. Crop Science 26:900-903. Improvement in cold tolerance for sorghum [Sorghum bicolor (L.) Moench] would allow expansion of this crop into cooler regions than the current production areas, as well as lessen stand reductions in cool soils currently in production. Experiments were conducted in 1981 and 1982 to evaluate effectiveness of selection for cold tolerance in sorghum. A genetically broad-based, random-mating grain sorghum population, Purdue Population 9 (PP9), was used as the source population for increasing seedling cold tolerance. Purdue Population 9 Cold Tolerant (PP9CT) was developed through a phenotypic recurrent selection procedure utilizing natural selection in early spring plantings. Progress from selection was evaluated in early spring plantings in 1981 and 1982. In 1981, the C_0 to C_3 generations of PP9CT and two check genotypes were evaluated in plots planted with 100 seeds in a randomized complete block design. In 1982, the C_4 generation was also included. Results from the first year indicated that a 10.6% increase in cold emergence had been accomplished after three cycles of selection. Data from 1982 indicated a 14.9% increase in cold emergence after four cycles of selection. Regression analysis on the combined tests showed a linear increase of 2.8% cycle. Plant height, days to half bloom, seed color, and grain yield were evaluated in trials planted at normal planting dates to determine the correlated responses in PP9CT following selection for seedling cold tolerance. Plant height showed an irregular response, days to half bloom decreased by 0.55 day cycle, seed color increased by 0.13 color unit cycle, and grain yield increased by 197.7 kg ha cycle.

Research Progress for Future Use

"Combining ability of high lysine lines of sorghum, Sorghum bicolor (L.) Moench, derived from P-721 opaque" by E.S. Monyo, G. Ejeta, W.E. Nyquist, and J.D. Axtell. Crop Sci. (In press). The P-721 opaque (P-721Q) endosperm of Sorghum bicolor (L.) Moench has better protein quality than normal sorghum endosperms. However, it has not been readily accepted for wide cultivation due to its lower yield potential and some other problems associated with the soft endosperm. The aim of this study was to determine whether hybrids retained the high yield and protein quality of some lines derived from P-721Q.

Ten high lysine lines of sorghum derived from P-721Q were tested for agronomic traits and protein quality in hybrid combinations. Each was mated with the same three female lines, also derived from P-721Q by backcrossing to sterile cytoplasm. F_1 lines derived from these matings were evaluated for grain yield, 100-kernel weight, protein concentration, and lysine as percent of protein.

Significant differences among general combining ability effects were observed for all characters except grain yield, while significant differences among specific combining ability effects were observed for grain yield only. Grain yield of 11 of 13 lines in hybrid combinations was significantly better than that of their single parent. Correlation between grain yield and percent protein in the 30 hybrids was negative and significant ($r = -0.63$); correlation between grain yield and lysine as percent of protein was also negative but not significant.

R-3 (P-850314) was the best male parent for agronomic and protein-quality traits. In hybrid combination, it produced hybrids with the highest lysine percentage. Among the female parents, A-2 (P-851045) produced hybrids with the highest grain yields and A-3 (P-851063) gave hybrids with the highest protein quality. The best single-cross hybrid for agronomic and protein quality was A-3 x R-3. This new hybrid has 35% more lysine than the normal cultivar P721N and yielded as much as the NK-180 check. Thus it has the potential of substituting for some other expensive protein and lysine sources in the semiarid tropics where sorghum is the main food crop.

Sorghum kafirins (prolamine) proteins are polymerized by cooking ("Polymerization of sorghum kafirin proteins by cooking" by B.R. Hamaker, A.W. Kirleis, and E.T. Mertz. Fed. proc., in press, 1985). The pepsin-indigestible proteins from cooked, lyophilized sorghum were put on an SDS-polyacrylamide gel and subjected to electrophoresis. The proteins were so large they could not enter the gel. The proteins, when reduced, however, all migrated to the 20-25,000 dalton range characteristic of monomeric kafirin proteins. Therefore, kafirin polymerization accounts for the lower digestibility of cooked sorghum, and can be reversed with reducing agents.

"Processing high tannin sorghum in East Africa." S.Z. Mukuru, J.D. Axtell and G. Ejeta. Brown-grain (high tannin) sorghums are exclusively grown and used for food in many parts of the world. Brown-grain (high tannin) sorghums have agronomic and production advantages (most important

being bird resistance) over non-brown sorghums and this is probably the main reason why they are still grown. Unfortunately the nutritional value of brown-grain, bird resistant sorghums has been reported as significantly lower than that of non-brown sorghums.

In the southern highlands of Uganda almost all the sorghums grown are brown-grain types. Over 70% of sorghum grain produced is traditionally processed before it is used for food. The processing method is simple and is carried out by the peasant farmers themselves. The grain is mixed with wood ash slurr, soaked overnight, after which the grain is put on the floor and left covered for four or five days after germination. As soon as the radicle is approximately one inch long, the grain is spread out on the floor and allowed to dry. Dried grain is pounded in a wooden mortar and winnowed. Usually large quantities of grain is processed and stored. Enough quantity of processed grain is ground into flour and used to prepare traditional beverages to last for two or three days.

Processed grain is only suitable for the preparation of beverages (thin porridge) and not Ugali (thick porridge). This is because germination of the grain increases amylase activity in the grain, thereby significantly reducing its viscosity and rendering it unsuitable for the preparation of Ugali.

"Rate and extent of digestion of cell wall components of brown-midrib sorghum species." J.H. Cherney, K.J. Moore, J.J. Volenec, and J.D. Axtell. Crop Science 26:1055-1059. Cell wall composition and structure are important factors influencing utilization of forages in diets of ruminant animals. Our objective was to compare the cell wall composition and rate and extent of digestion of cell walls of normal and brown-midrib (bmr) genotypes of sorghum [Sorghum bicolor (L.) Moench] species. Brown-midrib 'Greenleaf' sudangrass [Sorghum bicolor (L.) Moench], and 'Redlan' x 'Greenleaf' and Redlan x 'Piper' sorghum x sudangrass hybrids were planted in the field in a Zanesville silt loam soil (fine-silty, mixed, mesic Typic Fragiudalf) along with corresponding normal genotypes. Stover was harvested and analyzed sequentially for fiber components, total nonstructural carbohydrates, and neutral sugar and phenolic acid composition of cell walls. Samples were incubated in buffered rumen fluid for 0, 6, 9, 14, 21, 48, and 72 h and rate constants were determined for neutral detergent fiber (NDF), cellulose, and hemicellulose digestion. The NDF, cellulose, and

lignin concentrations of bmr genotypes were lower than the corresponding normal genotypes. This resulted in 7% higher in vitro dry matter digestibility of bmr tissues over the normal genotype. Rate constants for digestion of NDF, cellulose, and hemicellulose differed, averaging -0.083, -0.088, and -0.079 h^{-1} for the bmr genotypes, compared to -0.064, -0.068, and -0.066 h^{-1} for the normal genotypes, respectively. The bmr genotypes had a higher extent of NDF, cellulose, and hemicellulose digestion when compared to the normal genotypes. The lignin concentration in the cell wall of bmr genotypes was initially lower than normal genotypes, but as digestion progressed the lignin concentrations of both genotypes merged at 138 g kg^{-1} DNF. This indicates that the proportion of lignin in the cell wall may be a limiting factor for extent of cell wall digestion. A portion of the lignin initially present was apparently digested, with extent of lignin digestion at 111 g kg^{-1} for the bmr genotypes compared to 186 g kg^{-1} for its normal counterpart. Ferulic acid (FA) concentration on a NDF basis was higher and p-coumaric acid (PCA) concentration lower in the bmr genotype, indicating considerable differences in linkages may exist between core lignin and structural carbohydrates. The FA/PCA ratio was 0.75 and 0.34 for the bmr and normal genotypes, respectively. This agrees with the suggested positive relationship between cell wall digestion and the FA/PCA ratio.

"Breeding and utilization of grain sorghum for thin fermented porridges (beers)." J.N. Mushonga, L. House, J.D. Axtell. In Zimbabwe, sorghum is utilized in two major ways. This is as human food and animal feed. As it is with most countries where sorghum is used as source of energy, Zimbabwe is not an exception. Several preparations out of sorghum include a variety of porridges. There is thin fermented porridge prepared out of sorghum and other cereals. This type is used as medicinal preparations for ill people. It is the sole source of a breakfast meal for many families, particularly those in the rural areas where variety of food is limited. There are also sour and fermented porridges which are consumed at work, social gatherings, as well as a casual family drink. Although undoubtedly very important to people in the rural areas, city dwellers also use these but to a limited extent. Outside the thin porridges, there is another preparation made out of sorghum flour. This is a paste or thick porridge known as Sadza (or Sitshwala). This is widely used all over the country. It is generally

consumed with beef or chicken stew, fish, fresh or sour milk and vegetables. This is commonly served at lunch or dinner.

One form of sorghum product widely consumed is fermented beverages. These are classified into alcoholic and nonalcoholic. Nonalcoholic fermentations are sourings which are mainly influenced by fermentation, while alcoholics are beers and wines. Beers are commonly made from cereals and the steps involved in their preparation may be divided into two groups. The first group involves; (a) steps to convert the cereal into a mechanism suitable for yeast growth and alcoholic fermentation; and (b) steps that give beer some special characteristics, e.g., hop flavoring in the case of European beers and souring in the case of some African beers.

The art of traditional beer brewing probably goes back to prehistoric times when people first noticed grain sprouting in the field or storage in the presence of moisture. Sorghum malt is produced by soaking the grain in the water for about one to two days. The water is drained and the grain is allowed to germinate for a few days in a warm environment. The sprouted grain is allowed to sun dry. The malt is ground into flour and then mixed with cold water. A larger amount of malt is steeped in boiling water and the cold water malt preparation is mixed with the boiled materials. This is done probably for its amylolytic action and also as a source of organisms. This sweet wort may be drunk after less than one day's fermentation, as is done in many parts of Uganda. On the second day, it is boiled in the cooking pot and returned to the brewing pot for the alcoholic fermentation. The beer is kept for an additional several days, then strained through a coarse basket to remove the husks. The beer is then ready to drink. The critical point in the process is that the variety must have high diastatic power which is an important trait for breeders to select for.

Networking Activities

- Workshops

INTSORMIL/INRAN/NCRP Sorghum and Millet Collaborative Research Workshop held in Oct. 1985. Attended by 45 INRAN/INTSORMIL/NCRP and U.S. AID Mission staff, including Ambassador Bogosian. Proceedings in press.

Conducted External Evaluation Panel On-Site Review of INTSORMIL/Niger program - Oct. 19-22, 1986.

- Research Investigator Exchanges

  A partial list of research visitors:

  Mr. Mamadou Ouattara - Niger

  Dr. Sam Mukuru - India

  Dr. R. Jambunathan - India

  Dr. Lee House - Zimbabwe

  Mr. Mousa Oumarou - Niger

  Mr. Mousa Adamou - Niger

  Dr. Idrissa Soumana

- Germplasm and Research Information Exchange

  Considerable germplasm has been provided to INRAN/Niger, ARC in Sudan, ICRISAT/SADCC Zimbabwe, plus numerous seed lots in response to specific requests by both private and public sector institutions.

Travel

International

- Hyderabad, India; Soroti, Uganda; London, England. July 10 - August 5, 1985. John Axtell. Meet with Dr. Swindale for indepth review of ICRISAT Cereal Projects. Attend East African Sorghum and Millet Conference in Soroti, Uganda. Research planning session with Dr. Stuart, Plant Physiologist from University of London.
- People's Republic of China. August 26 - October 3, 1985. John Axtell. Visit sorghum nurseries and teach genetics classes at Henan Academy of Agricultural and Forestry Sciences. Present seminar at Shenyang and South China Agricultural College (No expense charged to INTSORMIL).
- Niamey, Niger. October 10-23, 1985. John Axtell. To participate in and serve as director of an INTSORMIL/INRAN/NCRP sorghum/millet workshop.
- Swaziland, Africa. November 9-20, 1985. John Axtell. AID Contract/Academy for Educational Development/CTTA (Communications for Technology Transfer in Agriculture). Meet with representatives of USAID and relevant institutions to discuss the potential of Swaziland serving as a CTTA diffusion site. (No expense charged to INTSORMIL).

Domestic

- Kansas City, MO. January 13-15, 1986. John Axtell. Joint meeting of the INTSORMIL Technical Committee and the Ecogeographic Zone Council Meeting.
- Kansas City, MO. March 2-3, 1986. John Axtell. Attend the INTSORMIL Board/Technical/EZC Meeting to plan the 1986-87 budget allocations. Chairman of EZC Committee.
- Puerto Rico. March 6-18, 1986. John Axtell. To evaluate Puerto Rico as a winter nursery site; including assessment of Vieques as a potential future site; pollination of INTSORMIL Purdue sorghum nursery.
- Kansas City, MO. March 19-20, 1986. John Axtell. Attend the INTSORMIL Ecogeographic Zone Council Meeting.
- Puerto Rico. March 31-April 11, 1986. Terry Lemming. Pollination of the second planting, harvest, thresh and package INTSORMIL sorghum winter nursery.
- Kansas City, MO. April 9-10, 1986. John Axtell. To attend the INTSORMIL Board Meeting to decide 1986-87 budget recommendations.
- Kansas City, MO. May 12-15, 1986. John Axtell. Meeting of INTSORMIL Niger Country Coordinating Committee and meeting of INTSORMIL Ecogeographical Zone Council Meeting.
- Nairobi, Kenya and Bujumbura, Burundi. June 17-July 16, 1986. Emmanuel Monyo. To visit Dryland Research Station at Kenya and interact with workers at the East African Sorghum and Millet Conference in Burundi.

Publications and Presentations

Refereed Publications

Hamaker, B.R., A.W. Kirleis, L.G. Butler, J.D. Axtell and E.T. Mertz, 1986. Improving the *in vitro* digestibility of sorghum with reducing agents. Proc. Natl. Acad. of Sci. USA (In press).

Monyo, E.S., G. Ejeta, W.E. Nyquist, and J.D. Axtell. 1986. Combining ability of high lysine lines of sorghum, *Sorghum bicolor* (L.) Moench, derived from P-721 opaque. Crop Sci. (In press).

Hassen, M.M., E.T. Mertz, A.W. Kirleis, G. Ejeta, J.D. Axtell and E. Villegas. 1986. Tryptophan levels in normal and high lysine sorghums. Cereal Chem. 63:175-176.

Hamaker, B.R., E.T. Mertz, A.W. Kirleis, and J.D. Axtell. 1986. Effect of cooking on the protein profiles and pepsin digestibility of sorghum and maize. J. Agric and Food Chem. 34:647-649.

Graham, G.G., W.C. MacLean, Jr., E. Morales, B.R. Hamaker, A.W. Kirleis, E.T. Mertz, and J.D. Axtell. 1986. Digestibility and utilization of protein and energy from Nasha, a traditional Sudanese fermented weaning food. J. Nutr. 116:978-984.

Cherney, J.H., K.J. Moore, J.J. Volenec, and J.D. Axtell. 1986. Rate and extent of digestion of cell wall components of brown-midrib sorghum species. Crop Sci. 26:1055-1059.

Bacon, R.K., R.P. Cantrell, and J.D. Axtell. 1986. Selection for seedling cold tolerance in grain sorghum. Crop Sci. 26:900-903.

Ibrahim, O.E., J.D. Axtell and W.E. Nyquist. 1985. Quantitative inheritance and correlations of agronomic and grain quality traits of sorghum. Crop Sci. 25:649-654.

Kitch, L.W., R.E. Shade, W.E. Nyquist and J.D. Axtell. 1985. Inheritance of density of erect glandular trichomes in the genus Medicago. Crop Sci. 25:607-611.

Ejeta, Gebisa and John Axtell. 1985. Mutant gene in sorghum that causes leaf "redding" and causes protein concentration in the grain. J. of Heredity 76(4):301-302.

Fighting Hunger With Research. A Five-Year Technical Research Report of the Grain Sorghum/Pearl Millet Collaborative Research Support Program. Edited by Judy F. Winn, (INTSORMIL Report, 1985).

Presentations

Axtell, J.D. 1985. Sorghum Nutritional Quality. East African Sorghum and Millet Conference. Soroti, Uganda.

Changes in Year 8

See Change in Objectives

Breeding Sorghum Varieties and Hybrids with Improved Grain Qualit
Drought Resistance and *Striga* Resistance

Project PRF-107

Gebisa Ejeta

Purdue University

Principal Investigator

Gebisa Ejeta, Purdue University, Department of Agronomy

Host Country Collaborators

Sudan

Agricultural Research Corporation

Dr. Abdellatif M. Nour, Sorghum Breeding

Dr. Osman Ibrahim El Obeid, Sorghum Breeding

Dr. AbdelJabar T. Babikher, *Striga* Research

Dr. Mohamed El Hilu Omer, Sorghum Pathology

National Seed Administration

Dr. Ahmad Abuelgassim

Dr. M.S. Joshi

Dr. Omar Fadil

Niger

INRAN/Niamey, Niger

Mr. Mousa Adamou, Sorghum Breeding

Dr. John Clark, Sorghum Breeding

Dr. Derek Laycock, *Striga* Research

Other Collaborators

Dr. Sam Mukuru, ICRISAT, Hyderabad, India

Dr. Vartan Guiragossian, ICRISAT/SAFGRAD, Kenya

Dr. Joseph Werder, ICRISAT Sahelien Center, Niger

U.S. Collaborators

Dr. John Axtell, Purdue University

Dr. Larry Butler, Purdue University

Dr. Herm Warren, Purdue University

Dr. Allen Kirleis, Purdue University

Dr. Darrell Rosenow, Texas A&M University

Dr. Edward Clark, Texas A&M University

Dr. Lynn Gourley, Mississippi State University
Dr. Lytton Musselman, Old Dominion University

Summary

Breeding sorghum varieties and hybrids for use in developing countries requires proper recognition of the major constraints limiting production, knowledge of germplasm and appropriate physical environment for evaluation and testing. Efforts in INTSORMIL project PRF-107 are attempts to meet these requirements. Through regular dialogue and interaction with colleagues in Niger and Sudan, the sorghum breeding program at Purdue provides the necessary back up both in terms of germplasm and information. Contributions are made to sorghum breeding programs in Niger and Sudan both at the time of initial design of experiments as well as in assisting during evaluation of nurseries in the field.

Progress has been made in identifying sorghum lines with increased levels of drought resistance, some of which are currently being incorporated into breeding programs both in Niger and Sudan, as well as in the USA. Sorghum germplasm with superior grain mold resistance has also been identified and the physico-chemical basis of this resistance characterized.

Collaborative research on Striga resistance mechanism in sorghum has led to the identification of a chemical exudate associated with sorghum root hairs with capacity for the stimulation of Striga germination and haustorial initiation. The behavior of root growth and patterns of root distribution in some Striga resistant sorghum varieties has been associated with a possible avoidance mechanism of host-parasite interaction.

Institutional Linkages

PRF-107 project activities are focused primarily in two African countries: Sudan and Niger. Results from our efforts will, therefore, be of immediate relevance and important to the two countries. Both countries are primary sites for two major ecogeographic zones and hopefully research results generated in the two major sites will have relevance and use in neighboring countries.

Sudan

The Agricultural Research Corporation provides the primary linkage for research under PRF-107 as it does for most INTSORMIL activities in Sudan.

The main thrust of PRF-107 activities in Sudan is towards developing improved sorghum varieties and hybrids for use both in the rainfed and irrigated sectors. To this end primary collaboration is with the sorghum breeders, Dr. Abdellatif M. Nour and Dr. Osman Ibrahim. The specific mode of collaboration entails joint planning of specific studies, joint nursery evaluation, and germplasm exchange. This is achieved through visits both at the time of planning and at the time of nursery evaluation just before harvest. Such a mode of collaboration has been found to be mutually useful and provides a mechanism for a continual evaluation of germplasm developed in the U.S. to be evaluated for use in Sudan. Useful collaboration also exists with other ARC scientists, namely, Dr. Mohammed El Hilu Omer, sorghum pathologist and Dr. Abdel Jobar T. Babikher, Striga specialist.

In addition to ARC, a less formal but functional linkage exists with the National Seed Administration (NSA) in Sudan. With staff at NSA, efforts are directed towards development of a seed industry in Sudan.

Niger

Mutually useful collaboration has quickly developed with INRAN. The main contacts in Niger are the sorghum breeders, Mr. Mousa Adamou, INRAN sorghum breeder stationed at Maradi, and Dr. John Clark, Purdue Cereal Research Project Team Leader, located at Niamey. Our mode of collaboration in Niger is the same as that described for Sudan, i.e., joint participation at the planning of experiments and evaluation of genetic material in experimental fields. Specific areas for which support from INTSORMIL Project PRF-107 is provided to Niger are in breeding sorghum for drought resistance and in development and evaluation of experimental sorghum hybrids. Another area of collaboration with INRAN is in training of graduate students. Two Purdue graduate students, Mr. Issoufou Kapran, a Nigerien M.S. student and Mr. Dale Hess, a Ph.D. candidate, are currently in Niger conducting field thesis research at INRAN stations.

Objectives and Production/Utilization Constraints

Moisture stress is perhaps the single most important constraint to sorghum production in both Niger and Sudan. Sorghum germplasm accessions with good levels of drought tolerance, while available in various programs around the world, had not been widely used in research programs in Niger and Sudan. Practical methodologies for screening sorghum germplasm for drought

tolerance are also lacking. Breeding efforts to incorporate drought tolerance with higher than average yield potential are limited by lack of a rapid field screening procedure as well as lack of knowledge of sources of sorghum germplasm possessing useful traits.

Striga, a parasitic weed of major sorghum growing tropical countries is another major constraint to sorghum production. There is very little sorghum germplasm with resistance to Striga and the mechanisms that render resistance to Striga are unknown. Knowledge of inheritance of this trait is also scant.

One of the constraints limiting adoption and use of exotic early maturing, high yielding sorghum varieties in parts of West Africa is the susceptibility of exotic lines to grain mold causing fungi. Tall, late maturing, photoperiod sensitive local varieties completing their grain filling period after cessation of rains tend to escape grain deterioration problems in the field.

Project Objectives

To develop sorghum varieties and hybrids with increased levels of drought resistance.

To work out a methodology for screening and incorporation of drought resistance with high yield potential.

To conduct basic studies towards understanding the mechanisms of drought resistance in sorghum.

To conduct basic studies to determine the inheritance as well as understand the probable mechanisms associated with Striga resistance in selected sorghum varieties.

To identify superior sources of grain mold resistant sorghum lines.

In collaboration with colleagues in Sudan, to work towards development of a private seed industry to promote use of hybrid sorghums in Sudan.

Training of graduate students.

Project Output

Research Findings for Immediate Use

Grain mold of sorghum: Search for resistant germplasm within a working collection of tropical sorghums maintained at Purdue University resulted in identification of over 20 mold-free sorghum lines during the 1984 crop season. In 1985, a study was undertaken on the physico-chemical

characterization of sorghum kernels for resistance to various fungi pathogens that cause grain mold. Repeated sampling of sorghum panicles at different post-flowering stages indicated that, while several fungi complex (Alternaria, Aspergillus, Fusarium, Curuvlaria, etc.) can infect the sorghum kernels, time of infection, weather, and the virulence as well as the population dynamics of the various pathogens more significantly determine the level of damage of kernels in sorghum panicles. Among the chemical constituents studied, a simple chemical assay for a lower molecular weight phenols, flavan-4-ol's, is more useful for predicting weathering resistance than any other chemical assay including tannins.

Sorghum Striga: Collaborative research on control mechanisms of Striga, a parasitic weed of sorghum, has led to the isolation and identification of a compound from sorghum roots. The major component of the exudate is a unique quinone which has just been named sorgoleone. A large amount of sorgoleone extracted from roots of sorghum grown in petri dishes was used in a bio assay. The results indicate that sorgoleone is a powerful germination stimulant for Striga, the first identified from a natural host plant.

In a trial conducted to compare root systems of resistant and susceptible sorghum cultivars, we observed that the root length and surface area estimated using the Tenant line intercept method, of P-967083, a Striga resistant cultivar, was less than all other cultivars. In soil cores from the field, both Framida, another resistant cultivar, and P-967083 produced significantly less root length and surface area than the susceptible cultivar Dabar in the upper 10 cm. of the core. P-967083 produced significantly less roots than the other two cultivars in the 10-20 cm portion of the soil core. These results suggest that P-967083 root growth may contribute to resistance to parasitism by reducing host-root and Striga-seed in the upper horizons of the soil profile.

Research Progress for Future Use

Development of Sorghum Varieties and Hybrids for Niger and Sudan With Increased Levels of Drought Resistance

Germplasm lines are now available with superior early and post-flowering drought resistance and good adaptation to drought prone areas of Niger and Sudan. Breeding efforts are underway to improve the yield potentials of these lines through intercrossing of selected exotic and local sorghum varieties. The approach that appears to have the most immediate

potential is the use of these germplasm sources as R-line parents in hybrid combinations. Intercrossing will be made in the U.S. for evaluation under drought conditions in both Niger and Sudan. Hybrid combinations developed from lines that already have been evaluated for adaptation and drought tolerance are expected to have a better chance for immediate utility. The impact of such a hybrid will be particularly significant in Sudan where use of commercial hybrid sorghum is already under development. In Niger the focus is towards evaluating the potential as well as feasibility of commercial sorghum hybrids in the next three years.

Understanding the Inheritance and Mechanism of Striga Resistance in Sorghum

An interdisciplinary project is currently underway on basic studies on the genetic as well as the biochemical and physiological basis of Striga resistance in sorghum. A significant portion of this project is undertaken by Dale Hess, a Ph.D. graduate student. Sorghum varieties resistant to Striga have been identified in a collaborative field evaluation project in Sudan. These lines as well as susceptible varieties from Sudan are being used in the project. Basic biochemical and root anatomy investigations are done at Purdue University while field evaluation to generate genetic information has been pursued by Dale Hess in Niger since June 1986 where he is serving as a research associate in the Purdue Niger Cereal Research Project. It is expected that at the end of this study significant information will be generated that will be very valuable to the small community of Striga researchers.

Networking Activities

- Workshops and Reviews

INTSORMIL/INRAN/NCRP Sorghum and Millet Collaborative Research Workshop held in October, 1985.

Represented INTSORMIL at the International Drought Symposium on Food Grain Production in Semi-Arid Regions of Sub-Saharan Africa. Nairobi, Kenya. 19-23 May 1986.

Participated in the International Workshop on Seed Production in Latin America. El Batan, Mexico. 13-17 Oct. 1985.

- Germplasm and Information Exchange

An effective mechanism has been developed for germplasm exchange with cooperators both in Sudan and Niger. Type and extent of germplasm introductions to both Sudan and Niger from our project is decided upon either specific request from the collaborators or based on preliminary evaluation of small sets of nurseries introduced the previous season. Such an approach has been found to be satisfactory and workable. A number of early generation as well as advanced breeding sorghum lines were introduced to both Sudan and Niger. Such germplasm constitutes a significant part of the core breeding program in both INRAN and ARC. Likewise, useful local sorghums from Niger and Sudan have also been introduced for initial intercrosses to be made in the winter nursery in Puerto Rico.

A significant networking activity involving information exchange is developing through the efforts of this project and its collaborators. Using information accumulated on germplasm and environmental data from the INTSORMIL collaborative effort in Sudan, varieties and hybrids that showed potential in Sudan are suggested for testing in similar environments in Niger. Research methodologies (on drought tolerance for example) as well as results, therefore, are also shared across countries and zones.

- Project Visitors - 1985/86

Dr. Sam Mukuru	India
Dr. R. Jambunathan	India
Dr. Lee House	Zimbabwe
Mr. Idrissa Soumana	Niger
Mr. Mousa Adamou	Niger

Travel

International

- Niamey, Niger. June 16-July 2, 1986. Gebisa Ejeta. Plan and organize 1986 INTSORMIL/Niger collaborative research projects.
- Nairobi, Kenya. May 16-25, 1986. Gebisa Ejeta. Attend International Drought Conference; Kaboka Experiment Station to look at INTSORMIL Sorghum Nursery.
- Mayaguez, Puerto Rico. February 3-17, 1986. Terry Lemming. Pollinate the Purdue INTSORMIL Sorghum Winter Nursery at Isabella Station.
- Mexico City, Mexico. October 13-19, 1985. Gebisa Ejeta. Participate in Workshop on Sorghum Seed Production in Latin America.

- Wad Medani and Khartoum, Sudan. October 28-November 15, 1985. Gebisa Ejeta. To provide technical assistance on sorghum breeding and hybrid sorghum seed production to colleagues in the Gezira Research Station and National Seed Administration.
- Niamey, Niger. June 17-July 3, 1985. Gebisa Ejeta. Plan 1985 INTSORMIL Research in Niger and discuss the proposed INTSORMIL West Africa Workshop in Sept.-Oct. 1985.

Domestic

- Huntsville, AL, Atlanta, GA, and Kansas City, MO. August 10-18, 1985. Gebisa Ejeta. Attend NCRP 2nd Annual Workshop and present paper on "The Role of INTSORMIL in Developing Nations" (Huntsville and Atlanta). Attend INTSORMIL Ecogeographic Zone Council (EZC) meeting.
- Kansas City, MO. August 14-15, 1985. Gebisa Ejeta. To attend the INTSORMIL Ecogeographic Zone Council (EZC) Meeting.
- Washington, D.C. September 3-4, 1985. Gebisa Ejeta. Panel discussion review of AID and University experience with collaborative research support programs (Seventy-Second Meeting BIFAD).
- Lubbock, TX. October 8-13, 1985. Gebisa Ejeta. Evaluate and supervise graduate student research at Texas A&M Experiment Station.
- Lubbock, TX. October 8-14, 1985. Emmanuel Monyo. Harvest and take notes on sorghum drought line test.
- Chicago, IL. December 1-5, 1985. Gebisa Ejeta. Attend the American Society of Agronomy Annual Meetings.
- Washington, D.C. April 6-7, 1986. Gebisa Ejeta. Discuss sorghum/millet research plan for Sudan with USAID and Winrock Team.
- Washington, D.C. July 24-25, 1986. Gebisa Ejeta. Make a congressional presentation regarding Collaborative Research Programs.

Publications and Presentations

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Other Research Publications

Ejeta, G. 1985. Breeding sorghum varieties and hybrids with improved grain quality, drought resistance, and *Striga* resistance. Ann. Rep. Int. Sorghum and Millet Collaborative Res. Support Prog. Univ. of Nebraska, Lincoln, NE.

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Breeding for Productivity in Sorghum

Project TAM-121

Fred Miller

Texas A&M University

Principal Investigator

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Host Country Researchers

J. Mann (Kenya - INTSORMIL)

H. Saadan - (Tanzania - TARO)

D. Meckenstock - (Honduras - INTSORMIL)

G. Vega Z. - (Mexico - INIA)

J. Narro S. - (Mexico - INIA)

L. Romero H. - (Mexico - UANL)

R. Maiti - (Mexico - UANL)

S. Bedolla - (Mexico - UNSON)

M. Alvarez - (Paraguay - IAN)

J. Fehr - (Paraguay - Col. Menno.)

K. Heinz - (Paraguay - Col. Menno.)

A. Donoso E. - (Paraguay - Int. Amer. Credit for Agri.)

C. Paul - (Mexico - ICRISAT)

M. Lierda - (Brazil - IPA)

J. Clark - (Niger - INRAN)

Y. Kebede - Ethiopia

S. Da - Burkina Faso

V. Guiragossian - ICRISAT/SAFGRAD - Kenya

L. House - ICRISAT/SADCC - Zimbabwe

U.S. Researchers

W. Jordan, Investigator

R.J. Newton, Investigator and S. Kresovich, Investigator

Others

D.T. Rosenow - Texas A&M University - Breeder

R. Smith - Texas A&M University - Tissue Culture

R. Toler - Texas A&M University - Virology

G. McBee - Texas A&M University - Crop Physiology

Summary

Extensive evaluation of lines and hybrids from TAM-121 was completed in Honduras, Niger, Sudan, Paraguay, Mexico and other sites within five of the six ecogeographic zones described by INTSORMIL. In addition, breeding materials derived from elite x identified sources of resistance to stresses and sources of yield or quality were distributed, selected and used in collaborating countries. Major emphasis was placed on yield and agronomic stability with disease resistance and grain quality.

A synthetic (TRPSS) with proven high yield, excellent food quality, vitreous endosperm and agronomically desirable characteristics was released and has been widely distributed. Two inbred lines possessing desirable food and agronomic traits were also released for distribution. Several superior lines and hybrids were identified in trials. One cultivar merits special mention, SC1207-2-1-1, a partially converted San Bernardo from Guatemala which has given superior yield and adaptation in Niger. This same line possesses excellent food quality (tortilla), and drought resistance in Honduras and Mexico, as well as superior performance in Tanzania and Southern Africa.

Major breeding support, travel, supplies, cooperative evaluations, mutual planning and germplasm have been provided to host country collaborators in Honduras, E. Salvador, Mexico, Paraguay, Tanzania, Kenya, Niger, Burkina Faso, Ethiopia and Mali.

A total of 2859 germplasm items were distributed as well as 71 evaluation trials. These materials were deployed to strengthen host country breeding efforts and to determine ranges of adaptation and yield expression.

Glossy lines may have internal mechanisms which allow them to maintain growth under soil water stress. Glossy does not appear to be associated with major differences in root type.

Unlike sugars, organic acids, and potassium ions, proline accumulates in cells subjected to severe stress.

The Finlay-Wilkinson stability procedure was used to classify a large number of lines into drought vs. yield groups. The procedure has credibility when viewed with a knowledge of the materials tested. However, tissue culture evaluation with polyethylene glycol was not consistent with the stability classification.

Institutions

Collaborating Host Countries: Sudan - Agricultural Research Corporation (ARC); Tanzania -Tanzanian Agricultural Research Organization (TARO); Mexico - Instituto Nacional de Investigaciones Agricolas (INIA); Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT); International Crops Research Institute for the Semiarid Tropics (ICRISAT); University of Sonora (UNISON); Universidad Autonoma de Nuevo Leon (UANL); Honduras - Ministerio de Recursos Naturales (MRN); Paraguay - Institute Agronomia Nacional (IAN); Institute Interamericano de Cooperacion Para la Agricultura (IICPA); Colonia de Menonites (CM); Brazil - Empresa Pernambucana de Pesquisa Agropecuaria (EMBRAPA).

U.S.: Texas A&M University

Linkages:

Research on productivity is being carried out in Africa (Kenya, Tanzania, Sudan, Ethiopia, Mali, Niger/Burkina Faso and Zimbabwe) in mostly informal relationships. The project supplies materials under Memorandums of Agreement (MOA's) in Tanzania, Sudan, Mali and Niger; all other interactions are not formalized under MOA's. The informal collaboration with researchers in several African countries expands the effectiveness of the MOA's.

Sorghum productivity in Mexico is carried out under three MOA's and also informal collaboration with several universities. The research on productivity with UNISON, INIA and UANL are broad based and aimed at yield, quality and resistance to pests or other constraints. Collaboration with ICRISAT/CIMMYT is close and intended to share germplasm and information. There is also informal collaboration with the Consejo Latinoamericana de Investigadores en Sorgo (CLAIS) - an international organization of regional sorghum workers from throughout Latin America.

Paraguay and INTSORMIL have initiated a broad program to develop a sorghum industry with emphasis on sorghum for food, livestock feeding and forage production. A secondary program development which is evolving portends that sorghum will be used for alcohol production and other energy related projects. The primary and immediate result of the program is to introduce elite germplasm, establish ranges of production and potential and to strengthen internal seed production potentials.

The formal and informal agreements with the several agencies in both South American and African countries is aimed to ensure a broad stability to the characteristics of productivity and to distribute useful germplasm effectively over a larger part of the sorghum growing area and to gain useful information on the characteristics of stability of production in tropical environments.

Ecogeographic Zones Benefited Most by Research

The greatest impact from this project will come in Central America, South America, East and West Africa, with some effect in Southern Africa. The reason is that sorghums with tropical adaptation and appropriate disease resistance and food traits measured in these areas are similar. The benefits of sorghum breeding and improvement programs from several projects are blended into TAM-121, so this is a delivery project.

Objectives, Research Procedures, and Production/Utilization Constraints

The general objective is to create germplasm pools and lines with high yield potential, good food quality, and a high level of resistance to significant disease, pests and stress factors. For such material in the individual country and area breeding programs we derive lines, hybrids and varieties best suited to specific conditions. Materials already developed in this manner are coming into use in a number of countries, and are expected to have a significant role in enhanced production throughout the world where sorghum is important.

Project Objectives

Develop through breeding, selection and appropriate evaluation stable, high yielding, agronomically desirable sorghums with high levels of disease, insect and agronomic stress resistance, high grain quality with weathering resistance and resistance to environmental stresses.

Assess the role of secondary traits on the overall drought resistance of superior inbred lines and performance in hybrid form.

Determine effects of photoperiod and especially temperature on growth and development as related to productivity.

Determine the relationship between yield and photosynthetic ability.

Assessment and utilization of physiological measures of drought resistance to improve sorghum.

Distribute improved lines, hybrids and early generation populations possessing superior productivity to collaborating LDC's.

Develop specific germplasm pools and resources for use in impacting productivity in Mexico, Tanzania/Kenya, Honduras and South America.

Provide graduate training for co-workers in collaborating LDC's and to assist in training programs within the collaborating countries.

Changes in Objectives for Previous Year

No significant changes existed in project objectives from previous year's program since a breeding project is necessarily stable and objectives are long term.

Sorghum/Millet Constraints

Germplasm diversity of useful form.

High and stable yields.

High quality grain for food or feed use with high nutritional quality.

Pests and stress factors.

Research Procedures

These included standard selection procedures utilized in breeding nurseries, yields obtained from replicated yield trials, laboratory screening and evaluations done using both duplicate and replication procedures where possible. Early generation breeding materials were provided to several national programs. A tandem, step-wise rotation of selection and evaluation is then done between countries to ensure broad ranges of stability and adaptation.

Breeding materials derived from elite x identified sources of resistance to stresses and sources of yield or quality were evaluated in international trials for local adaptation and performance. Emphasis was placed on yield and agronomic stability with disease resistance and grain quality.

Crosses among identified superior yielding stable inbred lines were made with high grain quality lines with white grain, tan plant color and round vitreous grain.

Materials from TAM-122, 123, 124 and 126 are integrated into the yield, grain quality program and reselected with the combined traits specifically focused. Both preliminary and advanced generation materials are incorporated into trials for critical selection based on evaluation within

Texas or internationally where competent personnel are available to make evaluation.

Project Output

Productivity is defined as a measure of yield per unit area of production. Yield is constrained by risks associated with unstable production. Breeding is an effective way to address most of these constraints. The goal of TAM-121 is to create germplasm pools, lines and hybrids with stable potentially high yield, good food quality, a high level of resistance to significant diseases, pests and stress factors while maintaining acceptance and nutritional quality - then to make these materials available to collaborators to attack constraints to production.

A germplasm pool with a high level of food quality, vitreous endosperm, substantially reduced polyphenol level and good yield (TRPSS) has been released. This synthetic has a proven ability to perform in Honduras, Tanzania, Ethiopia, Mali and Burkina Faso, as well as in the United States.

The tan plant color, white grain hybrid ATx631 x RTx435, has been identified as possessing very high yield potential and stability under a wide range of environmental parameters. This hybrid has been specifically extracted from trials and placed in production in Southern Africa, Mexico, Argentina, Paraguay and Honduras.

The breeding line SC1207-2-1-1 (partially converted San Bernardo from Guatemala) has been shown to be superior in Niger (food quality, production potential, drought resistance), produces excellent tortilla's in Honduras and Mexico, and has demonstrated wide adaptation and high yield potential.

In Paraguay ATx378 x RTx430 has emerged as the highest yielding, most widely adapted grain hybrid and is going into production. Dorado has been widely accepted as a food sorghum with greater stability of yield than local maize and has been increased for distribution to members of local cooperatives and extension service projects. ATx623 x Greenleaf sudangrass and ATx623 x Hegari are both in pilot seed production plots after being identified as the most productive forage hybrids.

Over 600 selections were made from the NaOH screened food quality sorghum selections growing at Ilonga, Tanzania for immediate use in the SADCC sorghum trials and breeding activities. These materials have demonstrated high yields, very high food quality characteristics and superior disease resistance.

Both photoperiod and temperature have significant effect on most stages of plant growth. Percent change in grain yield for tropically adapted types over temperately adapted types ranged from 98% in Puerto Rico to -3% in Halfway, Texas. Tropically adapted types produce more leaves at a faster rate, senesce at a slower rate, maintain a greater leaf area and produce more biological yield.

ATx623 and ATx626 remain receptive to fertilization longer than other females tested. Average panicle yield reductions were significantly less for ATx623 and ATx626 than for other lines after 6, 9, and 12 days delay in pollination. At full anthesis ATx623 stigmas were significantly higher in carbohydrates than in ATx378 and ATx399.

Thirty-five International Tropical Adaptation Trials containing parent inbreds and hybrids were distributed to collaborating countries. These trials are used to identify yield constraints and which are superior hybrids in specific environments.

A total of 2859 germplasm items were distributed during this year. This includes, A/B, R-line inbreds, composites, synthetics, F_2 populations and partially inbred breeding stocks.

Several advanced A/B lines possessing high yield, white grain, tan plant color, tropical adaptation and high levels of disease resistance have been distributed to LDC's for further evaluation. These materials possess the yield and wide adaptation that exists in ATx623. Numerous R-lines have been identified which have tan plant color and white or yellow endosperm (white pericarp) which produce excellent food type sorghum grain hybrids with currently useful white grain, tan plant color, tropically adapted females.

The hybrid combination A155 (experimental number) x SC1207-2-1-1 has been identified as possessing the capability to produce tortillas with superior quality (equal to or superior to white maize). This combination will be increased for widespread testing (food and agronomy) in Honduras, El Salvador, and Mexico.

Two cultivars were released during the year which possess high levels of disease resistance, lodging resistance and general combining ability. Tx2816 has tan plant color, very yellow endosperm, white translucent pericarp and nonsenescence. Tx2817 possesses excellent food quality grain,

easy decortication, nonsenescence, white translucent pericarp, red plant color and non-tillering.

In addition to the 35 International Tropical Adaptation Trials (ITAT's) which were distributed, 11 International Sorghum Virus Nurseries (ISVN), and 25 productivity trials were sent to international locations. These trials were deployed to monitor virus incidence and to determine ranges of adaptation and yield potential expression among elite lines and hybrids.

In comparisons of F_1 hybrids made with A_1 and A_2 cytoplasmic genetic male sterility, it appears that equivalent heterosis % can be obtained with either system. The advantages of using A_2 appears to be (a) more lines are potential females in more than one taxonomic group and (b) greater potential exists for finding superior combining ability.

Research Progress

Breeding to increase or maintain productivity is of paramount importance. Such an effort blends the activities of many disciplines. Because sorghum is generally grown in areas where risks can be accomplished, it is necessary to develop germplasm resources which can be properly tested and deployed.

Evaluation of sorghum callus to determine drought tolerance (pre-flowering) using polyethylene glycol (PEG) appears to increase the probability of selecting drought resistant cultivars.

"Glossy" lines were compared to RS610 at two moisture levels, 0 and -15 bars soil water potentials. At high soil water content, no differences were apparent, but at the lowest soil water content, the glossy lines had superior shoot and root growth. The glossy lines studied may have internal mechanisms allowing maintenance of growth under soil and water stress.

Glossy does not appear to be associated with gross differences in root morphology. Epicuticular wax density and cuticular transpiration were measured on normal and glossy types. Glossy lines do not appear different from RS610 or non-glossy sister lines when grown with adequate water.

Leaf temperatures of inbred lines recorded at anthesis tended to be higher than those associated with hybrids. The hypothesis is that lower leaf temperatures associated with hybrids cause less fixed carbon to be respired in vegetative parts, therefore more carbon is available for grain fill. This mechanism may be a contributing factor to the heterotic response. If this relationship (with more testing) is valid, breeders may

be able to use infrared measurements to rapidly screen breeding lines for high grain yield potential.

Callus tissue has been used to measure the cellular basis for drought tolerance. Sugars, organic acids, and potassium ions were reduced when callus was subjected to mild or moderate drought. These reductions appeared to be associated with reduced growth. Lower levels of solutes were found in drought tolerant and higher levels in drought susceptible types. Proline behaves in a similar fashion. Unlike sugars, organic acids, and potassium ions, proline accumulates in cells subjected to severe drought stress. In the dark, comparing the controls shoot elongation was reduced nearly 70% in RTx3197 (susceptible) seedlings when stressed, but was reduced only 50% in RTx430 (resistant).

Virus concentration in the cell differs between cultivars. Various concentrations of the virus in the cell produce different magnitudes of damage to the plant. It appears that some cultivars are able of maintaining significantly higher virus concentrations without damage phenotypically.

Breeding selections from Mexico and Guatemala have been evaluated at several locations for stability of production. These materials are mostly high yielding, tan plant color, possess a wide array of plant type and are highly disease resistant. Hybrids with these lines using three females will be evaluated in numerous locations next cycle.

New early generation breeding lines which have combined yellow, waxy, and normal endosperm, tan plant color, and nonsenescence will be evaluated in numerous U.S. and LDC locations next cycle.

Based on results of food type hybrid evaluations in Texas, these trials will be expanded next cycle to include LDC sites. An International Food Type Sorghum Trial (IFTST) will be distributed within the five ecogeographic zones (Central America, South America, West Africa, East Africa, and Southern Africa) listed as impact areas of this project.

The broad concept of building elite F_2 or advanced breeding germplasm pools from which to select superior lines based on crossing elite parental materials with other elite lines and selecting in a step by step fashion will continue. These elite pools will be distributed to collaborating scientists in numerous international locations.

Networking Activities

- Workshops

Sorghum tortilla production and evaluation workshop, Hermosillo, Mexico.

Sorghum workshop - La produccion' de la Semilla de Sorgo in America Latina, El Batan, Mexico.

Sorghum breeding and quality workshop, Pergamino, Argentina.

First Sorghum Conference, Gatton, Queensland, Australia.

Sorghum production seminar, Filadelfia, Paraguay.

14th Biennial Sorghum Research and Utilization Conference, Lubbock, Texas.

Sorghum Disease, Insect and Production Workshop, Beeville/Corpus Christi, Texas.

- Germplasm and Research Information Exchange

Distributed 2859 germplasm items in the form of A/B lines, R-lines inbreds, composites, synthetics, F_2 populations, and partially inbred breeding stocks. In addition, 35 International Tropical Adaptation Trials, 11 International Sorghum Virus Nurseries and 25 productivity trials.

- Assistance to Host Country Researchers

Provided breeding nursery supplies (pollinating equipment) to collaborators in Honduras, Mexico, Paraguay, and Kenya/Tanzania.

Training

There is no doubt that training at the graduate level is the single most important activity of this research program. Without this activity and the young people to work in international agriculture for the future, we have nothing. The interdiscipline research atmosphere provided in this project lends training background of how to work productively when the student returns to the research arena.

Travel

- Paraguay. September 20-October 9, 1985. To meet with government officials and USAID staff. Plan work schedule and design data collection for project.

- Mexico. October 13-20, 1985. Presented information on production of hybrid seeds in developing countries. Evaluated sorghum trials and breeding materials throughout sorghum growing area.
- Chicago, Illinois. December 1-5, 1985. Participated in American Society of Agronomy meetings. Received the Frank N. Meyer Award.
- Puerto Rico. January 8-February 7, 1986. (Project Personnel) conduct winter sorghum nursery research.
- Australia. January 29-February 16, 1986. Presented Keynote address to First Australian Sorghum Conference. Presented numerous seminars throughout sorghum growing areas of Australia.
- Paraguay. February 20-March 1, 1986. Evaluated sorghum trials, collected data on disease, insect screening nurseries. Presented workshop to PROSORGO at Pergamino on state-of-art inbreeding and quality.
- Paraguay. May 18-24, 1986. Developed work plan for next crop cycle, and presented this to USAID, Ministry of Agriculture and U.S. Ambassador.

Publications

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Perez, German Jose. 1985. Combining ability and heterosis studies for adaptation in newly developed male and female inbreds of sorghum, Sorghum bicolor L. Moench. Ph.D. dissertation. Texas A&M University, College Station, Texas.

Jaster, John R. 1985. Analysis of seed set and stigma receptivity among cytoplasmic male sterile sorghum (Sorghum bicolor L. Moench) cultivars. M.S. thesis. Texas A&M University, College Station, Texas.

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Changes in Year 8

Basic research plans will continue in Year 8. However, a few modifications will be made. These include:

Implement an International Food Type Sorghum Trial (IFTST) which will be aimed at the major ecogeographic zones (except India). This trial will include high yield potential, disease resistant, tropically adapted, tan plant color, white grain types to determine ranges of adaptation, stability of yield and local acceptance.

More intensive evaluation of the "glossy" trait lines will take place to determine their role in drought tolerance.

More international testing will take place on graduate student thesis problems.

Breeding for Disease and Drought Resistance and Increased Genetic Diversity

Project TAM-122

D.T. Rosenow

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Dan Meckenstock, Sorghum Breeder, INTSORMIL/SRN, Honduras

Rigoberto Nolasco, Head, Sorghum Investigations, SRN, Honduras

Francisco Gomez, Sorghum Breeder, SRN, Honduras (Summer-1986)

Abd Ellatif M. Nour, Sorghum Breeder, ARC, Sudan

Osman Ibrahim El Obeid, Sorghum Breeder, ARC, Sudan

M.E. Hilu Omer, Pathologist, ARC, Sudan

Moussa Traore, Physiologist, SRCVO/DAR/IER, Mali

Issaga Moriba Konate, Sorghum Breeder, SRCVO/DAR/IER, Mali

Oumar Niangado, Millet Breeder, SRCVO/DAR/IER, Mali

John Scheuring, Sorghum Breeder, ICRISAT/USAID, Mali

John Clark, Sorghum Breeder, INRAN/Purdue, Niger

Moussa Adamou, Sorghum Breeder, INRAN, Niger

Other Researchers (Host Country and U.S.)

J. Narro S., Pathology Breeding, INIA, Mexico

V. Guiragossian, Sorghum Breeder, ICRISAT/CIMMYT, Mexico

S.M. Farah, Physiology, ARC, Sudan

L.R. House, Sorghum Breeder, SADCC/ICRISAT, Zimbabwe

Tunde Obilana, Sorghum Breeder, SADCC/ICRISAT, Zimbabwe

R.E. Schaffert, Sorghum Breeder, EMBRAPA, Brazil

L.M. Gourley, Sorghum Breeder, Mississippi State University
D. Carter, Agronomist, Botswana
M. Mengesha, Germplasm, ICRISAT
R.K. Maiti, Physiology, ICRISAT
J. Mann, Sorghum Breeder, Kenya/TAMU
R.A. Frederiksen, Pathologist, TAMU
F.R. Miller, Sorghum Breeder, TAMU
G.C. Peterson, Sorghum Breeder, TAMU/TAES - Lubbock
L.W. Rooney, Cereal Chemist, TAMU
G.N. Odvody, Pathologist, TAMU/TAES - Corpus Christi
G.L. Teetes, Entomologist, TAMU
C.W. Wendt, Soil Physicist, TAMU
Gebisa Ejeta, Sorghum Breeder, Purdue University
J.D. Axtell, Sorghum Breeder-Quality, Purdue University
L. Claflin, Pathologist, Kansas State University
D.J. Andrews, Sorghum & Millet Breeding, University of Nebraska
J.D. Eastin, Physiologist, University of Nebraska
Mamourou Diourte, TAMU Graduate Student, Mali
Aden Ossoble, Texas Tech Graduate Student, Somalia
Verne Isbell, TAMU Graduate Student, USA/Mali
Emanuel Monyo, Purdue Graduate Student, Tanzania

Summary

A dual purpose sorghum variety called Sureño, which was selected in Honduras from material originally selected and distributed by TAM-122, was released in Honduras in 1985. The variety possesses high grain yield potential, white, food type-grain with excellent quality for tortillas and atole and grain which has resistance to grain mold, weathering, and to the maize weevil. It has good resistance to downy mildew and several leaf diseases. The stalks are juicy and sweet.

The new "stay-green" male sterile line, A35, performed extremely well in hybrid combination in the U.S. and LDC's, and has been distributed for immediate testing. Hybrids with this line possess excellent post-flowering drought tolerance and are very resistant to post-flowering lodging and charcoal rot.

New drought tolerant B lines (derived from B35 x Tx623 type crosses) with excellent pre- and post-flowering drought tolerance have been

identified, sterilized, and tested in experimental hybrids. Seed of the A & B lines and experimental hybrids has been sent to Sudan and other countries for testing. Enhanced lodging and charcoal rot resistance should be of immediate value in Sudan, where an improved version of Hageen Dura 1 could possibly be produced with these new male sterile lines.

A synthetic food-type population called TRPSS (Texas Reduced Polyphenol Sorghum Synthetic) was released and distributed. It is a heterogeneous germplasm source with white, vitreous, non-staining grain of good food quality, weathering resistance, reduced polyphenol content, and good yield.

Several disease resistant sorghum lines are being proposed for release. Many have already been distributed to LDC workers. They contain new sources and high levels of resistance to downy mildew, charcoal rot, head smut, grain mold, anthracnose, rust, gray leaf spot, zonate leaf spot, Fusarium head blight, and MDM. Two hundred and forty fully converted lines from the Sorghum Conversion Program were released for distribution. They contain great genetic diversity in germplasm usable world wide, and are excellent and new sources of resistance to disease, insect pests, and drought stress.

Institutions

Collaborating Host Country: Sudan - Agricultural Research Corporation (ARC); Honduras - Secretary of Natural Resources (Recursos Naturales) (SRN); Mali - Institute of Rural Economy (IER), Division of Agronomic Research (DAR), Food Crops Research Section (SRCVO); TROPSOILS; ICRISAT/USAID Mali; Niger - Niger National Institute for Agricultural Research (INRAN); Purdue NCRP/INRAN

Secondary Collaborative Institutions: Mexico (INIA, ICRISAT/CIMMYT), Brazil (EMBRAPA), Southern Africa (SADCC/ICRISAT), Colombia (MSU/CIAT), India (ICRISAT), Paraguay (IAN), Kenya (Min. of Agriculture).

U.S.: Texas A&M University, University of Nebraska, Purdue University, Kansas State University, Mississippi State University, University of Georgia, USDA-Puerto Rico.

Linkages:

Collaborative research agreements (MOU's) exist with Sudan (ARC), Honduras (SRN), Mali (IER, DAR) and Niger (INRAN). Research emphasis is on identification of sources and breeding for drought resistance and disease resistance. Also important is training, technical assistance, and

collection of native exotic sorghums for introduction and use in the U.S. Research consists of germplasm exchange and evaluation, testing, and selecting in both the host country and U.S. Also of vital importance is the development of elite breeding materials in the U.S. by crossing U.S. sources or elite lines with exotic sources followed by distribution of early generation segregating materials to the host countries for selection, breeding, and evaluation under the local environments. There also are short-term visits by U.S. scientists to host countries and by host-country scientists to the U.S. for training, evaluation of research, and developing collaborative research plans.

The project supplies disease and drought resistant materials as well as other germplasm to many other countries where formal MOU's exist, e.g., Mexico, Brazil, and Paraguay, as well as to many African, South and Central American, and Asian countries where no formal MOU's with INTSORMIL exist.

Extensive linkages exist with all other Texas projects and with the Purdue program in Niger and Sudan. Linkages involving screening, evaluation, and germplasm exchange exist with principal investigators in Nebraska, Kansas, Mississippi, and Georgia.

Ecogeographic Zones Most Benefited by Research

East Africa (Sudan), Central America (Honduras)/Mexico Caribbean, and West Africa (Mali, Niger).

Objectives, Research Procedures, and Production/Utilization Constraints

Project Objectives

Screen and evaluate in the U.S. and host countries, sorghum germplasm sources for resistance to diseases and drought tolerance.

Develop high yielding cultivars with disease resistance to internationally important diseases with emphasis on downy mildew, charcoal rot, grain mold (weathering), anthracnose, head blight, viruses, and acremonium wilt.

Develop through breeding and selection, agronomically desirable types with superior combinations of pre- and post-flowering drought tolerance for use in the U.S. and host countries.

Develop cooperative disease and drought trials and distribute, evaluate, and utilize improved disease and drought resistant breeding materials and new germplasm sources in host countries.

Develop and distribute early generation breeding materials involving disease and drought resistance specifically for selection and use in host countries with emphasis on Honduras, Sudan, Mali, and Niger.

Collect new sorghum germplasm, including wild species, and evaluate it for useful traits and introgression.

Using tissue culture techniques, select for cultivar differences for drought tolerance at the cellular level and relate findings to whole plant (field) tolerance.

Changes in Objectives from Previous Year

More emphasis in program on developing early generation breeding materials with disease and drought resistance specifically for selection and use in host countries. Added research on new germplasm, especially wild species.

Sorghum/Millet Constraints

Diseases and drought are serious constraints to sorghum production worldwide. Drought stress is the major constraint to sorghum and millet production in the world as well as in the U.S. Large differences exist among sorghum cultivars in their reaction to drought and performance under drought stress, therefore, much progress is possible in developing improved varieties with enhanced levels of drought tolerance. Texas has a semiarid environment plus high temperatures and is ideal for large scale field screening and breeding for improved drought tolerance. It has been verified that lines with identified high levels of specific types of drought tolerance in Texas, such as pre- or post-flowering drought tolerance, perform as expected regarding drought response in such countries as Sudan, Mali, Niger, and India.

Diseases are often region or site specific, and on-site evaluation is necessary to determine severity and possible race differences. Most of the internationally important diseases are present and are serious constraints in Texas, especially downy mildew, charcoal rot, grain mold (weathering), head blight and MDM virus. Many other diseases such as head smut, leaf blight, rust, zonate, gray leaf spot, and acremonium wilt are also present in Texas. The Texas environment is an ideal site for screening and breeding sorghums with high levels of resistance to most internationally important diseases.

Major host countries of collaboration which will involve TAM-122 researchers are Sudan, Honduras, Mali, and Niger. The major constraint in much of Sudan is drought, and drought related production problems. Moisture stress related charcoal rot and subsequent lodging is a serious disease problem. In Honduras, diseases are a major constraint, including downy mildew, grain mold (weathering), foliar diseases, and the recently identified disease, acremonium wilt. The food quality-weathering resistance complex is also important. Drought is also important in Honduras and the Central American Region. Improvement in the photoperiod sensitive, food-type maicillos criollos is a unique challenge, and most of the breeding and selection must be done under host country conditions. Improvement in the combine-type sorghums used over much of Central America can often result directly from introduction of Texas adapted germplasm. Mali and Niger are both drought prone areas, thus, drought tolerance, including both the pre- and post response, is extremely important to both countries. The sorghums of West Africa are unique, and improved high yielding introductions often fail due to the grain quality - head bug - grain mold complex, stand establishment problems, or improper maturity. Thus, much of the collaborative research in West Africa consists of providing source materials along with studying the traits of the West African Guineense type sorghums which make them uniquely adapted to the more humid areas of West Africa. In the drier, northern areas of Mali and in Niger where drought stress is severe, earlier, less-photosensitive material is needed, and the non-Guinea sorghums generally perform well. In these areas, U.S. developed drought tolerant materials may have direct application.

There is a constant need for new diverse sources of resistance to pests, diseases, and environmental stresses. New collections, including wild species, can provide new sources of desirable traits.

Research Procedure

Converted and partially converted lines from the Sorghum Conversion Program, exotic lines, new introductions, and breeding materials were screened and evaluated for sources of resistance to internationally important disease in a cooperative program with pathologists. Emphasis is on large disease screening nurseries utilizing natural infection in South Texas, with laboratory screening for certain diseases. Large field drought screening nurseries in West Texas were used to screen germplasm, similar to

that described above, for drought tolerance. Selected materials were evaluated for disease and drought at several host country sites.

Breeding material was generated from crosses among various disease resistant sources, agronomically elite lines, and new sources of disease resistance. The material was screened and selected in large field disease screening nurseries described above. Advanced generation materials were incorporated into various standard, replicated trials for more critical and extensive evaluation at several locations in Texas, other states, and in other countries where diseases and competent personnel exist.

Crosses among identified sources of drought tolerance (i.e., pre- and post-flowering drought tolerance) and elite, high yielding lines were made. Progeny were selected under field conditions for pre- and post-flowering drought tolerance at several locations in Texas which vary in their degree and time of moisture and heat stress.

Selected materials from the disease resistance and drought resistance breeding programs were distributed to LDC host countries and selected developed countries for selection and use. Standard replicated disease and drought trials were developed collaboratively with other INTSORMIL researchers. Seed was increased, and tests packaged at Lubbock. Tests were distributed to collaborators in host countries, as well as to many U.S. sites and collaborators, for evaluation for disease or drought resistance, and for use in their improvement programs.

Introductions from LDC's, including locals and improved breeding lines with desirable drought or disease resistance, or specific grain or plant traits, were crossed in Texas to appropriate elite U.S. lines and elite breeding materials. Seed of early generations was sent to the LDC's, especially in Honduras, Sudan, Mali, and Niger for selection of appropriate traits and adaptation. Assistance was provided, as time and travel permitted, in the selection and evaluation of such breeding material in the host country.

New germplasm was introduced through the quarantine greenhouse, and evaluated in Puerto Rico and Texas for useful traits. Some crosses were made of wild species with cultivated types to study crossability. Some of the introductions were collected by the P.I. from Niger, Mali, Sudan, and Honduras. Based on known traits, or upon evaluation in U.S., selected lines are entered into the cooperative TAES-USDA Sorghum Conversion Program.

A study of the comparison of field and *in vitro* tissue culture screening (using PEG to create osmotic stress) for drought resistance was completed. Callus from two cultivars in culture under PEG induced stress was extensively evaluated physiologically and chemically for comparison with whole plants. Screening for somaclonal variation was done on the first and second sexually derived progeny from an individual plant derived from cell culture, by evaluating eight agronomic traits.

Problems Regarding Achievement of Objectives

Fund reductions during the year and uncertain funding for the future were harmful. Unknown soil problems in Mali and Niger hindered the evaluation for drought tolerance in breeding materials.

Project Output

Research Findings

A sorghum variety, called Sureño, originally selected and distributed by this project, was released as a dual purpose grain/forage cultivar in Honduras in 1985. The variety has high grain yield potential, excellent grain quality for tortillas and atole, and resistance to downy mildew leaf diseases. The grain also has resistance to grain mold and weathering and to the maize weevil. The original selections were made at Lubbock, and it was evaluated in the TAM-122 developed GWT (Grain Weathering Test). It was sent to Honduras in 1982 as part of the TAM-122/Honduras collaborative program. The pedigree is [(SC423xCS3541)E35-1]-2 and the original material was supplied to us by Vartan Guiragossian (ICRISAT/CIMMYT). This variety, also known as VG146 and 82GWT-210, also has looked excellent in Philippines and Kenya (personal communication from Jerry Maranville and John Mann, respectively).

A synthetic food-type sorghum population called TRPSS (Texas Reduced Polyphenol Sorghum Synthetic) was released and distributed in cooperation with F. Miller (TAM-121) and L. Rooney (TAM-126). It is a heterogeneous germplasm source with white, vitreous grain of good food quality and weathering resistance, reduced polyphenol content and good yield. It contains a broad range of plant height, and other plant and panicle characteristics and should be useful for direct selection and use or in breeding programs.

Two hundred and forty fully converted lines (out of World Sorghum Collection) from the Sorghum Conversion Program were released for distribution. These are diverse germplasm source materials for use in breeding programs worldwide. These lines are excellent sources of resistance to anthracnose, downy mildew (pathotype 3), midge, drought, charcoal rot, and lodging, as well as many other desirable grain and plant traits.

New drought tolerant B lines (derived from "stay-green" x Tx623 type crosses) with excellent pre- and post-flowering drought tolerance have been identified, sterilized, and used in production of experimental hybrids. Seed of the lines and experimental hybrids were sent to Sudan, Mali, and Niger for immediate testing and use to produce hybrids with enhanced levels of the "stay-green" trait or post-flowering drought tolerance, charcoal rot, and lodging resistance. Enhanced lodging and charcoal rot resistance should be of immediate value in Sudan, where an improved version of Hageen Dura-1 could possibly be produced through use of a new "stay-green" female.

Results of a standard drought tolerance test under dune soils in Niger (cooperative with G. Ejeta and E. Monyo-Purdue) indicated that certain hybrids could possibly be used directly in the drier areas of West Africa. The Sudanese hybrid, Hageen Dura-1, was the best entry (1.7 rating) in the test, and was superior to the best local dune type varieties Bagoba and Babadia Fara (2.1 ratings). Two other introduced lines, P898012 and P954035 looked excellent with a 2.0 rating. These had been previously identified as having excellent pre- and post-flowering drought tolerance in West Texas, Sudan, and at other locations in Niger.

A new line, SC1207-2, was identified as a superior line in Niger and has been crossed into many Niger breeding materials. It was derived from the cross, Tx2817 x San Barnado (a Honduran Maicillos Criollos), and sent to Niger by F. Miller (TAM-121). This line was also identified as producing excellent hybrids with grain that possesses outstanding tortilla quality traits, which could have direct application in the Central America/Mexico region.

The new "stay-green" male sterile line, A35, performed extremely well in hybrid combinations under severe drought stress in 1985. The hybrids possess excellent post-flowering drought tolerance and are very resistant to post-flowering stress lodging and charcoal rot. The hybrid A35 x Tx430

topped the Dryland Statewide Hybrid Performance Tests at Lubbock and Halfway, and at Chillicothe yielded almost twice as much as ATx399 x Tx430, a commonly used commercial hybrid. Previous observation plantings of hybrids with this A-line in Sudan showed excellent drought tolerance. This A-line has been sent to breeders in Sudan for their possible use there. Under severe moisture stress in Paraguay in 1985, A35 hybrids were standing about 100% while all other hybrids were completely lodged. The line was derived from a partially converted (BC1) selection of SC35, an Ethiopian Durra, IS12555. The line is being proposed for release as A & BTx633.

Several disease resistant sorghum lines with good agronomic traits are being proposed for release. They contain resistance to downy mildew (pathotype 3), charcoal rot, head smut, grain mold, leaf blight, anthracnose, gray leaf spot, rust, zonate leaf spot, Fusarium head blight, and MDM. The lines include such entries as SC326-6, R6956, R4244, R3224, R3338, R9188, R4317, R6078, A & B4R, 80B2982, 1790E, NSA440, and BDM499.

Research Progress

Approximately 30 new F_2 populations involving elite U.S. lines and recently selected drought tolerant selections from Sudan were produced and selected. F_2 and F_3 seed is available for planting and selecting in host developing countries.

New early generation breeding selections containing P3 downy mildew resistance from several new sources were made and look very promising. After verification of their downy mildew resistance in laboratory screening, several will be released as new germplasm.

Early generation germplasm was developed for distribution and use in host countries. This contained crosses among U.S. elite lines, drought tolerant Guineense lines from West Africa, new drought tolerant converted lines, new disease resistant converted lines (anthracnose, downy mildew, grain mold), and food type sorghums.

One hundred additional accessions of wild sorghum species were introduced and crossability of some of these with *S. bicolor* have been determined. Analyses of constraints to introgression are being made.

Eighteen Maicillos Criollos out of the 48 introduced into the U.S. were entered into the Sorghum Conversion Program. Twenty-eight new lines (native varieties and elite breeding lines) were collected in Sudan, Niger, and Mali and introduced into the U.S.

Over 100 new R-lines and several new B-line materials containing B35, all developed in the drought breeding program, were evaluated over Texas for combining ability and tested for disease resistance and adaptation. Many showed very good performance and merit additional extensive testing.

Field evaluation for drought resistance, yield, yield stability and other traits was conducted at four field locations for 94 elite U.S. and TAES breeding lines and cultivars. Forty-three of those lines were also evaluated *in vitro* on a PEG screening medium. Preliminary statistical analysis to determine the relationship between *in vitro* and field performance is encouraging. About 75% of the best entries *in vitro* were in the top 50% of the field ranked entries. Evaluation for somaclonal variation continued with inconclusive results. Callus from two cultivars grown on differing levels of PEG is undergoing detailed chemical and physiological analysis for comparison with whole plant analysis in order to study mechanisms of osmotic adjustment.

Networking Activities

- Workshops

Participant and presented invited paper at the INRAN/INTSORMIL/NCRP Sorghum and Millet Workshop, October 14-17, 1985, Niamey, Niger.

Participant and presented invited paper at the Second West African Regional Sorghum Workshop, October 21-24, 1985, Bamako, Mali.

Participant and presented invited paper at the OAU/STRC/SAFGRAD International Drought Symposium, May 19-23, 1986, Nairobi, Kenya.

- Investigator Exchange

Issaga Moriba Konate, Sorghum Breeder, Mali, at Lubbock, Sept. 15-19, 1985.

Abd Ellatif M. Nour, Sorghum Breeder, Sudan, at Lubbock, Oct. 2-12, 1985.

Emanuel Monyo, Purdue Graduate Student, Tanzania, at Lubbock, July and August, 1985.

Laurence M'Ragwa, Millet Breeder, Kenya, Aug. 15-23, 1986.

Zana Sonago, Chief, DAR, Mali, July 10, 11, 1985.

Jose Sifuentes (Mexico) and Mamourou Diourte (Mali), TAMU Graduate Students, August and October, 1985.

Janos Berenji (Yugoslavia); Fran Bidinger (ICRISAT); John Peacock (ICRISAT); Qui Chengjian, Zhao Jinliu, Zhang Wenyi, Xin Huajum, Mei Jiren (Peoples Rep. of China); Idrissa Soumana, Salifou Mamane, Cisse Amadou, Allele Elhadji Halibou (Niger); Asgrow Seed Co. International Group; Steveen Harbert (Australia); Willie Schidel (Argentina); Pioneer International Breeders; K.V. Ramiah (ICRISAT).

October 13-18, 1985, Niger. D. Rosenow. Research evaluation and plans, and Sorghum Millet Workshop.

October 19-26, 1985, Mali. D. Rosenow. Research evaluation and future research and West African Regional Workshop.

October 29-November 11, 1985, Sudan. D. Rosenow. Assist AID and ARC in five year sorghum and millet research plan, plus nursery evaluation and future planning.

December 11-18, 1985, Honduras. D. Rosenow. Evaluation of program and research plots and future research plans.

May 18-24, 1986, Kenya. D. Rosenow. International Drought Symposium and research plot evaluation.

Verne Isbell, Ph.D. Graduate Student, to Mali, August-October 1985. Physiological equipment use, and physiology-drought research in Mali.

- Germplasm, etc., Exchange

Numerous germplasm lines and sources were distributed to Mali, Niger, Sudan, Honduras, and Mexico for mutual evaluation, selection, and information exchange. Germplasm was also sent to El Salvador, Brazil, SADCC, Kenya, Botswana, and Paraguay, plus many other non INTSORMIL collaborating countries such as Venezuela, Argentina, and Australia.

Germplasm was collected in Mali, Niger, and Sudan and introduced into the U.S.

- Equipment, Other Support

Procured physiology equipment cooperative with ICRISAT (hydraulic press, infared thermometer, Licor porometer), tested it in Texas, and transported to Mali (Verne Isbell), and in Mali, trained Malian scientists to use equipment. Paid for portion of Abd Ellatif Nour (Sudan) travel in U.S.A.

Procured and sent pollinating equipment and supplies to Honduras for INTSORMIL/SRN collaborative research use.

Travel

International

- Niger. October 11-18, 1985. D.T. Rosenow. INRAN/INTSORMIL/NCRP Sorghum Millet Workshop, present paper, and review INTSORMIL/Niger research.
- Mali. October 19-26, 1985. D.T. Rosenow. ICRISAT/SAFGRAD Second West African Regional Sorghum Workshop, present paper, and review INTSORMIL/ Mali research.
- Sudan. October 29-November 11, 1985. D.T. Rosenow. Assist USAID and ARC in writing a five year sorghum and millet research plan for Sudan, evaluate INTSORMIL/ARC collaborative research, and evaluate hybrid seed production.
- Honduras. December 11-18, 1985. D.T. Rosenow. Evaluate INTSORMIL/ Honduras collaborative research, and discuss Convenio revision.
- Kenya. May 24-June 1, 1986. D.T. Rosenow. International Drought Symposium and present paper, and evaluate INTSORMIL/Kenya cooperative sorghum nurseries.

Domestic

- Puerto Rico. January 15-February 3, 1986. C.A. Woodfin (Res. Assoc.) Cross in Winter Nursery.
- Puerto Rico. March 17-31, 1986. D.T. Rosenow, Truett Moore (Res. Assoc.-Chillicothe) Harvest Winter Nursery.
- South Texas (Corpus Christi). July 9-26, 1985. D.T. Rosenow. Harvest disease and breeding nurseries.
- College Station, TX. August 6-8, 1985. D.T. Rosenow. Meet G. Vollmar and D. Meckenstock to plan Honduran workshop.
- Kansas City, MO. August 14-15, 1985. D.T. Rosenow. Attend INTSORMIL EZC meeting.
- College Station, TX. January 5-9, 1986. D.T. Rosenow and C.A. Woodfin. TAES Staff Conference, and plan 1986 INTSORMIL research.
- Kansas City, MO. January 13-15, 1986. D.T. Rosenow. Attend INTSORMIL EZC meeting.
- Kansas City, MO. March 2-3, 1986. D.T. Rosenow. Attend INTSORMIL Board meeting.
- Kansas City, MO. March 19-20, 1986. D.T. Rosenow. Attend INTSORMIL EZC meeting.

- Kansas City, MO. May 12-13, 1986. D.T. Rosenow. Attend INTSORMIL EZC meeting.
- Washington, D.C. June 23-24, 1986. D.T. Rosenow. Attend JCARD meeting on CRSP activities.
- Corpus Christi, TX. June 25-26, 1986. D.T. Rosenow. Participate in South Texas Sorghum Field Day.
- Several other short trips by TAMU researchers within Texas for graduate student examinations, working nurseries, and taking notes.

Publications and Presentations

Publications

Frederiksen, R.A., D.T. Rosenow, D. Collins, and J. Craig. 1986. Registration of 6 bulks of downy mildew resistant sorghum germplasm. Crop Sci. 26:208-209.

Newton, R.J., S. Bhaskaran, J.D. Puryear, and R.H. Smith. 1986. Physiological changes in cultured sorghum cells in response to induced water stress. Plant Physiol. 81:626-29.

Krieg, D.R. and D.T. Rosenow. 1985. Genetic variation in gas exchange characteristics of Sorghum bicolor (L.) Moench. Proc. 14th Biennial Grain Sorghum Res. & Util. Conf. (SICNA) Feb. 17-20, 1985, Lubbock, TX. p. 51.

Clark, L.E. and D.T. Rosenow. 1985. Evaluation of sorghum hybrids under moisture stress. Proc. 14th Biennial Grain Sorghum Res. & Util. Conf. (SICNA). Feb. 17-20, 1985, Lubbock, TX. p. 86.

Pawar, M.N., R.A. Frederiksen, L.K. Mughogho, J. Craig, D.T. Rosenow, M.R. Bonde. 1985. Survey of virulence in Peronosclerospora sorghi isolates from India, Ethiopia, Nigeria, Texas (USA), Honduras, Brazil, and Argentina. Proc. 14th Biennial Grain Sorghum Res. & Util. Conf. (SICNA) Feb. 17-20, 1985, Lubbock, TX. p. 130.

Smith, R.H., S. Bhaskaran, S. Paliwal, and K. Schertz. 1986. Somaclonal variation from sorghum cell culture. 6th Int. Cong. of Plant Tissue Culture, Minnesota. Abstract.

Reilly, A.R., L. Panella, and R.H. Smith. 1986. Examination of osmotic tolerance and its inheritance in Sorghum bicolor (L.) Moench using a PEG screening technique. 6th Intl. Cong. of Plant Tissue Culture, Minnesota. Abstract.

Omer, M.E.H., R.A. Frederiksen, and D.T. Rosenow. 1985. Collaborative sorghum disease studies in Sudan in 1984. Sorghum Newsletter 28:93-94.

Rosenow, D.T., L.E. Clark, K.F. Schertz, and R.H. Smith. 1986. Breeding for Disease and Drought Resistance and Increased Genetic Diversity. p. 69-73. In: Fighting Hunger with Research. A 5-Year Technical Report of INTSORMIL, July 1, 1979-June 30, 1984. 225 p.

Presentations

Rosenow, D.T. 1985. Research on drought tolerance in sorghum. Proc. Second West African Regional Sorghum Workshop, Oct. 21-24, 1985. Bamako, Mali. (In Press).

Rosenow, D.T. and Gebisa Ejeta. 1985. Techniques and concepts on collaborative drought tolerance research sorghum in West Africa. Proc. INRAN/INTSORMIL/NCRP Sorghum and Millet Workshop, October 14-17, 1985, Niamey, Niger. (In Press).

Rosenow, D.T. 1986. Breeding sorghum for drought resistance. Proc. OAU/STRC/SAFGRAD International Drought Symposium, May 19-23, 1986, Nairobi, Kenya. (In Press).

Seminars by R.H. Smith on Sorghum Cell Culture Screening at Monsanto and Kansas State University.

Changes in Year 8

No major changes in breeding for disease and drought resistance programs, but expand the distribution of F_2 and F_3 seed of specific crosses for selection and use in host countries. The objective dealing with tissue culture involving Roberta H. Smith will be eliminated, due to the Board action in eliminating her from funding in Year 8. Keith Schertz was also eliminated from direct funding by the project in Year 8, however, the project leader will continue some cooperative research on new germplasm and evaluation of traits with Dr. Schertz with less emphasis on wild types and more emphasis on cultivated types.

Increasing Resistance to Insects and Improving Efficient Nutrient Use by Genetic Manipulation for Improved Grain Sorghum Production

Project TAM-123

G.C. Peterson and A.B. Onken

Texas A&M University

Principal Investigators

Dr. G.C. Peterson, Assistant Professor - Sorghum Breeding

Dr. A.B. Onken, Professor - Soil Fertility

Collaborating Researchers

Host Country

- Midge Resistance

  Dr. Dan Meckenstock, INTSORMIL, Honduras

  Mr. Rigoberto Nolasco, Recursos Naturales, Honduras

  Dr. Fransisco Gomez, Recursos Naturales, Honduras

  Ing. Rafael Reyes, CENTA, El Salvador

  Ing. Rene Clara, ICRISAT, Mexico

  Dr. Jose Waquil, EMBRAPA, Brazil

  Dr. C.J. Rossetto, EMBRAPA, Brazil

  Dr. R.G. Henzell, Queensland Dept. Primary Industries, Australia

- Sugarcane Aphid

  Mr. C.S. Manthe, DAR, Botswana

- Efficient Nutrient Use

  Dr. Moussa Traore, DAR, Mali

  Dr. Oumar Niangado, DAR, Mali

  Mr. Mamadou Simpara, DAR, Mali

  Mr. Mamadou Doumbia, DAR, Mali

  Dr. Bob Chase, AID Farming Systems Project, Mali

United States

Dr. G.L. Teetes, Entomology, Texas A&M University (TAM-125)

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Dr. C.W. Werdt, TROPSOILS, Texas Agric. Exp. Station

Summary

Progress continues in the development of grain sorghum lines and hybrids with improved levels of resistance to midge and greater yield potential. Elite lines are in the latter stages of development which will produce in hybrid combination good yields under heavy midge infestation. Some new resistant experimental hybrids appear to have the potential to outyield the best susceptible hybrids without midge present under certain conditions. Research continues to combine sources of resistance into a single genotype utilizing elite agronomic resistant lines and newly identified resistance sources. It appears that this is a feasible approach to improve the level of resistance in elite agronomic lines while diversifying the program genetic base and maintaining or improving yield potential.

We have found that sorghum genotypes differ in translocation of nitrogen from roots to the shoots. This coupled with a previous determination that sorghums differ in their ability to remove nitrogen from the soil may explain why: 1) greenhouse solution culture techniques are inadequate for use in screening for nitrogen use efficiency, 2) sorghum genotypes differ in grain production per unit of nitrogen supply, and 3) sorghum genotypes differ in their response to fertilizer nitrogen. We have suggested a modified definition for nitrogen use efficiency based upon these results.

An investigation of yield components has revealed that grain production at high nitrogen levels is strongly related to nitrogen in the grain and at low nitrogen level to total biomass at black layer.

Water use efficiency in sorghum was found to be significantly affected by sorghum line, fertility level, and the interaction of water level X fertility level. A positive relationship was found between grain yield and both nutrient and water use efficiency.

Institutions

Collaborating Host Countries: Honduras - Ministerio de Recursos Naturales; El Salvador - Ministerio de Agricultura y Ganaderia; Mali - Division of Agronomic Research; Botswana - Department of Agricultural Research; Brazil - EMBRAPA; Mexico - ICRISAT; and Australia - Queensland Department of Primary Industries.

U.S.: Texas A&M University, United States Department of Agriculture - Agricultural Research Service, and the University of Georgia.

Linkages:

Collaborative research sites have been established in Honduras, El Salvador, Mali and Botswana. Research is conducted under existing INTSORMIL agreements and/or linkages with interested scientists for the important biotic or abiotic stress conditions.

Germplasm resistant to sorghum midge has been evaluated in Honduras and El Salvador cooperatively with scientists from the national research organizations. A work plan has been negotiated with Recursos Naturales scientists for evaluating and developing midge resistant genotypes for Olancho state, Honduras. Ing. Rafael Reyes CENTA, entomologist, is evaluating germplasm developed by TAM-123 in El Salvador.

Collaborative research to evaluate sorghum for nutrient use efficiencies and fertilizer response as affected by drought has been initiated with Dr. Oumar Niangado and Dr. Moussa Traore in Mali. Mr. Mamadou Doumbia, an M.S. student at Texas A&M University, is conducting thesis research in Mali concerning the response of sorghum lines to applied urea relating to the chemical reactions in the fragile Mali soils. His research is sponsored by TROPSOILS in conjunction with INTSORMIL. The research will be conducted at the Cinzana Experiment Station.

Mr. C.S. Anthe, a Ph.D. candidate in entomology, is initiating the second year of research in Botswana on the genetics of resistance to the sugarcane aphid. The sugarcane aphid is a serious pest of sorghum in Southern Africa (it is not present in the U.S.) which is not easily controlled by cultural practices or insecticides.

Within the U.S., research is being conducted with Dr. C.W. Wendt in identifying sorghum lines that are nutrient use efficient and drought tolerant. The effects of soil fertility levels on dry matter production per unit of water transpired is being evaluated. Susceptibility of nitrogen

efficient sorghum lines to mite and greenbug infestations is also being investigated in cooperation with Dr. Tom Archer.

Linkages with other scientists and organizations is in the form of germplasm exchange, data collection and exchange, and joint nurseries. Participation on graduate committees of foreign graduate students provides the opportunity to establish appropriate linkages.

Ecogeographic Zones Benefited Most by Research

Central America, West Africa, and Southern Africa

Objectives, Research Procedures, and Production/Utilization Constraints

Year 7 Project Objectives

Obtain and evaluate germplasm for resistance to arthropod pests. Determine which resistance sources or mechanisms are most useful to sorghum improvement.

Determine the inheritance of insect resistance.

Develop and release high yielding, agronomically improved sorghums resistant to selected insects including the sorghum midge.

Identify and define potential sources of more efficient plant nutrient extraction and/or utilization in sorghum.

Develop agronomically elite sorghums with improved nutrient use efficiencies.

Develop new methods for determining nutrient use efficiencies and study responsible mechanisms when appropriate.° Determine the effects of nutrient use efficiency on water use efficiency in sorghum.

Changes in Objectives from Previous Year

None. Project objectives represent a combination of long and short term goals in a continually evolving program.

Sorghum/Millet Constraints

A series of abiotic and biotic stress factors constrain grain sorghum production in LDC and DC agricultural systems, resulting in some yield instability depending on the stress severity. Partial or complete alleviation of the stress factors will result in a more environmentally fit crop genotype and a higher yielding, more stable production system.

Insects are a problem in all areas of sorghum production, the severity of damage varying with the insect and location. As local production agriculture systems change with new technology and cultivars, insects will

become an increasingly severe problem. For example, the sorghum midge is the most widespread of all sorghum insect pests, being present in nearly all areas of sorghum production. As genotypes lose their photosensitivity in LDC sorghum improvement programs and become more photoperiod insensitive, midge damage will become increasingly severe. Development of cultivars resistant to insects as part of an integrated production and stress control strategy will readily integrate with other required inputs in an ecologically sound approach with large potential benefits in subsistence and mechanized agriculture. Host plant resistance to insects is a continual effort in response to a dynamic, continually changing production ecosystem.

It has long been assumed that water was the first limiting factor to plant growth in much of the semiarid tropics. However, Stroosnijder and his associates from the University of Wageningen have shown conclusively that due to a lack of nutrients, principally N and P, usable water is left in the soil profile even by native range plants. We have determined that on Alfisols in Texas (same soil family as many in SAT areas of Africa) usable water is left in soil zones of low nutrient supply. Consequently, increasing grain production under simultaneous low soil water supply and low soil fertility is important as well as conditions of low soil fertility with adequate water.

Research Procedure

Germplasm is obtained and evaluated for insects of economic importance in a cooperative program with entomologists. Sources of new germplasm include elite germplasm from other programs (including ICRISAT), plant introductions, and partially or fully converted genotypes from the sorghum conversion program. Germplasm is evaluated in large field nurseries or in greenhouses depending upon the insect.

New sources of resistance are identified and included in a crossing program in addition to current breeding material. The resistance mechanism and genetics of inheritance is determined when possible. Advanced elite materials are evaluated in nurseries at diverse locations in Texas for adaptation and reaction to other stress conditions. Elite lines and hybrids are provided to LDC cooperators for evaluation and use under their conditions.

Based upon data collected at several locations, crosses are made among elite lines to produce new germplasm for subsequent evaluation. Additional adaptation and stress resistance traits (disease resistance and/or drought tolerance) are incorporated into the germplasm whenever possible.

For insects of importance in LDC's but not in the U.S. (sugarcane aphid), an array of germplasm is provided to the LDC cooperator. Based upon the collected data, crosses are made to produce relevant germplasm for inheritance and entomological studies. These populations are then sent to the cooperator along with instructions for their use.

Diverse cultivars of grain sorghum obtained from the breeding programs at Lubbock are screened for N, P, and Fe use efficiencies in nutrient culture in greenhouse studies at Lubbock and field nurseries at Beeville, Berclair, Lubbock and Bailey Co., Texas. The first lines screened are those that have shown promise in previous tests including nurseries in DC's. Lines from the Sorghum Conversion Program will also be screened.

Genotypes relatively different in N and/or P nutrient use efficiency will be grown in a greenhouse in soil deficient in the respective nutrient. Water use will be determined and water use efficiency defined as dry weight production per unit of available water. Water use efficiency for selected genotypes differing in N use efficiency will be determined in an N deficient soil under field conditions based on grain and forage yields, available water, and water used. Water use will be determined by neutron probe.

Crosses will be made among lines for preliminary assessment of heritability. Based on heritability studies, crosses will be made among cultivars with high nutrient use efficiency and elite lines to produce breeding lines with high nutrient use efficiency and favorable adaptation and agronomic characteristics. Verification of selection will be made in the progeny of improved lines under field and solution culture screening.

Problems Regarding Achievement of Objectives

Increased funding would enable the project to progress at a faster rate. Project is constrained by a low level of funding which limits the ability of the project scientists to respond to research opportunities.

Project Output

Research Findings for Immediate Use

As reported in 1985, new sources of resistance to the sorghum midge have been identified and are being incorporated into the breeding program. Of the 213 lines evaluated for resistance, 10 have excellent levels of resistance under severe midge infestation and a larger number exhibit resistance under less severe infestation. Observation of breeding lines in the F_3 and F_4 generation indicates the new resistance sources are recessive and quantitative but can be recovered in segregating progeny. These new converted exotic lines are available for distribution to LDC scientists.

Lines and hybrids developed or being developed in TAM-123 are readily usable in LDC environments where midge damage present susceptible cultivars. Evaluations made in Honduras and El Salvador indicate that introduced midge resistant germplasm exhibits good levels of resistance and excellent yield potential. Some midge resistant hybrids yielded 1.5 to 2 times more than the best susceptible hybrids. Further evaluations on additional hybrids are being conducted this year.

Collaborative research has been initiated in Botswana on resistance to the sugarcane aphid. During Year 7 the following germplasm was sent to Botswana for on site evaluation: germplasm quantities of 422 fully converted exotic sorghum genotypes, nine standard lines, five experimental hybrids, and two segregating populations. Additional populations will be sent during Year 8.

We reported in 1985 that greenhouse techniques were inadequate for nitrogen use efficiency screening in grain sorghum when grain yield was a primary objective and proposed a definition for field screening as follows:

$$Gw/Ns = Gw/Np(Np/Ns)$$

where: Gw = grain weight at black layer

Ns = available soil nitrogen (residual and fertilizer)

Np = total N in the plant at black layer

Subsequently, our research suggests that an additional component may be required in this definition. We have found that sorghum genotypes differ in translocation of N from the roots to the shoots. For example, at low available N, SC630-11E translocates 93% and 77CS1 85% of the N taken up to the tops. At high available N, SC630-11E translocates 94% and 77CS1 80% of the N taken up. In both N levels, 77CS1 removed more N from soil. This may

explain why 77CS1 does not respond to N fertilization as well as SC630-11E. Therefore, we are suggesting that the definition of N use efficiency based on grain yield may need to be modified as follows:

$$Gw/Ns = Gw/Nt(Np/Ns)(Nt/Np)$$

where: Gw, Np and Ns are defined as before and Nt is total N in the above ground plant tissue. Thus, Gw/Nt is metabolic N use efficiency, Np/Ns is the uptake efficiency and Nt/Np is translocation efficiency.

A strong positive relationship was found between Gw/Ns and grain yield per acre at both high and low available N, whereas, in contrast, a strong negative relationship was found between Gw/Nt (metabolic N use efficiency) and grain yield at low N and no relationship at all at high N. In addition to differences in N use efficiency we have found differences in responsiveness to applied N.

An investigation of yield components has revealed that grain production prediction from measurement of a single variable can be accomplished for grain sorghum with a high degree of certainty. At high levels of available N, N in the grain should be measured ($R^2 > 0.90$) and at low available N total biomass at black layer should be measured ($R^2 > 0.90$), as indicators of yield potential. These techniques can be of immediate use to plant breeders in their research programs.

Research Findings for Future Use

Germplasm being developed for midge resistance appears to possess outstanding levels of resistance in an excellent agronomic type. Preliminary evaluation of new advanced lines in hybrid combination indicates that some lines will produce hybrids with yields equal or superior to the best susceptible hybrids without midge pressure. The yield difference in some new experimental hybrids versus standard checks is 20% greater yield for the experimental hybrids under late planting without midge present. The yield difference with midge present is of greater magnitude. Many of these lines are being evaluated in Central America presently and will be released from the program in one to three years.

Mode of inheritance of resistance to the sugarcane aphid should be available. This will enable breeding projects to develop lines which are resistant to the aphid, resulting in more yield stability without chemical or cultural control practices.

Two random mating sorghum populations are being developed which combine midge resistance with photoperiod sensitive and insensitive improved food quality genotypes, respectively. The populations should be ready for concurrent selection combining these two traits into a single genotype.

Since our results indicate a strong contribution of root systems to nutrient use efficiency when defined in terms of production per unit of available nutrient, we decided to test these lines with respect to production per unit of available water under dryland and irrigated conditions with high and low available nutrients. Several significant findings resulted: 1) Those breeding lines that produced the most grain per unit of available nutrient also produced more grain per unit of water used, 2) Higher available nutrients resulted in more efficient use of water in terms of grain produced per inch of water used, 3) If fertilizer is to be used to increase water use efficiency it will be necessary to apply it to sorghums that respond to fertilizer, and 4) There is a strong positive relationship between grain production and grain produced per inch of water used. In a lysimeter study of two sorghum lines, two water levels and five fertility levels, it was found that water use efficiency (water used per unit of shoot biomass) was significantly affected by sorghum line, fertility level and the interaction of water level x fertility level.

The results of the studies reported here have strong implications for developing countries, particularly those producing sorghum in the Sahelian ecological zone. The techniques being developed can be used without sophisticated and expensive equipment.

Networking Activities

- Workshops

October 15-29, 1985. A.B. Onken participated in the ICRISAT West African Regional Sorghum Workshop in Bamako, Mali as INTSORMIL representative. Reviewed INTSORMIL collaborative research and technical assistance mission with IER and initiated planning for research to be conducted in 1986-87.

October 13-17, 1985. G.C. Peterson represented INTSORMIL on the planning committee of the "Sorghum Seed Production in Latin America: Problems and Solutions" Workshop and presented a paper on the "Development

and Evaluation of New Genetic Material". The workshop held at CIMMYT had 111 participants.

October 28-31, 1985. G.C. Peterson was the INTSORMIL representative to the Fifth Annual Reunion of the Commission of Latin America Sorghum Workers (CLAIS) at Guatemala City, Guatemala.

- Research Investigator Exchanges

In addition to the project principal investigators making on-site visits to Mali, Mexico, Guatemala, and Honduras the following scientists were among these visiting the host plant resistance-nutrient use efficiency program:

Mexico - Angel Jimenez, Hector Garza

Argentina - Viente Tuecillo, Rodolfo Rossi

Brazil - Fernando Neto

Yugoslavia - Janos Berenji

China (Peoples Republic) - Qui Chengjian, Zhao Jinlin, Zhang Wenyi, Xin Huajum, Mei Jiren

Sudan - Abdel Latif M. Nour

Niger - Allele Elhadji Halibou, Idrissa Soumana, Salifou Mamane, Cisse Amadou

- Germplasm and Research Information Exchange

Including but not limited to the following countries and scientists within those countries: Argentina, Botswana, Brazil, France, Colombia, Mexico, Taiwan, Guatemala, Honduras, El Salvador, Yugoslavia, Spain, Italy.

- Assistance with Equipment and/or Other Support

August 28 - November 4, 1985 - As country coordinator A.B. Onken negotiated, arranged and supervised a technical assistance mission by Verne Isbell which had as its purpose training of IER personnel in drought physiology research techniques and to obtain data for understanding drought tolerance in Mali.

Travel

- CIMMYT, El Batan, Mexico. August 18-20, 1985. G.C. Peterson. Planning committee meeting for the "Sorghum Seed Production in Latin America: Problems and Solutions" Workshop.

- CIMMYT, El Batan, Mexico. October 11-19, 1985. G.C. Peterson. "Sorghum Seed Production in Latin America: Problems and Solutions" Workshop held October 14-17, 1985.
- Mali. October 15-29, 1985. A.B. Onken. Purpose was to represent INTSORMIL at the ICRISAT West African Regional Sorghum Workshop, to review INTSORMIL and DAR collaborative research and the technical assistance mission of Verne Isbell, and to begin development of a 1985-87 work plan and budget for INTSORMIL and DAR research.
- Guatemala City, Guatemala. October 26-November 1, 1985. G.C. Peterson. INTSORMIL representative to the Fifth Annual Reunion of the Commission of Latin America Sorghum Workers (CLAIS) held October 28-31.
- Chicago, Illinois. December 10-11, 1985. A.B. Onken. Purpose was to present an invitational paper entitled "Improving Nutrient Use Efficiencies in Sorghums" at the 40th Annual Meeting of the American Seed Trade Association.
- Honduras. December 11-18, 1985. G.C. Peterson. Member of INTSORMIL team which met USAID and Recursos Naturales officials to evaluate project performance, goals, and support. Sorghum germplasm was evaluated at several locations.
- Puerto Rico. March 19-25, 1986. G.C. Peterson. Disease ratings of insect resistant germplasm and select and harvest winter sorghum nursery.

Publications and Presentations

Refereed Journal Articles

Archer, T.L., E.°D. Bynum, Jr., and G.C. Peterson. 1986. Importance of plant senescence on grain sorghum resistance to the Banks grass mite (Acari: Tetranychidae). J. Econ. Entomol. 79:15-17.

Waquil, Jose M., George L. Teetes, and Gary C. Peterson. 1986. Adult sorghum midge (Diptera: Cecidomyiidae) nonpreference for a resistant hybrid sorghum. J. Econ. Entomol. 79:455-458.

Waquil, Jose M., George L. Teetes, and Gary C. Peterson. 1986. Sorghum midge (Diptera: Cecidomyiidae) adult ovipositional behavior on resistant and susceptible sorghum hybrids. J. Econ. Entomol. 79:530-532.

Waquil, Jose M., George L. Teetes, and Gary C. Peterson. 1986. Comparison of immature sorghum midge (Diptera: Cecidomyiidae) development on resistant and susceptible sorghums. J. Econ. Entomol. 79:833-837.

Teetes, George L., Marta I. Becerra, and Gary C. Peterson. 1986. Sorghum midge (Diptera: Cecidomyiidae) management with resistant sorghum and insecticide. J. Econ. Entomol. 79:1091-1095.

Archer, T.L., A.B. Onken and E.D. Bynum, Jr. 1986. Greenbug response to sorghum lines of varying nitrogen utilization efficiencies. Sorghum Newsletter.

Invited Presentations

Peterson, G.C. 1985. Development and evaluation of new material. In Proc. of La Produccion de la Semilla de Sorgo en America Latina, CIMMYT, El Batan, D.F., Mexico, October 14-17, 1985. p. 65-81.

Onken, A.B., M.J. Lavelle, and G.C. Peterson. 1985. Improving nutrient use efficiency in sorghums. In Report of Fortieth Annual Corn and Sorghum Research Conference of the American Seed Trade Association. Chicago, Il., December 11-12, 1985. p. 15-27.

Changes in Year 8

General objectives and research procedures in developing host plant resistant genotypes will remain largely unchanged. Additional emphasis in Year 8 will be placed on collaborative research in specific ecogeographic zones to address specific insect pests. Germplasm to meet specific pest conditions will be developed and sent to LDC's for evaluation and use.

As a consequence of the obvious interactive relationships that exist between sorghum grain production and available nutrient and water levels, as discussed earlier in this report, an increased emphasis will be placed on evaluation of these interactions and the contribution of root systems to both nutrient and water use efficiencies. These studies will be conducted in field trials and in lysimeters under a rainout shelter in order to insure good control of moisture. Our research effort will be expanded to include phosphorus since most developing countries have soil phosphorus as well as soil nitrogen deficiencies. We have sufficient data to separate several genotypes relative to their grain production under low soil phosphorus. Our plan is to also initiate preliminary research into nitrogen and phosphorus interactions as they relate to both nutrient and water use efficiencies.

Sorghum and Millet Improvement in Kenya

Project TAM-132

John A. Mann

Texas A&M University

Principal Investigators

Kenya

J.K. Rutto, Sorghum Agronomist, OIC, W.A.R.S., Kakamega; Sorghum Agronomist

Newton Ocharda, Research Officer, OIC Alupe Station, Sorghum Breeder

F. Lawrence M'Ragwa, Research Officer, Katumani Station; Millet Breeder

Ben Kenyenji, Research Officer, Katumani; Sorghum Breeder

U.S.

John A. Mann, Assoc. Res. Scientist, Texas A&M University; Sorghum Breeder

Other Researchers

A.S. Islam, Research Officer, Coast; Biometrics, Kenya

Mr. P.K. Kusewa, Director, N.D.F.R.S. Katumani, Kenya

Aziz Abubakr, OIC C.A.R.S., Kenya

Dr. Fred Miller, Texas A&M University, Sorghum Breeder

Summary

This project has been directed from its inception towards the development of sorghum and millet in East Africa. During the last two years the focus has narrowed to work primarily in Kenya, although work continues throughout the region. The work in Kenya has been directed initially at determining what kinds of germplasm fit the various ecological zones within Kenya, and with developing the capability of the Ministry to conduct meaningful sorghum and millet research. The last year has been successful in both regards. Trials in five locations have provided very good data on both the basic ecozones in the country, and what types of germplasm will fit those areas. In general we have found that three different zones exist, and that three different types of sorghum will be needed to fit these areas. Those types grown in the wetter areas of the west are most different in both adaptation and quality factors, and will require the most work.

Efforts to expand local capability have taken several forms, from financial assistance to training. TAM-132 funds have been instrumental in

maintaining local efforts, providing funds for nursery maintenance and materials necessary to continue work there. In addition, TAM-132 provided the means to bring to the U.S. for short-term training the senior sorghum/millet breeder in the country. This, together with in-country planning exercises, has made a significant contribution towards developing a local capacity to do meaningful research on sorghum and millet.

Institutions

Collaborating Host Country: Ministry of Agriculture and Livestock Development (MOALD), Kenya Industrial Research and Development Institute (KIRDI), Kenya Agriculture Research Institute (KARI), University of Nairobi, Faculty of Agriculture, and OAU/SAFGRAD/ICRISAT.

U.S.: Purdue University.

Linkages:

Linkages established with the various entities within the MOALD are still informal, but well established. Collaborative work is on-going with three major Research Centers across the country. The links with KIRDI and the Faculty of Agriculture are just beginning, and are related to the new work being started with high-tannin sorghums for the Western Zone of Kenya. Purdue is helping with some of this work on an informal basis.

Ecogeographic Zones Most Benefited by Research

TAM-132 research will benefit two ecogeographic zones, as each has similar germplasm and production systems. It will be most useful in the center of these areas, namely Ethiopia, Kenya, Uganda, Tanzania, Mozambique and Zambia.

Objectives, Research Procedures, and Production/Utilization Constraints

Year 7 Objectives

- Germplasm Evaluation
- Germplasm Enhancement
- Visiting Scientist
- Project Design

Changes in Objectives from Previous Year

These objectives are the same as Year 6 with the exception of the addition of the Visiting Scientist objective.

Sorghum/Millet Constraints

The chief constraint in much of Kenya to increased sorghum and millet production remains attitudinal, i.e., these two crops are not considered "modern". There is evidence that attitudes are changing, and if this happens, many of the subordinate constraints such as bird depredation will be easier to solve. In terms of constraints which can be addressed by this project, the development of high-yielding sorghums with quality aspects similar enough to local types to be accepted is of paramount importance.

Research Procedures

The development of MS3 steriles for use as the basis of synthetic varieties has continued to be an important research procedure. During the year nurseries were planted at five locations in Texas, and an off-season nursery was planted in Puerto Rico. In these local nurseries work has concentrated on the MS3 backcrossing program, and the development of a standard pedigree program based both on hand-emasculated and MS3 crosses. In Kenya, work continued to concentrate on the assessment of germplasm in many locations across the country. Serious breeding work will have to wait for increased funding for the local programs, or the beginning of the USAID project.

Problems Regarding Achievement of Objectives

The main problem encountered during the year is the same as reported last year; namely the slow movement of the USAID project which is the main reason for this project. As of July 1, the Project Paper was finally nearing completion. A second problem was the reduction of funding in Year 7. The primary result of that was the elimination of the chance to bring a second Kenyan scientist here for the summer.

Project Output

Research Findings for Immediate Use

Twenty-seven Texas elite lines are now at the BC4 stage in the MS3 program, and are available in both Coes and exotic cytoplasms. The lines are ready for the development of synthetics, and for the development of superior local-exotic populations. In addition, a number of tall selections from these crosses are sufficiently stabilized to begin yield testing in Kenya where well adapted. In excess of 300 F2 populations from adapted

parents are to be planted in Kenya in the coming year, and should provide a solid germplasm base for the national program.

Research Findings for Future Use

As in any breeding program, improved germplasm is always in the pipeline. Of special interest is the work just now eight months along which is looking at the advantages of the purple testa in sorghum. More than 30 crosses were made this past summer, and will be planted in Puerto Rico and College Station next summer to look at the genetic and utilization characteristics of this trait. Its association with the local sorghums of western Kenya make it an important part of the project.

Project Design

One of the most critical areas of the work in Year 7 was that done to assist the USAID mission in Kenya on the design of the Agricultural Research Project. About 10 days during the year were spent in formal and informal discussions with mission personnel on a wide range of topics. The advantages of INTSORMIL involvement in the project were emphasized both to the mission and to MOALD colleagues. The "output" will become evident in October when the Request for Proposal is made public.

Networking Activities

- Workshops

I attended the 4th annual Sorghum and Millet Workshop for Eastern Africa, sponsored by OAU/SAFGRAD. Scientists from eight East African nations were there, as well as three representatives from INTSORMIL.

- Research Investigator Exchanges

TAM-132 brought to the U.S. the senior sorghum/millet breeder in Kenya for an eight week stay. Mr. M'Ragwa worked in the programs of Drs. Rosenow, Miller and Mann in Texas, Mr. Stegmeier in Kansas and Mr. Andrews in Nebraska. In addition, he was able to spend time with many other INTSORMIL scientists at Nebraska, Kansas State, Purdue and Texas A&M Universities. Dr. Frederiksen spent one week in Kenya, and I spent about seven weeks there working with Kenyan colleagues in the Ministry.

- Germplasm Exchange

About 3000 sorghum lines from TAM-132 and the TAES program were sent to Kenya in Year 7. In addition, millet from the Kansas State University

program was forwarded at the request of the Kenyan breeder. Material for quality analysis was brought back to College Station for the work being supported by our Project Support Grant.

- Support for Local Scientists

During Year 7 more than $1200 was passed on to TAM-132 collaborators in Kenya for cooperative nurseries. In addition, $450 worth of supplies were purchased here or in Kenya and passed on to their projects. These funds and supplies have meant the difference between work and no work, as local funding has been severely limited this past year. This money has kept sorghum and millet research going at Katumani, Kiboko, Kikambele (Coast), and Alupe, the four major sites for these crops in the country. Supplies have included pollination bags, envelopes, staples, tags, etc.

Travel

- Kenya, Uganda. July 11-August 18, 1985. John A. Mann. Attend S/M Workshop in Serere, Uganda, review last season's nurseries and plan next season's with Kenyan colleagues.
- Texas, Kansas, Nebraska, Indiana. August 14-October 14, 1985. F.L. M'Ragwa. Review sorghum and millet programs at INTSORMIL Institutions.
- West Lafayette, Indiana. October 6-9, 1985. John A. Mann. Make final arrangements for departure of F. M'Ragwa, and plan cooperative work with INTSORMIL colleagues.
- Chicago, Illinois. November 30-December 5, 1985. John Mann. Attend and participate in Annual Meetings of the ASA.
- Mayaguez, Puerto Rico. January 16-February 6, 1986. John Mann. To work TAM-132 winter nursery in Isabella, PR.
- Kenya. February 13-March 9, 1986. John Mann. To make assessments and selections in TAM-132 nurseries at four locations, and plan for cooperative work in the March-July rains at same locations.

Changes in Year 8

The primary change in Year 8 research will be the expansion of work on high tannin sorghums as food-types. Initial work in western Kenya indicates that most of the sorghum eaten there has a purple testa, and apparent high tannin levels at least during grain maturation. This work is being funded for the most part by a Project Support Grant, but is directly in line with

the stated goals of TAM-132. Crosses have been made with Hegari and SC166 to begin determining basic genetic parameters, and Dr. R. Waniska is doing quality assessments of samples brought back from Kenya to determine how local sorghums from Kenya change during maturation in terms of polyphenol quality and quantity. Mr. Newton Ochanda is also doing work on the problem in Alupe, and in this year we should begin to collect data on how these sorghums are used in the local environment. Such data will greatly help our overall project goals, especially as it would appear the USAID position will be posted in the west, and have primary responsibility for that area of the country. Project funding will not allow much else that is new, and will preclude the funding of another visit by a Kenyan scientist to the U.S. this year.

Entomology

Executive Summary

Research was completed on the ability of four stored-grain insect species to successfully attack and damage sound and damaged kernels of two contrasting millet and two contrasting sorghum cultivars, and the amount of damage done.

Laboratory studies were begun on the exchange of gases (CO_2 and O_2) between soil and grain in closed containers preparatory to field studies of grain storage in underground pits. (KSU-109)

Several major insect pest constraints to sorghum production in Honduras have been identified. The complex of insect pests varies depending on cropping systems, region and topography and environment.

Research emphasis is on soil inhabiting seed and seedling sorghum insect pests, and insect pests on the foliage, stalk and panicle (seed) in polycropping systems of production, particularly in southern and central Honduras. The pest control tactics evaluated for practical utility have included development of specific cropping practices, selecting and/or developing host plant resistant sorghums for insect population suppression, practical utilization of biological control agents in routine subsistence farming systems, and the use of chemical applications for insect control.

Successes have been achieved in all areas, but the more simplistic use of insecticide, using specific application techniques suitable for subsistence farming, appears to show the most promise for the short term. (MSU-105)

The species of head bugs infesting sorghum in Niger have been collected and the most abundant identified in several sorghum growing areas. At least two species reach density levels high enough to reduce seed density. Damage assessment experiments are in progress. The damage by stemborers and the head girdler of millet in Niger has been severe and associated parasite species are being collected and identified and their efficacy determined.

Sorghums resistant to sugarcane aphid in Botswana were identified. Experiments to determine resistance mechanisms and inheritance are in progress. Natural enemies of the sugarcane aphid in Botswana are being collected and identified.

Sorghum stemborer damage and parasites have been identified in Honduras and an exotic species was released in Honduras and El Salvador. (TAM-125)

LDC Sorghum/Millet Storage Problems -- Research and Training

Project KSU-109

Robert B. Mills and John R. Pedersen

Kansas State University

Principal Investigators

Robert B. Mills, Professor, Department of Entomology, Kansas State University

John R. Pedersen, Associate Professor, Department of Grain Science and Industry, Kansas State University

Other Researchers

Valerie F. Wright, Assistant Professor, Department of Entomology, Kansas State University

Summary

Nour A.E. Sinada, Sudan, completed her research on the ability of four stored-grain insect species to successfully attack and damage sound and damaged kernels of two contrasting millet and two contrasting sorghum cultivars, and the amount of damage done.

Anne Itto, Sudan, began laboratory studies on the exchange of gases (CO_2 and O_2) between soil and grain in closed containers preparatory to field studies of grain storage in underground pits.

Two manuscripts were completed based on C.T. Asanga's (Cameroon) M.S. thesis research completed in June, 1985. One paper on pit storage of millet was published and the other on laboratory studies on hermetic storage of millet has been accepted for publication. Two additional manuscripts are prepared.

Institutions

Collaborating Host Country: Sudan. Dr. M.E. Hassan Shazali visited Kansas State University in late August 1985; a plan for cooperative research was drawn up, but arrangements between INTSORMIL and Sudan were not completed before our project was terminated. We did send supplies to Dr. Shazali that he could not obtain in Sudan.

Ecogeographic Zones Benefited Most by Research

Stored-grain insects are cosmopolitan, although more serious in tropical or subtropical areas, particularly the humid areas. The pit storage research is more applicable to dry areas where it is more commonly used (West Africa, East Africa, and the Asian Subcontinent, especially India and Pakistan); however, the potential for use of pit storage in more moist areas should be investigated.

Objectives and Research Procedures

Project Objectives

Conduct cooperative research in-country (LDC's) and at Kansas State University to:

Identify storage problems in the Sudan and other selected developing countries, particularly problems caused by insects and molds.

Evaluate storage facilities and practices on farms and in villages in Sudan and other LDC's as cooperative arrangements are made.

Identify and determine effectiveness of control measures being used.

Collect and test sorghum and millet varieties from LDC's for resistance to stored-grain insects.

Continue studies of hermetic and underground pit storage or sorghum and/or millet (at KSU).

Evaluate in-head and threshed sorghum storage with regard to damage by various species of stored-grain insects.

Evaluate simple methods of sampling stored sorghum and millet.

Determine the type and amount of damage done by individual insects to sorghum and millet kernels.

Training and Information Transfer. Training LDC graduate students at Kansas State University, with the expectation that some will subsequently be in-country research cooperators.

Transfer information through publications, seminars, and other means.

Changes in Objectives from Previous Year

The objectives were changed little; they became more specific to include references to hermetic and underground storage, evaluation of storage of in-head vs. threshed sorghum and millet, and type and amount of damage done by different species of insects.

Research Procedures

Laboratory investigations were completed in determining damage done by several insect species to resistant and susceptible cultivars of sorghum and millet, and comparisons of insect susceptibility of sorghum cultivars stored in-head vs. threshed. Laboratory studies were begun to determine the atmospheric changes that take place in underground pits, and the rate of gas exchange between soils of different types and underground pits and their linings.

Project Output

Research Findings for Immediate Use

A Sudanese graduate student determined that rice weevils and lesser grain borers caused greater weight losses in two cultivars of sorghum than in two cultivars of millet. Sound kernels of sorghum cultivars were resistant to the first, second or third instars of rice moths and almond moths. About 50% of the second and third instars of rice moths successfully fed and developed to the next instars on sound kernels of millet. Damaged kernels were equally susceptible to all three instars of the rice moth. The first instars of the almond moths were less successful in attacking damaged kernels of millet than those of the rice moth, but the second and third instars of both insects had equal success in attacking damaged kernels of each grain.

Another Sudanese graduate student determined that grain sorghum stored unthreshed favored Angoumois grain moth population development, but when stored threshed, rice weevil population development was favored. Storage method did not affect percent weight loss caused by Angoumois grain moths, but greater losses occurred in threshed grain due to rice weevils. Sorghum cultivars showed various susceptibilities to both species. Angoumois grain moths and rice weevils appeared to favor rough-surfaced sorghum kernels for larval penetration and oviposition, respectively. Pericarp cell layer arrangement and presence/absence of starch granules in the mesocarp did not appear to influence development of either species. Condensed tannins from two cultivars had no observable effect on rice weevil or Angoumois grain moth, although survival of the red flour beetle was greater in control samples compared to 0.5, 1, and 2 times normal tannin levels.

Networking Activities

Dr. M.W. Hassan Shazali, Sudan, spent about two weeks at Kansas State University in 1985. We sent some supplies needed by Dr. Shazali to conduct host resistance studies.

Publications and Presentations

Asanga, C.T. and R.B. Mills. 1985. Changes in environment, grain quality, and insect populations in pearl millet stored in underground pits. Underground Space 9:316-321.

Asanga, C.T. and R.B. Mills. Hermetic Storage of pearl millet, Pennisetum americanum (L.) Leeke; Laboratory studies. J. Stored Products Research. (Accepted for publication).

Sinad

of stored-product insects in cultivars of sorghum and millet. M.S. Thesis, Department of Entomology, Kansas State University.

Wongo, L.E. 1986. Factors affecting the storage of sorghum [Sorghum bicolor (L.) Moench] grain. Ph.D. Dissertation, Department of Grain Science and Industry, Kansas State University.

Biological Investigations and Management of the Fall Armyworm and Other Insect Pests on Sorghum

Project MSU-105

Henry N. Pitre

Mississippi State University

Principal Investigators

United States

Henry N. Pitre, Entomologist, Mississippi State University

Billy R. Wiseman, Entomologist, Georgia Coastal Plain Experiment Station, Tifton, Georgia

Host Country

Dr. Dan Meckenstock, Agronomist, TAM-131, Honduras

Dr. Keith Andrews, Entomologist, Pan American Agricultural School, (E.A.P.), Honduras

Other Researchers

Host Country

Dr. Leopoldo Alvarado, Head, Department of Agricultural Research, Ministry of Natural Resources, Honduras

Ing. Fausto Cabrera, Southern Regional Director of Agriculture, Department of Extension, Honduras

Ing. Orly Garcia, Southern Regional Head of Agriculture, Department of Extension, Honduras

Regional Extension personnel in Southern Honduras

Dr. Catalino Flores, Agronomist, MSU-111, Colombia

United States

Dr. Lynn Gourley, Agronomist, MSU-104, Mississippi State University

Dr. Sonny Ramaswamy, Insect Physiologist, Mississippi State University

Ms. Willye Harrison, Quarantine Officer, USDA, Stoneville, Mississippi

Summary

The INTSORMIL, MSU-105 Project at Mississippi State University has identified, with the collaborative efforts of agricultural research and extension personnel, several major insect pest constraints to sorghum production in Honduras. The complex of insect pests varies depending on

cropping systems utilized, region and topography and environment. Research emphasis is on soil inhabiting seed and seedling sorghum insect pests, and insect pests on the foliage, stalk and panicle (seed) in polycropping systems of production, particularly in southern and central Honduras. The pest control tactics evaluated for practical utility in this area have included development of specific cropping practices (planting systems), selecting and/or developing host plant resistant sorghums for insect population suppression, practical utilization of biological control agents in routine subsistence farming systems, and the use of chemicals for insect control. Factors associated with the plants in the various stages of growth and development are under investigation. Successes have been achieved in all areas, however the more simplistic use of insecticide, using specific application techniques suitable for subsistence farming, appears to show the most promise for the short term. This holds true for insect pests on all stages of sorghum growth. Cultural practices and biological control show some promise as tactics for implementation in subsistence farming operations, but as with the utilization of host plant resistance, there is need for more research to provide a better understanding of the relationships between plants, pests and the control tactic. Additional attention will be given to the development of these low-economic farming input insect control tactics for use on subsistence farms.

Institutions

Collaborating Host Country: Honduras: Ministry of Natural Resources, Agricultural Research and Agricultural Extension; Pan American Agricultural School (E.A.P.); Colombia: MSU-111 (at CIAT).

U.S.: U.S.D.A., Insect Biology and Population Management Research Laboratory, Tifton, Georgia.

Linkages:

Honduras: A collaborative research agreement between the Secretary of Natural Resources and the International Sorghum and Millet Program (INTSORMIL) has been successfully employed. The MSU-105 project is linked with INTSORMIL research (TAM-131) and with agricultural and extension personnel and programs of the Ministry of Natural Resources. In-country research programs are in place and two graduate students from Honduras are participating. The students (1 M.S. + 1 Ph.D.) receive technical and

professional assistance from Extension personnel in the Department of Agriculture, Southern Region. Research and extension leaders cooperate in the development of research programs, particularly by assisting in establishing entomological research needs and priorities in sorghum and corn production in Honduras.

The MSU-105 project has established a working relationship with Dr. Keith Andrews and the Pan American School (E.A.P.) at El Zamorano, Honduras. Dr. Andrews is entomologist and Head, Insect Pest Management programs at the School. Dr. Andrews will serve as in-country advisor to entomology students in the INTSORMIL, MSU-105 Project. The students conduct most of their research on farms, but have access to land for research purposes at the E.A.P. Also, the students utilize laboratory facilities at the School.

Colombia: The MSU-105 Project has been active in cooperating with the INTSORMIL, MSU-111 Project in Colombia (stationed at CIAT). This effort is mainly represented by evaluations of sorghum materials for possible resistance to the fall armyworm, evaluations of aluminum tolerant sorghum lines for resistance to fall armyworm and influence on insect biology, and surveys for biological control agents, mainly parasitoids, of the fall armyworm.

Mexico: Linkage research relationships have been established in Mexico, primarily with INIA, CIAB. The limitation of this relationship is the lack of graduate student participation in the in-country research program. Attempts are being made to find interested and suitable students.

Brazil: Linkage relationship with EMBRAPA. (The same limitation as above.)

Ecogeographic Zones Benefited Most by Research

Central America and South America

Objectives, Research Procedures, and Production/Utilization Constraints

Year 7 Project Objectives

Determine soil inhabiting insect pests damaging seed and seedling plants in the hills (ladera) and plains (plano) sorghum production regions of southern Honduras. Determine species composition and seasonal distribution and assess sorghum plant damage.

Determine methods to reduce damage to the seed and seedling sorghum plants, including seeding rate and depth of planting, selection of seed size

and color and the use of insecticide seed treatments and granular insecticides applied to the soil at planting - (Honduras).

Determine diversity and abundance of soil inhabiting phytophagous insects (seed and seedling feeders) and insect pests on the foliage, in the stalk and on the fruiting structures of sorghum and corn in slash and burn sorghum + corn, and slash and burn sorghum + corn + pigeonpea intercropping systems. Assess the role of parasitoids in the regulation of lepidopterous larval populations in cropping systems - (Honduras).

Determine host plant preference and suitability for fall armyworm oviposition, larval feeding and establishment, and adult fecundity and longevity on sorghum, corn or pigeonpea plants growing in intercropping systems.

Continue to evaluate sorghum genotypes for fall armyworm resistance, conclude biological (survival and development) and host plant resistance studies with fall armyworms on aluminum tolerant sorghum varieties, and conclude comparative studies on sex pheromones from fall armyworms originating in the U.S. and Honduras as part of a population study to assist in determining the origin, distribution and movement of this species in the Americas - (U.S.A.).

Changes in Objectives from Previous Year

The objectives of the MSU-105 Project have been developed based on entomological needs determined by the cooperating scientists in the developing country involved and the principal investigators on the project. Expansion of these objectives has resulted from knowledge gained from on-site host country and U.S. research. Particular investigations are planned for each host country based on the available information on specific pest species or complex of species on sorghum in the specific linkage host country. It is the intent of these investigations to develop as quickly as possible practical and implementable insect pest control methods for immediate utility in the affiliated developing host country and other areas with similar insect pest problems. Some aspects of several objectives (e.g., insecticide susceptibility and biological similarities in fall armyworm populations) contribute to our understanding of this serious pest as it occurs in the continental U.S.

Sorghum Constraints

Insect pests, including soil inhabiting species, damage or destroy the sorghum seed and reduce plant stands; stem and stalk borers weaken and/or destroy the plants; and head feeding insects destroy the seed, thus reducing yield. The insect pest problems in Honduras differ from one area to the next, particularly when considering differences in environment, topography and agricultural production practices. This holds true for the other areas where MSU-105 linkage arrangements have been established. Therefore, a range of insect pest management tactics have been evaluated to ascertain the effective practices that have application in the developing countries in the ecogeographic zone of operation. Principal emphasis has been on developing non-chemical or other approaches utilizing minimum amounts of chemical insecticides in production areas where financial investment in crop production must be held at a minimum. These control methods have emphasized host plant resistance, cultural control tactics, and biological control.

Research Procedures

Biology, ecology, behavior and population dynamics. Aspects of pest and beneficial insect biology and behavior are essential in developing pest control techniques and understanding mechanisms in host plant resistance studies. Knowledge of basic host plant-insect interactions, ecology and aspects of population dynamics in defined geographical areas is critical in developing practical integrated insect pest management strategies for utility in LDC's. Most research emphasis has been on ecological approaches to pest management, namely cultural, biological and host plant resistance strategies. Many basic and applied investigations have been and will continue to be conducted in Honduras and Mississippi utilizing the naturally occurring pest and natural enemy populations.

Studies of age-specific mortality and partitioning of mortality of immatures of the fall armyworm and certain soil inhabiting insect pests, the composition and impact of parasitoids, and the role of entomopathogens (cooperative efforts of the insect pathologist at Mississippi State University) will again be conducted on insect populations on sorghum in southern Honduras. Developmental rate studies are in progress to compare fall armyworm populations originating in Honduras and several areas in the Caribbean Islands and the U.S. These comparative studies utilize several host crops, including sorghum and corn, in determining larval and pupal

development times, and adult fecundity and longevity. Comparative studies on feeding rates, host preference for oviposition, parasitoid acceptance and sex pheromone investigations are in progress. Studies of the differences in sex pheromone activity and chemistry (Dr. S. Ramaswamy, insect physiologist, MSU Cooperator) and behavior of fall armyworm populations will be related to surveillance of pest populations and immigration patterns. The relationship of fall armyworm immigration into the U.S. from LDC's to the South emphasizes the importance of coordinated ecological studies in both areas (Honduras and U.S.).

Studies to identify the role of soil insect pests of sorghum seed and seedlings will be conducted in southern Honduras. Comparisons of arthropod fauna obtained in soil and seedling plant samples will be made in cropping systems which include hillside vs. lowlands, burn vs. no-burn and soil preparation vs. no soil preparation. Sampling procedures used in Mississippi for similar studies will be standardized for this study. Samples will be taken weekly and examined for insect pests; these pests will be evaluated in relation to crop and non-crop host plant phenology, population density and fluctuation, and crop damage.

Host plant resistance. Natural infestations of the fall armyworm will be used to evaluate sorghum cultivars at Tifton, GA. Mass rearing of this pest at both Mississippi State University and Tifton provides the source of insects required for intensive host plant resistance investigations in the field, greenhouse or laboratory. The new technique using soft dough grain mixed into a meridic diet has been refined for evaluating fall armyworm feeding response differences among grain sorghums. Selected germplasm lines with insect resistance characters (i.e., glossy, trichome, tannin) will be further evaluated for effects on biological parameters in feeding trials to determine mechanisms of resistance. Investigations with native and improved varieties of sorghums from Honduras have been expanded (work in Mississippi, Georgia and Honduras).

Develop pest management strategies for LDC's. Additional investigations on the use of trap crop planting and insecticide efficacy and application techniques on sorghum foliage feeding and root and stem feeding insect pests will be conducted in Year 8 in Honduras and Mississippi. Fall armyworm behavior in relation to sorghum and a corn trap crop will be investigated in the field and in field cages. Insecticide investigations

will be conducted according to standardized procedures established by Dr. John Young (Tifton, GA, cooperator) for regional insecticide tests on the fall armyworm. Sorghum seed planting practices and insecticide seed treatments will be investigated for control of seed and stem feeding insects. The results obtained from these studies will be used to develop insect pest control strategies applicable to specific host countries.

Problems Regarding Achievement of Objectives

The lack of trained entomologists involved in sorghum research in the linkage countries remains as a problem and restricts the extent of conduct of entomological investigations in these areas. Also, the lack of well qualified students from the linkage countries has hindered the expansion of the project and/or progress of in-country research in the developing countries. This problem will be lessened when entomologists trained in INTSORMIL return to their home host country to provide leadership in insect pest management.

Project Output

Research Findings

Honduras: The diversity and density of soil insect pests in sorghum cropping systems in southern Honduras were studied during 1986 for the second year. The insects (large numbers of diverse species) are being identified by taxonomist specialists in Washington. Numerical survey data collected during the early part of the sorghum growing season in 1985 and 1986 are being analyzed and will be prepared as part of a Master of Science Thesis to be published in an appropriate scientific journal and the Department of Agriculture Annual Report for Honduras.

The populations of selected soil inhabiting pest species on sorghum varied from one year to the next and in the various planting systems. In general white grubs and wireworms were the most prevalent species; their density and distribution varied in hills (ladera) and plains (plano) fields and in burned fields compared to fields not burned. This information will provide guidance for the development of more definitive studies on specific soil insect pests and can be used in the development of control recommendations for specific pests in specific production areas experiencing specific cropping practices.

Additional investigations will be conducted in 1986 relating to reductions in sorghum seed and seedling damage by soil inhabiting insect pests. Data collected included number of seed, seed color, seed size, planting depth and use of insecticide and other chemical seed treatments. The information obtained from these studies is being analyzed for publication. Of the chemical seed treatments evaluated, Promet (furathiocarb) provided the best protection to the sorghum seed and seedlings from soil insect pests, followed closely by kerosene. Kerosene is less expensive than the test insecticides and is easy to obtain for use on small, subsistence farms. The small, brown seed appeared to be preferred by many small insect pests.

The insects causing extensive sorghum and corn seedling damage, which often requires replanting in southern Honduras, were identified. Two lepidopterous pests, one the yellow stripped armyworm, Spodoptera ornithogalli (30% of the population), and the other an unidentified species were responsible for the severe damage to early planted sorghum. These pests severely damaged or destroyed young sorghum in early planted fields in the hills, but were not present in late planted sorghum in the plains plantings. Both species were encountered damaging the crops only during early plant development (apparently one generation on the crops). The population dynamics of these pests will be investigated in 1987, with initial studies planned to begin during March-May.

A Mermithid nematode parasitized 2% of S. ornithogalli larvae and 25% of the unidentified larvae collected on sorghum and corn in June 1986. This parasitization rate compared with 56-71% for fall armyworm larvae collected on sorghum in 1983-1985. In 1986, 11-25% of the fall armyworm larvae collected on sorghum and in July were parasitized by a Mermithid nematode. Parasitization declined to insignificant levels in August in some areas. Nematode parasitization increased with rainfall and as populations of armyworms increased; rainfall accounted for 93% of the variation in parasitization.

Chelonus insularis, a braconid, parasitized 20-64% of fall armyworm larvae collected on several occasions on sorghum in hills fields and 45-100% in plains fields during July 1986. Less than 20% parasitization of larvae was recorded during 1984 and 1985. This hymenopterous parasite has the potential of being used effectively as a biological control agent in an

insect pest management program. The factors associated with the inconsistent rate of parasitization from year to year needs to be investigated.

Lorsban sprayed on seedling, whorl stage sorghum and corn plants, provided effective control of Spodoptera ornithogalli, whereas Sevin insecticide was not effective. This information will be effectively used in recommending control of this destructive early season pest in southern Honduras.

Intercropped pigeonpea with sorghum and corn was investigated as an alternative cropping system to conventional sorghum-corn planting systems in Honduras. Spodoptera ornithogalli selectively attacked pigeonpea causing more severe damage on the legume than on the sorghum and corn plants growing in close spacial planting arrangement. This system shows potential for use of the legume pigeonpea in this planting system in reducing damage to the sorghum and corn crops, and providing an additional food product.

Studies of sex pheromone activity and chemistry of fall armyworm moths from Honduras and Mississippi are almost complete. This information related to populations from the two areas will contribute to our understanding of the origin and movement of this pest species. The relationship of fall armyworm immigration into the U.S. from areas to the South emphasizes the importance of coordinated biological and behavioral studies in both areas (Honduras and U.S.).

Mechanisms of resistance in sorghum to fall armyworm larvae have been further investigated. Resistance in sorghum panicles to neonate larvae was demonstrated by incorporating: (1) panicles of different cultivars; (2) different stages of panicles; (3) different concentrations of panicles; and (4) different parts of the panicles in artificial diets. Tannin content of the panicle did not appear to be the primary source of resistance to the fall armyworm; factors in the glumes had the greatest effect on the larvae. The chemicals in the glumes responsible for resistance appears to be highly antibiotic rather than nutritional. These basic investigations contribute to our understanding of the host plant resistance factors associated with the armyworm-sorghum plant relationships and provide a base for further breeding of sorghums with the potential for resistance to insect pest species.

Colombia: Aluminum tolerant sorghum varieties were provided from the MSU-111 program for evaluations of host plant resistance to fall armyworm larvae. The results of larval feeding and development studies are being analyzed.

Networking Activities

- Germplasm and Research Information Exchanges

Sorghum germplasm received from TAM-131 (Honduras; Meckenstock) for evaluation for fall armyworm resistance and comparative insect feeding and development studies; sorghum germplasm (with aluminum tolerance) received from MSU-111 (Colombia, Gourley/Flores) for evaluation for fall armyworm resistance and comparative feeding and development studies.

- Assistance to Host Country Researchers

Research supplies (sampling, collecting, preserving, etc.) and small equipment (refrigerator, heating plate, mixers, etc.) plus partial payment on a vehicle for travel in-country. Construction costs of laboratory space (sampling and separating equipment, cages, etc.) in Honduras.

Travel

- Honduras. May 7 - August 15, 1986. Carlos Trabanino. To conduct collaborative research on seed and seedling insect pests on sorghum and corn with personnel in the Department of Natural Resources on small subsistence farms in southern Honduras and to conduct complementary, basic investigations on insect control tactics at El Zamorano (Pan American School) with Dr. Keith Andrews advising.
- Honduras. May 10, 1986 - January 3, 1987. Marco Castro (Ph.D. student). To conduct research on early, mid- and late season insect pests on sorghum in different cropping systems on small subsistence farms in central and southern Honduras and to conduct complementary basic investigations at El Zamorano (Pan American School) with Dr. Dan Meckenstock advising.
- Honduras. May 12-18, 1986. Henry Pitre (PI). To reestablish working relationships and coordinate research activities with the Department of Agriculture, Research and Extensions Divisions, in regard to the continuation of the MSU-105 Project in Honduras and to work out arrangements for the graduate students (Castro and Trabanino) to utilize facilities and conduct research at the Pan American School at

El Zamorano. Much time was devoted to the location of appropriate research sites, with assistance from Extension personnel in group meetings with farmers in Southern Honduras.

- Chicago, Illinois. October 3, 1985. Henry Pitre. TC meeting.
- Kansas City, Missouri. January 14-15, 1986. Henry Pitre. TC meeting.
- Kansas City, Missouri. March 18-19, 1986. Henry Pitre. TC meeting.
- Kansas City, Missouri. September 2-3, 1986. Henry Pitre. TC meeting.

Publications and Presentations

Publications

Pitre, H.N. 1985. Habits and management of the sorghum midge. Proc. Miss. Entomol. Assoc. 3: 45-47.

Thead, L.G. and H.N. Pitre. 1985. Sorghum webworm control and flower bug mortality on sorghum in Mississippi. Insecticide and Acaricide Tests. 10:

Wiseman, B.R., H.N. Pitre, and S.L. Fales. 1985. A laboratory bioassay for sorghum resistance to the fall armyworm. Proc. 14th Biennial Grain Sorghum Res. and Util. Conf.

Pitre, H.N. 1985. Insect problems on sorghum in the United States. pp. 73-82. In Proc. Inter. Entomol. Workshop, Texas A&M University, College Station, TX. 423 pp.

Castro, Marco. 1985. Development of the fall armyworm, Spodoptera frugiperda (J.E. Smith), larvae from Honduras and Mississippi on sorghum and corn, and larval infestations on sorghum-corn cropping systems in southern Honduras. M.S. Thesis. Mississippi State University. 62 pp.

Presentations

Pitre, H.N. 1985. Habits and management of the sorghum midge in Mississippi. Mississippi Entomol. Assoc. Meeting. Mississippi State, Mississippi.

Wiseman, B.R., H.N. Pitre and S.L. Fales. 1985. A laboratory bioassay for sorghum resistance to the fall armyworm. Fourteenth Biennial Grain Sorghum Res. and Util. Conf. Lubbock, Texas.

Changes in Year 8

A significant change in the project occurred in Year 7 with the expansion of research objectives in Honduras to include investigations of

soil inhabiting seed and seedling insect pests on sorghum and corn in subsistence farming cropping systems in southern Honduras. The objectives expressed in the Year 8 work plans will remain largely unchanged for the next year. These research priorities and work procedures have been developed by MSU-105 and the Ministry of Agriculture, Departments of Research and Extension, and include basic and applied investigations to be conducted over a two to three year period. Changes, however, have been made in the cropping systems research conducted by the Ph.D. student in Honduras. Insect pest and natural enemy diversity and density levels will be studied throughout the growing seasons in central and southern Honduras. Observations will be made on pest population dynamics, including foliage, stalk and panicle (seed) feeding insect pest species. Intercropping (polycropping) investigations will be expanded. Insecticide control, biological control, damage assessment, and host plant preference studies will be continued or expanded. The work in Colombia will continue to emphasize sorghums with host plant resistance qualities, as well as observations on the role of parasitoids in regulating armyworm populations.

Development and Evaluation of Systems for Controlling Insect Pests of Sorghum/Millet by Integration of Resistant Varieties, Cultural Manipulation and Biological Control

Project TAM-125

George L. Teetes and Frank E. Gilstrap

Texas A&M University

Host Country Principal Investigators

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Dr. N. Nwanze, ICRISAT Entomologist - Niger

Dr. John Clark, NCRP Program Leader - Niger

Mr. Chris Manthe, DOA Entomologist - Botswana

Dr. Keith Andrews, EAP Entomologist - Honduras

Dr. Dan Meckenstock, INTSORMIL Plant Breeder - Honduras

Other Researchers

Host Countries

Mr. R. Reyes, Entomologist - El Salvador

Dr. K.V. Seshu Reddy, Entomologist - Kenya

Mr. C.J. Rossetto, Entomologist - Brazil

Dr. K. Leuschner, Entomologist - India

United States

Dr. Gary Steck, Texas A&M University, Niger, Entomologist

Mr. Ousmane Youm, Texas A&M University, Niger, Entomologist

Mr. Ronaldo Sequeira, Texas A&M University, Honduras, Entomologist

Dr. Gary Peterson, Texas Ag. Exp. Stn., Lubbock, Plant Breeder

Dr. Jerry Michels, Texas Ag. Exp. Stn., Amarillo, Entomologist

Dr. Richard Frederiksen, Texas A&M University, Pathologist

Dr. Fred Miller, Texas A&M University, Plant Breeder

Dr. Harold Browning, Texas Ag. Exp. Stn., Weslaco, Entomologist

Summary

A complex of insect pest species attack sorghum and millet during and after production and reduce yield and yield stability, and increase risk. To address these constraints, the Sorghum/Millet Entomology project at Texas A&M University has concentrated on adapting plant resistance and biological control technology to LDC situations and training graduate students. On-site collaborative research is underway in Niger, Botswana and Honduras

supported by local research conducted by LDC graduate students. The species (34) of head bugs infesting sorghum in Niger have been collected and the most abundant identified in several sorghum growing areas. At least two species reach density levels high enough to reduce seed density. Damage assessment experiments are in progress. The damage by stemborers and the head girdler of millet in Niger has been severe and associated parasite species are being collected and identified and their efficacy determined. Life table studies are in progress.

Sorghums resistant to sugarcane aphid in Botswana were identified. Experiments to determine resistance mechanisms and inheritance are in progress. Natural enemies of the sugarcane aphid in Botswana are being collected and identified.

Sorghum stemborer damage and parasites have been identified in Honduras and an exotic species was released in Honduras and El Salvador. Experiments to determine establishment and effectiveness are in progress. Sorghum midge resistant sorghum hybrids were evaluated in Honduras and they performed as they do in the U.S. Several new sources of resistance to sorghum midge were identified in the U.S. by a Sudanese graduate student.

Institutions

Collaborating Host Countries: Niger: Institut National de Reserches Agronomiques du Niger (INRAN), Tarna Experiment Station, Maradi, Purdue Cereals Research Project, Kolo Experiment Station; Botswana: Department of Agriculture, Gaborone; Honduras: Ministerio de Recursos Naturales and Escuela Agricola Panamericana; El Salvador: Ministerio de Agricultura Y Ganaderia; and Brazil: EMBRAPA.

United States: Texas Agricultural Experiment Station, Texas A&M University; Purdue University and Kansas State University.

Linkages:

On-site collaborative research is underway in Niger, Botswana and Honduras. Appropriate agreements with the respective agencies have been approved and in some cases programs are in their second year. Dr. Gary Steck, a research associate under the supervision of Dr. Teetes, is stationed and working at Maradi, Niger conducting collaborative research on assessing sorghum panicle feeding bug damage with Dr. Maiga, INRAN Entomologist. Mr. Ousmane Youm is a Ph.D. student directed by Dr. Gilstrap

conducting his dissertation research in collaboration with Dr. John Clark in Niamey and Kolo, Niger on stemborers and the head girdler of millet.

Mr. Chris Manthe, a Ph.D. student directed by Drs. Teetes and Gilstrap, is in Botswana conducting his dissertation research on plant resistance and biological control of the sugarcane aphid on sorghum. He will be on-site for at least two years. His research is also sponsored by USDA and the Botswana Department of Agriculture.

Mr. Ronaldo Sequeira, an M.S. student directed by Dr. Gilstrap, is conducting his thesis research with the approval of the Ministerio de Recursos Naturales in Honduras. His major emphasis has been on stemborer pests of sorghum and their natural enemies. He has also released imported natural enemies (parasites) in Honduras and El Salvador and is currently evaluating their establishment and effectiveness. He is collaborating with a number of national scientists, and scientists at the Panamerican school.

Linkages with other host countries are in the form of technical assistance, especially information supply, project design, germplasm supply, and review of research procedures and results. Foreign graduate student training has provided good, new linkages with several developing countries such as Malawi and El Salvador.

Ecogeographic Zones Benefited Most by Research

West Africa, Southern Africa and Central America

Objectives, Research Procedures, and Production/Utilization Constraints

Year 7 Objectives

Determine the nature and role of head bugs as sorghum pests, determine species composition and distribution, and assess damage in Niger.

Screen exotic converted sorghums for resistance to sugarcane aphid and determine resistance mechanisms and inheritance, and inventory biological control agents in Botswana.

Determine biological control agents and assess natural enemy efficacy of stemborers of sorghum in Honduras, and stemborers and the head girdler of millet in Niger.

Screen exotic converted sorghums for resistance to sorghum midge, improve their agronomics and evaluate selected lines and hybrids in Honduras and the U.S.A.; and determine spacial distribution and sampling procedures.

Changes in Objectives from Previous Year

Project TAM-125 objectives are directed at entomological problems in selected host countries and are being met by stationing on-site research associates or research assistants. The specific objectives continue to evolve as research information is gained. For example, head bug research objectives are moving from species identification and abundance determination to damage assessment, and biological control research from natural enemy identification to efficacy assessment and parasite release.

Sorghum/Millet Constraints

A complex of insect pest species attack sorghum and millet during and after production and reduce yield and yield stability, and increase risk. Insect pests become especially severe when farming systems change from traditional to the use of improved cultivars and greater inputs. Insecticidal control is common in developed countries but is dangerous and expensive in lesser developed countries. Plant resistance to sorghum pests and biological control of sorghum/millet pests were the main control tactics chosen for research because they require little farmer input, are economical, ecologically compatible and usually fairly persistent. Their use would ensure greater and more stable yields, and are applicable to developing world situations.

Research Procedures

Specific research procedures used are described in detail in the Plan of Work for Year 7. General procedures include those applicable to the implementation of plant resistance to insects and biological control and the necessary biological and ecological support data. The expertise of research associates and graduate students in a training mode is used to carry out research objectives and established research procedures. Local research is of the type to establish and test procedures applicable to LDC situations and to provide the support of on-site research in terms of data, germplasm, biological control agents and other procedural needs.

Problems Regarding Achievement of Objectives

There remains a lack of trained entomologists assigned responsibility for sorghum/millet insect research in many LDC's. This fact stresses the need for graduate student training with appropriate follow-up support. Host

country funds for sorghum/millet insect research is low to none. Procedures to funnel small amounts of money to certain LDC's need to be established.

Project Output

Research Findings for Immediate and Future Use

Thirty-four species of phytophagous Hemiptera were censused on sorghum panicles in Niamey, Dosso, Tahaou, and Maradi, Niger during August-October, 1985. Eurystylus sp. and Campylomma spp. were consistently collected in large numbers. Densities of Eurystylus peaked very early and quickly at all sites. Campylomma densities increased more slowly and peaked later. Creontiades pallidus, Nysius sp., and a pentatomid species may be considered occasional pests. The sorghum varieties most heavily infested were early maturity types such as El Mota Galmi. Much of the sorghum grown in the Konni and Galmi areas was heavily infested. Early maturity varieties at Bengou and Tama also were heavily infested. Local, later-maturity varieties in the Maradi and Bengou areas were not heavily infested. Panicle compactness was not an important factor in determining head bug infestations in variety trials. However, the presence of very susceptible varieties harboring large numbers of bugs may be endangering nearby plantings of relatively nonsusceptible types. In an experiment where head bug densities were great, seed density was significantly lowered, and average seed weight was consistently lower than where bugs were controlled with insecticides.

Field trips were conducted in the department of Niamey, Maradi, and other locations in Niger to collect eggs and larvae of stemborers and/or the millet head girdler and make observations in the fields or experimental plots to evaluate the importance of the damage caused by these pests. Though these two pests did not cause damage or were not collected at Kola (mid- to late July), observations at Maradi (ca. 10 km south) where farmers had planted early, damage by the millet head girdler was apparent. This is an area where millet head girdler occurs almost every year due to the availability of early planted millet to the emerging adults for oviposition. This indicates that cultural control practices based on manipulation of planting dates could face serious difficulties due to multiple pest problems. In other words, early planting may reduce damage by stemborers, but increase chances of attack by the millet head girdler. Likewise, delayed planting may constitute a suicidal emergence for the adult millet head girdler, but could increase the damage caused by stemborers.

During May 1985 through January 1986, studies were completed in Honduras identifying stemboring pyralid pests, associated parasites and crop losses due to stemborers at several locations; quantifying the effects of four different sorghum cropping systems on the population dynamics of several pests of sorghum and maize; and the effects of releases of an exotic parasite of stemborers. The data are undergoing analysis and the results will be prepared as a M.S. thesis. Parasites of stemborers are being sent to Honduras and El Salvador for release and permanent colonization. To date, about 90,000 parasites have been sent and plans are to send about 50,000 more before the end of calendar year 1986. These parasites are called Cotesia (=Apanteles) flavipes and are proven extremely efficient in Texas and Caribbean countries where already established. All work not yet published will be submitted for publication in the near future.

Three sorghum lines from the TAES sorghum breeding/entomology program, TAM428, IS12610C (SC110-14) and IS12661C (SC170) were rated highly resistant to the sugarcane aphid in Botswana. Other sorghum lines showed varying levels of feeding damage. One local Botswanan sorghum variety, Marupantse, supported a high number of aphids longer than other local varieties before being killed.

The following converted exotic sorghum lines were identified as resistant to sorghum midge: IS2665C (SC692), IS8232C (SC642), IS8112C (SC725), IS7193C (SC694), IS8237C (SC644), IS6946C (SC763), IS7132C (SC693), IS8087C (SC704), IS6984C (SC338), and IS3390C (SC572). These restorer lines crossed to susceptible female parents indicated a range in dominance and recessiveness.

Data were collected on in-field infestations of sorghum midge and other panicle feeding insects in commercial sorghum fields in the U.S. These data are being used to determine spacial distribution patterns and sampling procedures. Preliminary analyses suggest that statistically reliable estimates of panicle pest densities, especially sorghum midge, may require sample sizes in excess of those normally used by farmers. Research efforts to develop more efficient and reliable sampling procedures for these important sorghum pests are continuing. Also, data are being collected on adult sorghum midge density and resulting progeny in commercial sorghum fields to validate a mathematical model for sorghum midge.

Life-table studies on Heliothis in compact and loose sorghum panicles revealed that oviposition was greatest during the flowering stage of sorghum, egg abundance was greatest on panicles of the compact panicle type, and larval density was very low. Egg parasitism accounted for some mortality, as did predation.

Networking Activities

- Workshops/Symposia

October 13-17, 1985. INRAN/INTSORMIL/NCRP Sorghum/Millet Workshop. Niamey, Niger. Title: Niger research on head bugs of sorghum and stemborers of millet.

December 8-13, 1985. Entomological Society of America Symposium. Hollywood, Florida. Entomology of Indigenous and Naturalized Systems and Agriculture; Title: Entomology of Johnson grass/sorghum/sorghum midge agriculture.

- Research Investigator Exchanges

Host for nine LDC scientists who visited the sorghum entomology program at Texas A&M University.

- Germplasm and Research Information Exchange

Sorghum midge resistant germplasm sent to El Salvador, Kenya, Honduras, Paraguay, Colombia, and other LDC's; sugarcane aphid resistant germplasm sent to Botswana; information exchange with 13 LDC scientists.

- Host Country Assistance with Equipment and Supplies

Insect cage materials, curating supplies, nets, preserving materials, etc., sent to Niger for sorghum head bug and stemborer research. Similar supplies were sent to Botswana for sugarcane aphid research and to Honduras for biological control research on stemborers.

In October 1985, Ronaldo Sequeira and two El Salvadoran scientists prepared a joint work plan for 1986-87 stemborer biological control research in El Salvador, and in November 1985 Sequeira trained a Nicaraguan scientist (affiliated with INRA-Nicaragua) on the same topic for work in Central America. Mr. Sequeira gave reports of his research findings at an October 1985 meeting in Guatemala (Central American Sorghum Research Group), and at a second meeting in December 1985 in El Salvador (Second Basic Grains Seminar in San Salvador), and at a third meeting in El Salvador in March

1986 (Central American Food Crops Research Group). In April 1986, two Salvadoran scientists visited the Gilstrap laboratory in order to obtain specialized training in biological control procedures for stemborers attacking sorghum. As a result of Sequeira's research in Honduras, a very intensive program on biological control of stemborers is now in place and making progress in Honduras and El Salvador.

Travel

- Maradi, Niger. July 26-November 2, 1985. Gary Steck. Conduct collaborative research on sorghum panicle feeding bugs with Dr. Maiga.
- Niamey and Maradi, Niger. October 6-20, 1985. George L. Teetes. Assess sorghum head bug severity and review on-site research being conducted by Dr. Gary Steck and Dr. Seyni Maiga.
- Niamey and Maradi, Niger. May 4-16, 1986. Gary Steck. To make preparations of the 1986 sorghum field season in consultation with Dr. Seyni Maiga, and to conduct field collections during the dry season of host plants of sorghum head bugs.
- College Park, Maryland. April 23-25, 1986. George L. Teetes. Confer with Executive Director of the Consortium for International Crop Protection relative to pest and pesticide management opportunities in several LDC's.
- Kansas City, Missouri. May 12-13, 1986. George L. Teetes. Develop budgets for Niger collaborative research.
- Niamey, Maradi and Kolo, Niger. July 16-August 16, 1985. Ousmane Youm. Make initial contacts with Niger officials, and to conduct preliminary studies on the millet head girdler and millet stemborer.
- San Salvador, El Salvador. March 17-21, 1986. Ronaldo Sequeira. Participate as an invited speaker at the Programa Cooperativo Centroamericano Para El Mejoramiento De Cultivos Alimenticios.

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Presentations

Entomological Society of America Section F Symposium. (Entomology of Indigenous and Naturalized Systems and Agriculture) Hollywood, Florida. Dec. 8-13, 1985. Title: Entomology of Johnsongrass/sorghum/sorghum midge agriculture.

Entomological Society of America. Hollywood, Florida. Dec. 8-13, 1985. Title: Seedling sorghum responses to yellow sugarcane aphid injury.

Niger (INRAN/INTSORMIL/NCRP) Sorghum/Millet Workshop. Niamey, Niger. Oct. 13-17, 1985. Title: Niger research on head bugs of sorghum and stemborers of millet.

TAEX/TAES Guide Revision Conference. Sorghum insect research. Oct. 29-31, 1985.

TAEX State Staff Conference. Economic threshold levels. July 17, 1985.

Changes in Year 8

The objectives of Project TAM-125 will remain largely unchanged. However, significant changes occurred in the approach to collaborative research from Year 6 to Year 7. Research under this project emphasizes in-country, on-site activities. The research will be concentrated in Niger, Botswana, and Honduras with students or research associates located in each country. Support activities will be carried out largely by foreign graduate students in order to continue the supply of insect resistant sorghum germplasm, effective natural enemies, and research procedures and information.

Food Quality and Nutrition

Executive Summary

Human nutritional studies have demonstrated that the digestibility of sorghum proteins in some foods is significantly poorer than that of other cereal proteins in similar foods. This impairment of sorghum protein digestibility occurs during the cooking process. This research has therefore focused on the chemical changes that occur when sorghum proteins are heated. We found that the relatively indigestible protein in cooked sorghum is the kafirin fraction. Its digestibility is partially controlled by high molecular weight glutelin proteins and is diminished during cooking by formation of intermolecular complexes linked by disulfide bonds. Addition of compounds (2-mercaptoethanol, dithiothreitol or sodium bisulfite) which reduce disulfide bonds almost completely prevent the loss of digestibility associated with cooking. Now that the basis for the loss in digestibility on cooking has been established, this knowledge is being applied to the improvement of the nutritional value of sorghum by appropriate modification of processing methods. (PRF-103B)

In November 1985 two University of Nebraska researchers traveled to Dakar, visiting the facilities at ITA and the Senegalese Institute for Agricultural Research in Bambey. Verbal agreements were made to establish a collaborative project and in May 1986 a host country scientist visited the University of Nebraska campus. As a result of this visit, additional insight was gained as to the direction the millet work needs to go in terms of types of convenience products the Senegalese would like to have. We also decided on various quality analyses which should be done and are analyzing the 1985 growing season varieties. (NU-119)

Tortillas from sorghum were made in commercial tortillerias in Mexico and in pilot plant facilities at the University of Sonora, which confirm that white, tan plant sorghums produce the best tortillas. However, they lacked the texture and flavor of typical maize tortillas. Maize/sorghum mixtures gave excellent tortillas with good flavor and keeping properties. Sorghum required less alkali and had reduced cooking and steeping times compared to maize. Sorghums could be processed with existing equipment. White, purple plant color sorghums gave off-color tortillas.

Sorghum meal was extruded to provide a wide array of products with good potential for snack and breakfast foods.

Information on the role of nontannin phenolic compounds in weathering resistance of sorghum is accumulating. More information to confirm apparent relationships between specific phenolic acids and sorghum mold resistance properties is required. (TAM-126)

Research on sorghum polyphenols is usually confined to the seed, where they defend against herbivores and pathogens, and diminish its nutritional value, but droplets of an oily phenol-rich exudate were recently observed on each sorghum root hair. A possible relationship to Striga resistance was considered because Striga must encounter this material on attacking sorghum. No one else has reported this exudate; all other studies have been of water-soluble exudates. With collaborators it was found that this exudate is a powerful stimulant of the germination of Striga seeds (the seeds do not germinate unless stimulated to do so by a chemical signal from the host root). With help from Dr. D. Lynn, it was determined that the chemical structure of the main component of the exudate is a highly substituted quinone never found before in sorghum or in any other organism. We named it sorgoleone. This is the first Striga germination stimulant ever identified from a natural host.

The question of why sorghum should produce a material having such a harmful effect upon itself has been resolved by the finding that this exudate has herbicidal activity. It strongly inhibits elongation of roots of certain plants. Presumably sorghum produces exudate to defend itself against weed competitors, and Striga has focused on the exudate as a host-specific recognition signal.

This discovery may offer new, effective means of Striga control; none is now available. (PRF-104B)

Evaluating Pearl Millet Germplasm for Food Quality

Project NU-119

Charles Walker

University of Nebraska

Principal Investigator

Dr. Charles Walker, Professor, Food Science and Technology, UNL

Other Researchers

Dr. David Andrews - Professor, Agronomy, University of Nebraska

Dr. Ababacar N'Doye - Cereal Scientist, ITA, Dakar, Senegal

Janet Buck - Cereal Scientist, University of Nebraska

Summary

The project began in July 1985, focusing on Senegal as the most appropriate representative country of West Africa because of its collaborative base - Institut de Technologie Alimentaire - in Dakar. In November 1985 researchers Walker and Buck traveled to Dakar, visiting the facilities at ITA and the Senegalese Institute for Agricultural Research in Bambey. Verbal agreements were made to establish a collaborative project and in May 1986 Dr. Ababacar N'Doye visited the UNL campus for six weeks in continuation of this agreement. As a result of this visit, we gained additional insight as to the direction the millet work needs to go in terms of types of convenience products the Senegalese would like to have. We also decided on various quality analyses which should be done and are in the process of analyzing the 1985 growing season varieties.

A Memorandum of Understanding has been written, in preparation for signing by the government of Senegal.

Institutions

Collaborating Host Country: Institut de Technologie Alimentaire (ITA), Dakar, Senegal

U.S.: University of Nebraska

Linkages:

In November 1985, Dr. Walker and Janet Buck visited ITA in Dakar to discuss the possibility of establishing a collaborative program. They were amenable to the idea and in May and June 1986, Dr. N'Doye, head of millet quality research, came to the University of Nebraska for six weeks. Current plans are to continue this exchange as necessary.

Ecogeographic Zones Benefited Most by Research

West Africa

Objectives, Research Procedures and Constraints

Year 7 Objectives

To establish and maintain linkages with LDC(s) to form a cooperative research program.

To determine quality standards for grain and for finished foods, by host country definition.

To select appropriate methods for testing grains (chemical, physical and functional).

To apply those appropriate tests to each year's samples.

To conduct cooking evaluations on selected samples in the host country.

To provide information back to the plant breeders to help guide them in their selections.

Since the 1985-86 year was the first of our involvement with INTSORMIL, we did not change any objectives from previous years.

Constraints

We have not experienced any constraints in carrying out this research.

Research Procedures

A trip to ITA in Dakar, Senegal was made by UNL researchers to make initial contact with that institute's researchers, see their facilities and research first-hand and establish a base for collaborative research. Dr. N'Doye spent six weeks at UNL to begin the research program.

Dr. N'Doye worked with us to help define quality standards for grains and prepared foods such as couscous and arraw.

During the exchange while Dr. N'Doye was in Nebraska, we discussed appropriate evaluation techniques and worked on the development of some of these. They included procedures such as test weight, grain hardness, pearling test, and milling yield.

We worked to develop analytical tests which can be performed with equipment and expertise possessed by ITA, as well as UNL.

Analysis of samples from the 1985 growing season is underway.

We have not yet made another trip to Senegal. It will be possible, however, in subsequent visits, to conduct sensory evaluations of the various varieties.

We are in frequent contact with Dr. Andrews.

Project Output

Research Findings for Immediate Use

We have not yet acquired enough data to make conclusions which are relevant for immediate use.

Research Findings for Future Use

By screening for food quality the varieties of millet which Dr. Andrews develops, we will be able to correlate agronomically desirable characteristics such as yield with qualities which are desirable in terms of foods. He will then be able to select for these traits when performing his crosses.

The development of traditional foods which are convenient to prepare would be a great help to the Senegalese women, and hence Senegalese society in general. Women now spend hours of each day preparing the staple foods which are consumed daily in every household. If the processes could be developed and then performed commercially, this would free vast amounts of women's time, which could then be used for other productive tasks, such as obtaining education or contributing in the work force or teaching children.

If these procedures are experimentally developed, it is entirely possible that their commercial production could begin within three years.

Networking Activities

The visits by Walker and Buck to Senegal and N'Doye to Nebraska have already been mentioned.

We are in the process of shipping to ITA a Nuhull Dehuller, a machine which is capable of both batch and continuous operation. It can dehull 15-50 lbs. of grain in a batch or 1000-1500 lbs./hr. if run continuously and will be of great assistance to the researchers in Senegal while scaling up the production of the convenience millet foods.

We have purchased a mini-dehuller and a Buhler mill for our laboratory. These pieces of equipment are not directly for use by the Senegalese researchers, but duplicate equipment which they already possess and will

allow us to work more effectively with this project, because we can do the same types of research they are doing.

Travel

- Dakar, Senegal (ITA). November 17-23, 1985. Dr. C.E. Walker and Janet Buck. To initiate a collaborative project with Senegalese researchers.
- Lincoln, Nebraska (UNL). May 4 - June 16, 1986. Dr. Ababacar N'Doye. To begin cooperative program - on quality evaluation of grain and food production.

Publications and Presentations

As this is the first year of our involvement with the INTSORMIL project, we do not yet have any publications as a result of our work.

Changes in Year 8

The main changes in the Year 8 project plans from Year 7 are the additional development work on convenient traditional foods and the supplementation of the weaning food which has already been developed.

Chemical and Physical Aspects of Food and Nutritional Quality of Sorghum

Project PRF-103B

Allen W. Kirleis

Purdue University

Host Country Collaborators

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Dr. Laila Y. Monawar, Nutritionist, FRC, Sudan

Dr. Abdellatif M. Nour, Sorghum Breeder, Agriculture Research Corporation (ARC), Sudan

Dr. Osman Ibrahim El Obeid, Sorghum Breeder, ARC, Sudan

Mr. Moussa Oumarou, Cereal Chemist, INRAN, Niger

Dr. John Clark, Sorghum Breeder, INRAN/NCRP, Niger

Dr. R. Jambunathan, Biochemist, ICRISAT, India

Other Researchers

Dr. Sam Mukuru, ICRISAT, India

Dr. K.E. Bach Knudsen, National Institute of Animal Science, Denmark

Dr. B.O. Eggum, National Institute of Animal Science, Denmark

Dr. George G. Graham, Johns Hopkins University

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Dr. Edwin Mertz, Purdue University

Dr. Maribeth A. Cousin, Purdue University

Dr. Arun Chandrashekar, CFTRI, India

Mr. Bruce Hamaker, Purdue University

Summary

Human studies have shown that some sorghum foods have poor protein digestibility compared to similar food preparations made with other cereal grains. Our work has, therefore, focused on the chemical changes that occur when sorghum proteins are heated. We have found that a number of reducing agents can be used to significantly improve the digestibility of uncooked and cooked sorghum proteins. The addition of a reducing agent brought

sorghum protein digestibility to the level of maize, barley, rice and wheat. When sorghum flour was soaked in a solution containing a reducing agent for 12 hours, over 70% of the sorghum proteins were digested in the first 15 minutes compared to about 40% in untreated flour, and about 20% in sorghum that had been cooked.

We have identified the scientific reason why sorghum proteins digestibility decreases after cooking. With this knowledge we can modify traditional processing methods and develop new processing methods to improve the nutritional value of sorghum.

We also now know that porridge quality differences result from protein-starch interaction caused by sorghum matrix protein structural differences. For example, cooking hard grain cultivars in the presence of a reducing agent affects disintegration and dispersal of the protein matrix and allows a greater degree of starch gelatinization. This provides a means for controlling porridge stiffness. Thus, we now have an understanding of how to control porridge stiffness, which is an important food quality trait in Africa.

Institutions

Collaborating Host Countries: Sudan - The Agricultural Research Corporation, Food Research Centre; Niger - INRAN/NCRP; Peru - Institudo de Investigacion Nutricional and ICRISAT - Hyderabad, India.

U.S. and Others: National Institute of Animal Science, Copenhagen, Denmark; Purdue University, Texas A&M University, and Johns Hopkins University.

Linkages:

PRF-103B project activities are focused primarily in two African countries - Sudan and Niger. Results from project work will, therefore, be most relevant and important to these two countries. Both countries are primary sites for major Ecogeographic Zones and hopefully research results generated in these two sites will be relevant to neighboring countries.

Sudan: The Food Research Centre (FRC) and Agricultural Research Corporation (ARC) provide the primary linkage for our research activities in Sudan. The main thrust of our activities in Sudan is toward developing improved testing procedures for evaluating the food quality of improved sorghum varieties and hybrids being developed for Sudan. To this end,

primary collaboration is with the Department of Cereal Technology at the FRC (Drs. S.E.M. Badi and L.Y. Monawar) and ARC sorghum breeders (Drs. A.M. Nour and O.I. El Obeid). Collaboration involves joint planning of work and joint evaluation of breeders' sorghum samples for food quality.

Niger: Useful collaboration has also been developed with INRAN. The main contacts in Niger are Mr. M. Oumarou, Cereal Chemist and Head of the Cereal Quality Laboratory, and Dr. J. Clark, Purdue Cereal Research Project Team Leader and sorghum breeder. Our mode of collaboration in Niger is much the same as that described for Sudan, i.e., participation in the planning of work and joint evaluation of sorghum samples for food quality. Another area of useful collaboration with INRAN is the preparation of a manual for "Testing Sorghum Food Quality in West Africa". The manual will be available in both French and English sometime in 1987.

Objectives, Research Procedures and Production/Utilization Constraints

Year 7 Project Objectives

Develop simple screening test procedures for use in LDC breeding programs to predict grain food quality of sorghum.

Conduct basic studies to determine what components in sorghum are related to the functional properties of the grain that constitute food quality.

Identify sorghum grain processing and cooking procedures that lead to improved nutritional quality and acceptable food quality using both chemical and biological methods.

Train LDC personnel in cereal chemistry.

Changes in Objectives from Previous Year

There are no major changes in the research objectives listed above. The specific areas addressed in Year 8 will be:

Characterize changes that occur in starch and protein components of sorghum grain during cooking as they relate to food quality.

Characterize changes that occur in sorghum protein during heating that lower protein digestibility.

Examine the changes that occur in protein components of sorghum during extrusion cooking that result in improved protein digestibility.

Sorghum/Millet Constraints

Relatively little is known about the cooking characteristics (i.e., functional properties) and nutritional properties of sorghum/millet in comparison to other major staple cereal crops. Thus, we must continue to develop basic knowledge about the chemical composition and physical properties of sorghum/millet grain components and how these influence the end-use or food and nutritional quality of the grain. This kind of information will allow the development of better testing methods for evaluating the traditional food quality of improved sorghums and the development of new non-traditional nutritious foods as a means of using sorghum/millet surpluses.

A key to overcoming the constraints limiting sorghum utilization is to have a network of functioning food quality laboratories located in LDC's. These laboratories must be staffed with well trained scientists and must be adequately equipped to effectively carry out their work. It is also important that there be close cooperation between LDC scientists and scientists conducting basic work on sorghum/millet grain. This is necessary to keep LDC scientists informed of the newest findings and the basic scientists aware of current problems in the field.

Project Output

Research Findings for Immediate Use

Sorghum Protein Digestibility Studies

As human studies have shown that some sorghum foods have poor protein digestibility relative to food preparations made with other cereal grains, we have focused our work on the chemical changes that occur when sorghum proteins are heated. This research has led to a greater understanding of the biochemical nature of the sorghum proteins, how they react during the cooking process, and how protein associations may affect digestibility.

We believe protein digestibility of sorghum, whether it is low or comparable to other cereals, is primarily dependent on the method or conditions under which the grain is prepared and cooked. Previous *in vitro* protein digestibility studies in our laboratory using pepsin have shown that there is a sizable reduction (20 to 30%) in protein digestibility when a sorghum/flour suspension is cooked to a gruel in a boiling water bath for 20 minutes. Decreases in protein digestibility of sorghum flour that has been cooked have also been reported in chickens (31.5% decrease) and rats (7%

decrease). Thus, our goal is to develop processing and cooking conditions that will prevent the protein digestibility decreases normally observed when sorghum is made into a gruel.

Means of Improving Protein Digestibility

The addition of small amounts of a reducing agent, such as 2-mercaptoethanol, dithiothreitol, or sodium bisulfite, to the flour/water suspension before cooking results in little or no decrease in *in vitro* digestibility due to cooking. Protein digestibilities remain at the level of the uncooked flour and are comparable to digestibilities of other major cereals. Furthermore, addition of weaker reducing agents such as L-cysteine has a significant effect on maintaining adequate digestibility. Further digestibility studies are planned using animals to relate these findings more directly to the human.

Working with Dr. Sam Mukuru we have identified a local Uganda process for eliminating the adverse effects of tannins on sorghum protein digestibility. The treatment involves soaking and germinating high tannin sorghums in the presence of wood ash and is a common practice in the southern highlands of Uganda. *In vitro* protein digestibility of a porridge made from a Uganda high tannin sorghum was improved from 7% to 50% by the local wood ash treatment.

Research Progress for Future Use

Why Sorghum Proteins are Less Digestible Than Other Cereal Proteins

In vitro digestibility experiments showed that kafirin proteins were the predominant indigestible fraction of uncooked sorghum. Cooking reduced the digestibility of the kafirins to an even greater extent. Although kafirins were most resistant to pepsin digestibility in flour, when kafirin proteins were extracted from flour, mixed with starch, cooked and digested, they were found to be highly digestible. This may also be true for kafirin-2 proteins as there is no evidence suggesting that kafirin-1 proteins are different from kafirin-2 proteins. Digestibility appears to be dependent on accessibility of the protein bodies to enzyme attack.

The addition of reducing agents substantially increased the *in vitro* digestibility of uncooked and cooked sorghum. This was most dramatically seen after 15 min of pepsin digestion. Cooked sorghum protein was only 22%

solubilized compared to 32% for flour cooked with 2-ME and 41% for uncooked flour compared to 72% for flour soaked in 2-ME for 24 hr.

Protein polymers linked by intermolecular disulfide bonds were shown to form during cooking. The glutelin and to a lesser degree the kafirins were found to be the proteins involved in polymerization. The major glutelin polymers (50,000-70,000 monomers) were quite large, yet were highly digestible. Three other glutelin proteins, approximately 100,000-120,000 daltons (monomeric form), which are believed to be closely associated with protein bodies appear to influence kafirin protein digestibility. When these glutelin proteins were brought into solution with a reducing, dissociating solvent, kafirin solubility was increased. The 100,000-120,000 dalton glutelin proteins were also the last proteins of cooked sorghum to be digested by pepsin prior to the onset of kafirin digestion. This suggests that these high molecular weight glutelin proteins may form a protein coat surrounding the protein bodies.

Scanning electron micrographs supports this hypothesis as it shows that the protein matrix was digested more readily than protein bodies, that cooking does not visibly disrupt the structure of the protein bodies, and that a protein coating covers the protein bodies.

The observed reduction in protein digestibility after cooking could be due to a combination of two factors. First, kafirins, to some degree, appear to form protein complexes linked by intermolecular disulfide bonds during cooking. Second, the heavy molecular weight glutelins may influence kafirin digestibility by coating the protein bodies with disulfide-linked complexes which must be digested before kafirins are exposed to enzymatic attack.

Sorghum Starch Gelatinization

Sorghum grain is commonly consumed as a stiff porridge or gruel throughout Africa. Thus, it is important to understand why certain sorghum cultivars produce porridge with acceptable quality while others do not. In general it has been shown that cultivars with hard grain produce better porridge than soft grain cultivars. Starch is the most likely grain component affecting porridge quality. However, an examination of the gelatinization properties of isolated sorghum starches from hard and soft grain revealed that no major differences existed between these starches. However, when the cooking characteristics of either sorghum flour or

semolina were examined it was found that starch swelling and gelatinization were limited by protein. In fact, starch swelling was limited to a greater extent in hard than in soft grain cultivars of sorghum.

When cooked sorghum flour was examined by scanning electron microscopy, two kinds of protein matrix were found--one which contains protein bodies connected to matrix protein and a second type of matrix protein without protein bodies. The former structure appears to completely enclose the starch granules even after cooking and is predominantly found in the hard grain cultivars. The latter type matrix releases the starch granules during cooking and thus allows a greater degree of starch gelatinization. This type matrix is primarily found in soft grain cultivars of sorghum.

Accordingly, we now know that porridge quality differences result from protein-starch interaction caused by matrix protein structural differences. For example, cooking hard grain cultivars in the presence of a reducing agent affects disintegration and dispersal of the protein matrix and allows a greater degree of starch gelatinization. This provides a means for controlling porridge stiffness. Thus, we now have a greater understanding of the grain components controlling porridge quality.

Networking Activities

- Workshops

INTSORMIL/INRAN/NCRP Sorghum and Millet Collaborative Research Workshop October 14-17, 1985. Niamey, Niger. Presented work on protein digestibility.

- Research Investigator Exchange

Mr. Dammain Wamajj, Cereal Chemist, Serere Agricultural Research Station, Uganda worked in our laboratory for six weeks during August and September 1985. During his visit research was done on sorghum and millet composite flour bread baking and he was trained to do food quality tests on sorghum.

Dr. Arun Chandrashekar, Cereal Chemist, Central Food Technological Research Institute, Mysore, India has been doing Post Doctoral research work in our laboratory since January 1986. He is working on starch-protein interactions that occur in sorghum during cooking.

- Research Information Exchange

Research findings on protein digestibility have been shared with scientists at the Food Research Centre (Sudan) and the Cereal Quality Laboratory (Niger). At the request of host country scientists from the above laboratories, sorghum samples have been evaluated for food and nutritional quality in our laboratory. Results from these analyses have been shared with the host country scientists.

- Assistance to Host Country Researchers

Arrangements were made for purchase and shipment of some $25,000 of research equipment for the Agricultural Research Corporation (ARC). This equipment will be used by the ARC scientists cooperating with INTSORMIL in Sudan.

Travel

International

- Niamey, Niger. October 12-24, 1985. A.W. Kirleis. To participate in the INTSORMIL/INRAN/NCRP Sorghum/Millet Workshop.
- Khartoum/Wad Medani, Sudan. October 29-November 12, 1985. A.W. Kirleis. Assist ARC with the preparation of a five year sorghum/millet research plan.

Domestic

- Orlando, Florida. September 22-26, 1985. A.W. Kirleis and B.R. Hamaker. Attend Annual Meeting of the American Association of Cereal Chemists. Presented paper at the meeting.
- Kansas City, Missouri. January 14-15, 1986. A.W. Kirleis. Attend joint meeting of INTSORMIL Technical Committee and Ecogeographic Zone Council.
- Kansas City, Missouri. March 20, 1986. A.W. Kirleis. Attend Ecogeographic Zone Council Meeting.
- Washington, D.C. April 7, 1986. A.W. Kirleis. Attend Winrock Team Evaluation Report briefing on Western Sudan Agricultural Project.
- Kansas City, Missouri. May 13, 1986. A.W. Kirleis. Attend Ecogeographic Zone Council Meeting.

Publications and Presentations

Text

Rooney, L.W., A.W. Kirleis, and D.S. Murty. 1986. Traditional Foods From Sorghum: Their Production, Evaluation and Nutritional Value. In "Advances in Cereal Science and Technology". Y. Pomeranz, Ed.: American Association of Cereal Chemists. Vol. 8 pp. 317-353.

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Hassen, M.M., E.T. Mertz, A.W. Kirleis, G. Ejeta, J.D. Axtell, and E. Villegas. 1985. Tryptophan levels in normal and high lysine corn. Cereal Chem. 63:175-176.

Hamaker, B.R., A.W. Kirleis, E.T. Mertz, and J.D. Axtell. 1986. Effect of cooking on the protein profiles and in vitro digestibility of sorghum and maize. J. Agric. Food Chem. 34:647-649.

Hamaker, B.R., A.W. Kirleis, L.G. Butler, J.D. Axtell and E.T. Mertz. 1987. Improving the in vitro protein digestibility of sorghum with reducing agents. Proc. Natl. Acad. Sci. (USA). 84: IN PRESS.

Stuart, M.A. P.E. Johnson, B.R. Hamaker, A.W. Kirleis. 1987. Absorption of zinc and iron by rats fed meals containing sorghum food products. J. Cereal Sci. 87: IN PRESS.

Research Abstracts

Chandrashekar, A. and A.W. Kirleis. 1986. Influence of matrix protein on starch gelatinization in sorghum. Cereal Foods World. 31:604.

Hamaker, B.R. and A.W. Kirleis. 1986. Increased in vitro protein digestibility of cooked sorghum grain by the addition of reducing agents. Cereal Foods World. 31:608.

Hamaker, B.R., A.W. Kirleis, and E.T. Mertz. 1986. Polymerization of sorghum kafirin proteins by cooking. Federation Proceedings. 45:1093.

Presentations

Hamaker, B.R., and A.W. Kirleis. 1985. "Characterization of cooked and uncooked sorghum proteins." American Association of Cereal Chemists Annual Meeting. Orlando, Florida. September 24.

Kirleis, A.W. 1985. "Digestibility of Sorghum Proteins". INTSORMIL/INRAN/NCRP Sorghum/Millet Workshop. Niamey, Niger. October 12.

Changes in Year 8

The project objectives are broad-based and focus on the most important problems limiting utilization of sorghum. The major focus for Year 8 will continue to be work on protein digestibility and characterizing the functional properties of grain components as they relate to local sorghum foods consumed in Sudan and Niger. Hopefully this will lead to the development of improved methods for evaluating the food quality of breeders' sorghum samples.

Tannins and Other Phenols: Effects on Sorghum Production and Utilization

Project PRF-104B

Larry Butler

Purdue University

Principal Investigator

Dr. Larry Butler, Purdue University

Other Researchers

Host Country

Dr. M. Oumarou, Director, National Food Quality Laboratory, Kolo, Niger

Drs. R. Jambunathan and S. Mukuru, ICRISAT

Dr. P. Pushpamma, Andra Pradesh Agricultural University, Hyderabad, India

United States

Drs. Axtell, Kirleis, Nicholson, Rogler, Ejeta, Housley, Purdue University

Dr. Don Carlson, University of California, Davis

Dr. James Riopel, University of Virginia, Charlottesville

Dr. David Lynn, University of Chicago

Summary

Although our work on sorghum polyphenols is usually confined to the seed, where they defend against herbivores and pathogens but also diminish the nutritional value, we recently observed droplets of an oily phenol-rich exudate on each sorghum root hair. We pursued a possible relationship to *Striga* resistance because *Striga* must encounter this material on attacking sorghum. No one else has reported this exudate; all other studies have been of water-soluble exudates. With collaborators we found that this exudate is a powerful stimulant of the germination of *Striga* seeds (the seeds do not germinate unless stimulated to do so by a chemical signal from the host root). With help from Dr. D. Lynn, we determined the chemical structure of the main component of the exudate. It is a highly substituted quinone never found before in sorghum or in any other organism; we named it sorgoleone. This is the first *Striga* germination stimulant ever identified from a natural host.

The question of why sorghum should produce a material having such a harmful effect upon itself has been resolved by our finding that this exudate has herbicidal activity. It strongly inhibits elongation of roots of certain plants. Presumably sorghum produces exudate to defend itself against weed competitors, and Striga has focused on the exudate as a host-specific recognition signal.

This discovery may offer new, effective means of Striga control; none is now available. The conventional strategy is to develop a stable synthetic derivative of sorgoleone, highly active, to treat the field and induce suicidal germination in the absence of the host. In addition to this possibility, we are exploring the marked instability of the active form of sorgoleone. It may be possible to inactivate it before it can stimulate the germination of the Striga seed. These and other possible means of controlling Striga are being pursued with our collaborators.

Linkages

National Food Quality Laboratory, Kolo, Niger (M. Oumarou). After a training period here for Dr. Oumarou, we have supplied equipment and chemicals to be used in establishing various analyses in the laboratory there. We have experienced slow and ineffective communications about some details.

ICRISAT (Jambunathan and Mukuru). Both of these investigators have spent or are spending a sabbatical year at Purdue working wholly or partly in our laboratory. Two papers have been published and data have been collected for a third. We have described important evidence linking resistance to weathering with the presence of flavan-4-ols in the seed. We find that a simple chemical assay for flavan-4-ols may be useful in predicting weathering resistance. In addition, Mukuru is carrying out additional work on tannin detoxification by traditional Ugandan alkali treatments. Striga-resistant cultivars have been sent to us from ICRISAT.

Andhra Pradesh Agricultural University, India (Pushpamma). We are exploring the role of sorghum phenols in resistance to stored grain insects. We are identifying, from the sorghum collection here at Purdue, lines of sorghum which are low in tannin (and therefore nutritionally good) and high in other phenols. Dr. Pushpamma is testing these for resistance to insects in storage, which is a severe problem in India.

Objectives, Research Procedures, and Production/Utilization Constraints

Objectives

To establish capability for tannin/phenol assays in the laboratories of our collaborators: Dr. Oumarou and Dr. Pushpamma.

To elucidate the biochemical basis for the antinutritional effects of sorghum tannins and other phenols.

To elucidate the biochemical basis for the resistance to predatory birds, fungal pathogens, weathering, stored grain insects, and *Striga*, which is provided by sorghum tannins and/or other phenols.

To eliminate or diminish the antinutritional effects of sorghum tannins and other phenols while maintaining or enhancing their agronomic benefits.

Constraints

Sorghum relies more on chemical defenses against biological constraints than do any of the other cereals. The tannin and other phenols which are the subject of our investigation play a prominent role in sorghum's chemical defense against several of the biological constraints: bird damage, weathering, fungal pathogens, preharvest germination, and *Striga*.

Research Procedures

A combination of laboratory bench analyses, tissue cultures, greenhouse and field trials, and animal feeding trials.

Problems Regarding Achievement of Objectives

Our problems are the common ones of insufficient funds, inadequate equipment or facilities, communication with LDC collaborators, etc. These matters do not deter us from pursuing the interesting, challenging scientific problems before us.

Project Output

Research Findings for Immediate Use

Tissue Culture: Drs. Elhag and Cai have succeeded in regenerating large numbers of complete sorghum plants from undifferentiated callus tissue. We have regenerated plants of three cultivars growing in the field to produce a seed crop. We also have growing in the field plants of four cultivars from seeds of regenerated plants grown in the greenhouse. We have hundreds of regenerated plants developing. The significance of this achievement is that we have done it with high tannin sorghums, which are the

most difficult to manipulate, and that we have done it with a wide variety of explant tissue, especially including seedlings and mature embryos (from seeds). Thus we have a convenient source of tissue explants without growing mature plants. We have already observed somaclonal variation, which we are evaluating for its potential utility. We expect to see variants in phenol production because the process of establishing a culture involves selection against this trait.

Mold Resistance: With Drs. Jambunathan, Mukuru, and Ejeta we have found that our assays for flavan-4-ols provide a good correlation with mold resistance. This finding is being extensively explored both in further field trials and in laboratory analyses to identify the specific components directly responsible for resistance.

Striga: With Drs. Riopel and Lynn, Dr. D. Netzley has shown that the oily exudate he found previously on root hairs is a powerful stimulant of Striga seed germination. We have determined its structure, the first stimulant identified from a natural host of Striga, and named it "sorgoleone". Manuscripts describing its structure and germination - stimulating activity have been submitted for publication. We have shown that this exudate inhibits root growth of certain competing plants. Characterization of sorgoleone has led to proposal of a new strategy for protection of sorghum against Striga, whereby we inactivate the stimulant by certain fertilization or cultural practices before it stimulates Striga germination. This and other methods of control are being investigated.

Research Findings for Future Use

Tannin Biosynthesis: L. Putman has isolated the enzyme which catalyzes the last step in tannin biosynthesis, the polymerization of flavonoid dimers and trimers into the condensed tannins found in sorghum seeds. She is characterizing the reaction (requires free oxygen, is very fast) and the substrate (catechin, a monomer, works poorly). V. Reddy has found how to efficiently incorporate 14C-labeled phenylalanine into tannin precursors and the tannin. In addition to an independent method of studying tannin synthesis, this gives us 14C-labeled tannin for following through digestion to determine unequivocally its metabolic fate.

Drug/Tannin Interactions: Dr. J. Rogler and C. Morell have found that addition of 0.05% propranolol to rat diets greatly magnifies the effect of dietary tannin. After adaptation to this drug (a beta-adrenergic

antagonist) rats on low tannin sorghum grow at their normal rate, but rats on high tannin sorghum do not grow at all. Several digestive enzymes show no response to either propranolol or tannin, indicating that the antinutritional effect of tannin is not due to alteration of the amounts of these enzymes.

Defense Against Dietary Tannin: Dr. S. Mole and K. Martino have devised an assay for the proline richness of salivary proteins, a measure of the tannin-induced tannin-binding proteins which greatly diminish the antinutritional effects of dietary tannin in rats and probably in other animals. Assay of human saliva has shown large differences between individuals, which are being evaluated for their genetic vs. dietary basis. We are also applying the assay to saliva from other animals; so far a series of ruminants have shown differences which seem to reflect their dietary preferences. This assay will also be applied to feces, which should provide further correlations with adaptation to dietary tannins.

Networking Activities

- Meetings/Workshops

Plant Flavonoids in Biology and Medicine, July 1985, Buffalo, NY (invited paper).

American Chemical Society Symposium on Allelochemicals: Role in Agriculture, Forestry and Ecology, September 1985, Chicago (poster).

Workshop on Orobanche and *Striga*, January 1986, Agricultural University, Wageningen, Holland (invited paper).

Gordon Conference on Plant-Herbivore Interactions, January 1986, Oxnard, CA (poster).

Bio/Expo 86, April 1986, Boston, MA (poster).

3rd Annual Meeting, International Society Chemical Ecology, June 1986, University of California, Berkeley (organized a symposium on Defensive Strategies Against Tannins).

- Research Investigator Exchanges

Dr. Wilma Pace, Instituto Sperimentale per La Zootechnia, Rome, Italy, at Purdue from September - December 1986.

- Exchange of Samples and Information

Numerous examples with the collaborators listed above, other minor examples too numerous to mention.

- Assistance to Host Country Researchers

See Linkages.

Travel

- Buffalo, NY. July 1985. Larry Butler presented paper at meeting/ workshop on Plant Flavonoids in Biology and Medicine.
- Chicago, IL. September 1985. Larry Butler. American Chemical Society Symposium on Allelochemicals: Role in Agriculture, Forestry and Ecology.
- Oxnard, CA. January 1986. Larry Butler. Gordon Conference on Plant-Herbivore Interactions.
- University of California, Berkeley. June 1986. Larry Butler. 3rd Annual Meeting, International Society of Chemical Ecology. Organized a Symposium on Defensive Strategies Against Tannins.
- Chicago, IL. September 1985. Dr. D. Netzley. Attended American Chemical Society Symposium on Allelochemicals: Role in Agriculture, Forestry and Ecology.
- University of Virginia, November 1986 and University of Chicago, September 1986. Dr. D. Netzley. Work on Striga stimulant.
- Washington, D.C. June 1986. Dr. D. Netzley and Lesley Putnam. Presented poster at the American Chemical Society meeting.

Publications and Presentations

Publications

T.N. Asquith and L.G. Butler, Use of a Dye-Labeled Protein as a Spectrophotometric Assay for Protein Precipitants Such as Tannins, J. Chem. Ecology, 11, 1535-1544 (1985).

S.F. Pascholati, L.G. Butler, and R.L. Nicholson, Phenylalanine Ammonia Lyase Activity and Anthocyanin Accumulation in Wounded Maize Mesocotyls, J. Phytopathology, 115, 165-172 (1986).

C.L. Yu, B. Swaminathan, L.G. Butler, and D.E. Pratt, Isolation and Identification of the Major Mutagen of Red Wine, Mutation Research, 170, 103-113 (1986).

R. Jambunathan, L.G. Butler, R. Bandyopadhy, and L.K. Mughogho, Polyphenol Concentrations in Grain, Leaf, and Callus Tissue of Mold Susceptible and Mold Resistant Sorghum Cultivars, J. Agric. Food Chem., 34, 425-429 (1986).

T.N. Asquith and L.G. Butler, Interaction of Condensed Tannins with Selected Proteins, Phytochemistry, 25, 1591-1593 (1986).

D.H. Netzley and L.G. Butler, Roots of *Sorghum bicolor* exude Hydrophobic Droplets Containing Biologically Active Components. Crop Science, 26, 775-778 (1986).

L.G. Butler, J.C. Rogler, H. Mehansho and D.M. Carlson, "Dietary Effects of Tannins" (Chapter) in V. Cody, J.B. Harborne, and E. Middleton (eds): Plant Flavonoids in Biology and Medicine: Biochemical, Pharmacological, and Structure-Activity Relationships; Alan R. Liss, Inc. New York, p. 141-157 (1986).

Presentation (in addition to those listed under Networking Activities)

Chemical Ecology of Sorghum: Tannins and *Striga*, seminar at ICRISAT, April 2, 1986.

Changes in Year 8

The major change will be increased emphasis on the *Striga* problem as a followup of our observations this past year. I am pursuing other sources of funding for this work, but so far have none. We are making good progress on our other objectives; they remain unchanged.

Food and Nutritional Quality of Sorghum and Millet

Project TAM-126

Lloyd W. Rooney

Texas A&M University

Principal Investigators

United States

Dr. L.W. Rooney, Professor, Food Science and Agronomy, Texas A&M University

Cooperator: Dr. R.D. Waniska, Assistant Professor, Food Science, Texas A&M University.

Host Country

Md. M. Haidara, Md. S. Coulibaly, Food Technologists, IER-Mali.

Dr. M. Traore, Plant Physiologist, IER-Mali.

Dr. O. Niangado, Plant Breeder; Mr. Maribou Konate, Sorghum Breeder; IER, Mali, Dr. J. Scheuring and Dr. Shetty, ICRISAT-Mali.

Dr. D. Meckenstock, INTSORMIL Sorghum Breeder, Honduras, Mr. F. Gomez, Honduras, Graduate Student, Texas A&M University.

Drs. D.S. Murty, Appa Rao, Subramanian, Jambunathan, ICRISAT - Hyderabad, India.

Dr. K.V. Ramaiah, ICRISAT, Sorghum Breeder, Dr. S. Da, IBRAZ, Dr. C. Pattanayak, ICRISAT - Burkina Faso.

Other Researchers

Dr. J. Clark and Mr. Omarou, Plant Breeder and Chemist, Niger.

Dr. Octavio Paredes-Lopez; Centro de Investigacion y de Estudios Avanzados del IPN: Unidad Irapuato; Irapuato, GTO, Mexico.

Ing. Helbert Almeida-Dominguez, Professor; Instituto Tecnologico de Marida; Merida, Yucatan.

Ing. Hector Cejudo Gomez; Cereal Quality Lab; INIA; Chapingo, Mexico.

Dr. S. Bedolla, Professor and Head and Dr. Sergio Sema-Saldivar, Professor; Centro de Investigacion de Alimentos; University of Sonora; Hermosillo, Sonora, Mexico.

Dr. J.O. Akingbala, Professor; University of Ibadan; Ibadan, Nigeria.

Summary

Pearl millet kernels with globular shape produce significantly higher levels of decorticated grain than those with long hexagonal kernels. Pearl millet pericarp is more organized than that of sorghums. Pearl millet does not have a thick, pigmented testa and does not contain condensed tannins. Major factors that affect the appearance of pearl millet grain are pericarp, aleurone and peripheral endosperm color.

Tortillas from sorghum were made in commercial tortillerias in Mexico and in pilot plant facilities at the University of Sonora, which confirm that white, tan plant sorghums produce the best tortillas. However, they lacked the texture and flavor of typical maize tortillas. Maize/sorghum mixtures gave excellent tortillas with good flavor and keeping properties. Sorghum required less alkali and had reduced cooking and steeping times compared to maize. Sorghums could be processed with existing equipment. White, purple plant color sorghums gave off color tortillas.

Sorghum meal was extruded to provide a wide array of products with good potential for snack and breakfast foods. Extrusion of the new white, tan plant sorghums make outstanding food products. The nutritional value of extruded sorghum is increased under low moisture, high shear conditions where the structure of the sorghum endosperm is more completely destroyed.

Weathered sorghum produces poor quality, off colored food products. The grain is soft, cannot be efficiently dry milled and produces dusty flour with poor keeping properties. Thick porridges produced from weathered grain have sticky, mushy texture with very poor keeping properties.

Couscous quality of sorghum is mainly affected by decortication yields of the grain. Once flour is obtained, the couscous yields did not vary significantly among normal sorghums with a wide array of kernel properties. Thus, selection of sorghum with the properties required for efficient decortication will produce sorghums with good couscous properties as well.

Information on the role of nontannin phenolic compounds in weathering resistance of sorghum is accumulating. More information to confirm apparent relationships between specific phenolic acids and sorghum mold resistance properties is required.

Institutions

Collaborating Host Country: Institute of Rural Economy, Mali; ICRISAT-Mali; Ministerio de Recursos Naturales, Honduras; ICRISAT-Hyderabad, India; ICRISAT and Institut Burkinahe de Recherache Agronomique et Zoologique, Burkina Faso.

U.S.: Purdue University, University of Nebraska, and Kansas State University.

Linkages:

Major efforts have been focused in Mali, Honduras and Mexico. These linkages have been established for several years, and the work has been continued and expanded. The return of Dr. Francisco Gomez to Honduras will strengthen the efforts in Honduras.

Ecogeographic Zones Benefited Most by Research

Africa, Latin America - The research on food quality cuts across most geographic areas and produces information, techniques and concepts applicable worldwide. However, the specific areas targeted are Africa and Latin America. The work in Mexico continues to be a very practical, cost efficient way of developing technology for Central America. Collaboration with ICRISAT continues with emphasis on pearl millet characterization, sorghum weathering and basic chemical analyses to determine the major factors affecting quality.

Objectives, Research Procedures, and Production/Utilization Constraints

Year 7 Objectives

Determine how sorghums are processed, prepared, and consumed in traditional village foods and determine the grain characteristics that affect organoleptic properties of the traditional food products.

Develop simple, practical laboratory methods for use in breeding programs to assess important grain quality characteristics.

Determine physical, chemical and structural factors that affect the food and nutritional quality of sorghum and seek ways of modifying the properties or improving methods of processing.

Determine the factors that affect resistance to grain molds and field deterioration in sorghum and devise laboratory procedures to detect genotypes with resistance.

Changes in Objectives from Previous Year

The objectives are broad-based and still cover the essential needs. The first objective has been accomplished, except for additional observations to clarify exceptions to and variations from previous findings. The other three objectives have been pursued most vigorously. Increased emphasis has been given to processing and utilization research on sorghum, i.e., extrusion and millet research has been expanded to determine factors affecting quality for traditional foods.

Sorghum/Millet Constraints

Human food is a major use of sorghum and millet which must be included in the crop improvement programs. Factors affecting food quality, processing properties, and nutritional value of sorghum/millet critically affect the significance of other attempts to improve the crops. If the grain cannot be processed and is not accepted for consumption, then the agronomic and breeding research has been wasted. This project relates quality to measurable characteristics that can be used to select for sorghum (millet) with acceptable traditional and industrial utilization attributes.

Research Procedures

Procedures used to facilitate host country research have been to exchange samples of sorghum and millets and processed products for chemical, physical, structural and processing evaluation. In certain situations, research has been conducted in villages and commercial tortillerias and additional biochemical information has been obtained in our laboratory. This has involved close interaction among researchers at the University of Sonora and our Texas A&M program. Similar activities have been conducted in Mali but unreliable communications hamper effectiveness. Communications are improving, however, and substantial progress is happening.

Problems Regarding Achievement of Objectives

Industrial tortilla production and evaluation of sorghum-maize mixtures has been hampered by lack of collaborators in Honduras. Dr. Francisco Gomez who worked in our laboratory on food quality as part of his Ph.D. effort is returning to Honduras, which will enable us to put into practice in Honduras, information obtained in Mexico. Cooking trials in village households provide useful information on acceptability of sorghum for tortillas in traditional processing. However, they are variable and cannot

provide critical information on the factors affecting quality. That is why the tortilla work in Mexico is of critical importance to our work in Honduras. The use of Mexico to develop information directly transferable to Central America is cost effective.

Project Output

Research Findings for Immediate Use

Structure, composition and processing properties of millet. Information obtained on millet kernel structure and characteristics will provide guidelines for millet improvement programs to use in selecting for grain quality. The best pearl millet kernel for dry milling has a spherical kernel, modestly thick pericarp with a high proportion of corneous endosperm. The hard endosperm would resist breakage during decortication. Pearl millet cultivars with long, slender kernels have poor milling properties. Food technologists in Mali first demonstrated the effect of kernel shape on milling properties in village trials. Our laboratory work has confirmed their findings which are relevant to all areas where pearl millet is decorticated. Globular kernels would improve milling yields substantially.

Commercial alkali cooking and processing of tortillas from Sorghum. Sorghum has been successfully made into tortillas alone and in mixtures with maize in commercial tortilla plants in Mexico. Dr. Bedolla and coworkers at the University of Sonora, Hermosillo, Mexico have completed several trials using whole sorghum and decorticated sorghums in various mixtures with commercial maize. Whole sorghum with tan plant color, white pericarp and intermediate texture made acceptable tortillas. However, the sorghum tortillas had a bland flavor and staled more rapidly than maize tortillas. The best tortillas were made when 50 and 75% of the white and yellow maize was replaced by white, tan plant color sorghum. When grain of a white sorghum with purple plant color was compared, only 30 and 50% of the white and yellow maize could be replaced by the sorghum. Sorghum requires less cooking and steeping time than maize. Optimum cooking times for sorghum varied; but cooking in 0.8% Ca 0 for 20 min at 83-89 C followed by 10 hrs steeping was typical.

In Mexico, large quantities of imported yellow maize is converted into greenish-yellow off color tortillas. Substitution of tan plant white

sorghum for maize would improve tortilla acceptability significantly. Sorghum with purple plant color produced off color tortillas which was accentuated by higher levels of alkali. Sorghums that undergo weathering also produce a significant increase in color of the products.

The experiments conducted in Mexico and in our laboratory show that sorghum does have potential for use in tortillas using common equipment with only slight modifications. However, the sorghum should have tan plant color and white grain. White sorghum that is weathered will produce off colored tortillas. Decortication prior to cooking is promising, but more information on cooking and staling is required.

An improved laboratory method of evaluating the alkaline cooking properties of sorghum for tortillas was developed based upon the commercial studies. The method used lower levels of lime, shorter cooking and steeping times and the pericarp was removed by using a modified waring blender. The nixtamal was ground on a modified hand grinder by adding carborundum stones to achieve desirable masa particle size. This method developed by F. Gomez, graduate student - Honduras, will be applied in Honduras to select for sorghums with improved tortilla quality.

Couscous. Sorghum and millet couscous quality was evaluated using a laboratory method developed by a graduate student from Senegal. The major factor that affected couscous quality was the decortication properties of the grain. Sorghum flours from cultivars with corneous to floury endosperm did not vary in couscous yield or properties significantly. However, milling yields were significantly different and affected couscous yields. Waxy endosperm sorghums had lower yields of couscous. To select for improved couscous quality, sorghums with properties that produce high milling yields are required. There is no apparent need to cook samples into couscous.

Pearl millets representing typical souna and sanio types grown in West Africa were decorticated, milled into flour and made into couscous using traditional procedures. The sanio millet has spherical kernels while the souna had long, slender (hexagonal) kernels. The milling yield of souna was 54%, compared to 65.3% for sanio while sorghum had a yield of 75.3%. The yield of couscous prepared from flour was similar for pearl millet and sorghum although pearl millet couscous had significantly greater gelatinization of starch granules. The souna couscous had the darkest

color. The major conclusions are that the milling properties of pearl millet are critically important to yield and color of couscous. Once a flour is obtained, the couscous making properties of sorghum and pearl millet are similar. Milling properties of pearl millet are clearly of major importance and relate to kernel shape, size and texture.

Extrusion processing of sorghum. Sorghum has been extruded to form snacks and breakfast cereals; the extrudates were ground to form flours for production of precooked porridges and other products. Waxy and nonwaxy food sorghums were extruded using a wenger X-5 lab extruder and a large 4.5 inch Anderson Expander extruder. Extrusion cooking caused extensive gelatinzation of the starch granules and changes in protein digestibility as well. The extent of starch and protein alteration was inversely related to moisture content of the sorghum during extrusion. Waxy sorghum extrudates had higher expansion, water solubility and water absorption than nonwaxy endosperm sorghum extrudates. Extrusion at high shear rates (low moisture) causes sufficient disruption of sorghum endosperm structure to enhance in vitro starch and protein digestibility.

Extrusion cooking can be used to produce a wide variety of products from sorghum with excellent potential for use as human foods. Experimental prototype food products from sorghum have been made by many commercial food companies in the U.S. from recently released new white sorghums with tan plant color. Improved food type sorghums are relevant to all sectors of sorghum producing areas of the world. The extrusion of new food type sorghum hybrids permits an array of attractive new products to be produced from sorghum. The nutritional value of the products is quite acceptable depending upon the process variables.

Research Progress

Effect of weathering on food quality of sorghum. Sorghum subjected to molds, wetting and drying and the onset of sprouting has significantly impaired food quality. Weathering decreased test weight and density of the grain in direct relation to the extent of deterioration. The weathered grain is softer and cannot be decorticated because the kernel falls apart when subjected to the abrasive milling procedures used in commercial milling or traditional hand pounding. The flour produced from weathered sorghum produces thick porridges (tô) with poor texture and even poorer keeping

properties. The combination of head bugs and molds causes severe losses of grain and the grain produced has unacceptable quality in Mali and other areas of Africa.

We have found that a leachate test is an effective method of monitoring the extent of grain weathering. The method is based on the principle that the conductivity of water, in which grain is steeped, is increased when grain is partially deteriorated. The method works well on a laboratory basis, but in a breeding program, subjective evaluations in the field were highly correlated to the leachate test.

Pearl millet structure and composition. The structure of pearl millet kernel was similar to that of sorghum. Millet varieties varied from nearly 100% soft endosperm texture to 100% hard, corneous endosperm. Standards for rating pearl millets for texture, pericarp thickness and color were developed. None of the pearl millets in 79 samples from the world collection had a pigmented testa similar to that obtained in high tannin sorghums. The external appearance of the kernel is due to the combined effects of pigmentation in the pericarp, testa, aleurone and endosperm.

None of the pearl millet samples contained significant levels of condensed tannins as measured by the catechin assay. The total phenol content of pearl millet grains varied from 0.13 to 0.30 mg/100 mg. The phenolic acids of pearl millet were tentatively identified as ferulic caffeic, syringic, p-coumaric, gentisic, protocatechuic, p-hydroxy benzoic, sinapic and cinnamic plus several unidentified compounds. Ferulic acid was the major component of phenolic acids; it is probably located in the cell walls similar to sorghum.

Sorghum nontannin phenols. Nontannin phenolic compounds in sorghum and millets have been under evaluation using high pressure liquid chromatography and light, fluorescence and scanning electron microscopies. Significant levels of at least 19 different phenolic components including gallic, protocatechuic, p-hydroxybenzoic, vanillic, caffeic, syringic, p-coumaric, sinapic, ferulic and cinnamic acids were tentatively identified. Many of the compounds identified inhibit microbial spore germination and mycelial growth which could affect molds that attack sorghum grain.

Mature grain provided by Dr. Bandyopadhyay (sorghum pathologist, ICRISAT) differed significantly in the kind and quantities of free phenolic acids present. Sorghums with a red or white pericarp contained sufficiently

different phenolic acid patterns to classify both the red and white pericarp varieties into mold resistant and susceptible groups. The flavan-4-ol composition of these Type I sorghums was significant only for the red pericarp varieties with higher levels of flavan-4-ols observed in resistant varieties. The free phenolic acids, especially p-coumaric, vanillic, caffeic, unidentified 'B' and ferulic acids, were lower in resistant varieties compared to susceptible varieties regardless of environmental conditions. Microbial metabolism of cellular constituents significantly modified the free phenolic acid patterns of weathered sorghum grain.

Free phenolic acids were monitored during the development of sorghum varieties exhibiting different levels of grain mold resistance. Sorghum panicles were inoculated with Fusarium moniliforme and grown in a moist environment (misted periodically) or the panicles were not inoculated and grown using standard agronomic practices. Inoculation with fungi did not affect the levels of the free phenolic compounds and phenolic acids between -2 and 5 days after anthesis. Varieties resistant to grain molding exhibited increased levels of free phenolic compounds starting at seven days after anthesis for the inoculated treatment. The glumes of resistant cultivars exhibited a greater response than the grain. The resistant varieties also had more pigment development, earlier in the glumes than the susceptible varieties.

This suggests an important role of nongrain tissues, i.e., glume tissues, in the plant's defense mechanisms against grain molding.

These studies on the nontannin, low molecular weight phenols of sorghum will be continued to provide information on the factors affecting insect and disease resistance. Bioassays to determine the biological activity of major phenolic acids have shown ferulic acid inhibits germination of microbial spores. Studies of the changes in nontannin phenolic acids and phenols when sorghums are inoculated with molds and spores at anthesis will continue. The structure of the kernel, plant color, panicle morphology and other factors critically affect molding and deterioration of sorghums, but the nontannin phenols may play the most significant role in mold and insect resistance.

Networking Activities

- Workshops

Participated in the International Pearl Millet workshop held at ICRISAT in Hyderabad, India by presenting the major paper on Food Quality and Consumer Acceptance of Pearl Millet. Discussions with Drs. Subramanian, Appa Rao and Jambunathan on pearl millet food quality led to additional current research on characterization of pearl millet structure in relation to processing properties.

- Research Investigator Exchanges

Two scientists (Ms. M. Cohaiudara and Ms. S. Coulibaly) from the IER Food Technology laboratory, Mali spent several weeks in the Cereal Quality Laboratory for short term training and experience in laboratory procedures. Samples from their Malian research program were analyzed. They were familarized with nixtamalization of maize and sorghum. They found that commercial dry corn masa flours produce excellent quality tô. They are attempting to produce dry masa flours from sorghum and maize in Mali.

Dr. K.V. Ramiah, (ICRISAT, Sorghum Breeder, Burkina Faso) spent six months sabbatical leave conducting research on phenolic compounds in Striga resistant sorghum varieties. Samples from Burkina Faso were used in his research which was conducted jointly with Dr. Waniska.

- Research Information Exchange

Dr. Santiago Bedolla, Head (Food Science and Technology, University of Sonora) spent two weeks conducting specific analyses of sorghum samples in our laboratory from the collaborative work on nixtamalization and extrusion of sorghum and maize underway at the University of Sonora. Dr. S. Serna-Saldivar spent two weeks using our laboratory facilities to complete chemical analyses. Dr. Cheryl Earp, Research Associate, Cereal Laboratory, presented a one week short course on microscopy of cereals, especially sorghum and millet, to graduate students and staff at the University of Sonora, Hermosillo, Mexico. She assisted in setting up a microscope and helped graduate students initiate research projects.

- Assistance to Host Country Researchers

Laboratory analyses have been conducted to support work in Mali, Mexico and Honduras. Small items of equipment, supplies, chemicals and samples of sorghum have been sent to support research efforts as well. Large

quantities of sorghum have been decorticated and sent to Mexico. Numerous visitors from all over the world have spent time in our laboratory exchanging information on sorghum and pearl millet quality.

Travel

- Athens, GA. August 3-8, 1985. L.W. Rooney. Participated in the Ruminant Nutrition Section, Animal Science Society Symposium on Starch Digestion and Utilization by presenting a review entitled: Factors Affecting Starch Digestibility with Special Emphasis on Sorghum and Corn.
- Orlando, Fl. September 1985. L.W. Rooney. Participated in the American Association of Cereal Chemists annual meeting. Eight of our students and staff presented 11 poster papers or technical presentations on various aspects of sorghum millet and maize quality. Conferred with many international scientists participating in the conference.
- Dallas, TX. February 20, 1986. L.W. Rooney. Southern Seedsman Association conference to present an overview of Sorghum Quality Improvements for Food, Feed and Industrial Utilization.
- Hyderabad, India (ICRISAT). April 1986. L.W. Rooney. Participated in the International Pearl Millet workshop by presenting a paper on Food Quality and Consumer Acceptance of Pearl Millet.
- Dallas, TX. June 16, 1986. L.W. Rooney and M. Gomez. Participated in the Institute of Food Technologists Food Exposition. A poster paper on Extrusion of Sorghum was presented. New developments in food processing were reviewed.
- Hermosillo, Mexico. June 1986. Dr. C.F. Earp, Research Associate. Presented a short course on microscopy of cereals, especially sorghum and millets. Several graduate students were instructed in the use of microscopy.

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Gomez, M.H., L.W. Rooney and E.W. Lusas. 1986. Extrusion cooking of sorghum. Abstract. IFT Annual Meeting. Dallas, Texas.

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Changes in Year 8

Research on dry milling properties of sorghum will be expanded to determine the effect of different parental lines on milling properties. This will be related to porridge and tortilla quality. More emphasis will be placed on grain weathering research. Work to determine changes in starch, protein and other constituents during tô and tortilla making will be expanded to support studies in Mali, Mexico and Honduras. Additional research in Honduras will be initiated when Dr. Francisco Gomez returns.

Pathology

Executive Summary

A bacterial disease of millet in West Africa was diagnosed as Pseudomanas rubrilineans -- the causal organism of red stripe disease of sugarcane. This is the first report of this pathogen infecting millet. Pathogenicity tests reveal that corn, sorghum and sugarcane are hosts, and strains isolated from sugarcane are pathogenic on millet and vice versa. It is assumed that the bacterial pathogen is seed-borne.

Epidemiological studies have shown Pseudomonas andropogonis (causal agent of bacterial stripe disease in sorghum) is favored by temperatures of 32-36°C. Conversely, Xanthomonas campestris pv. holcicola (causal agent of bacterial streak disease in sorghum) is favored by temperatures of 20-24°C. High relative humidities (above 90%) were not as important as temperatures for maximum disease expression.

Several sources of resistance to X. campestris pv. holcicola have been identified in the germplasm from the Texas A&M University Disease and Insect Nursery accessions. (KSU-108)

Work done during the past year indicated that there are sorghums with resistance to all known pathotypes of the sorghum downy mildew pathogen (Peronosclerospora sorghi). Ten sorghum cultivars with resistance to isolates of P. sorghi from seven countries are now included in breeding programs. The high rate of variability of the pathogens causing anthracnose and maize dwarf mosaic can also be identified using a uniform system that is available to all sorghum workers. Resistance to such diseases as grain mold and stalk rot appears much less affected by variation in the pathogen and probably results from physiological factors in the plant.

High populations of susceptible plants permit the rapid increase of diseases such as downy mildew. Intercropping with non-host plants, crop rotation, and host resistance all can be used to reduce the potential damage of this and many other sorghum diseases. However sorghum and corn intercropping in Honduras significantly increased incidence of MDMV.

The identification of host resistance to brome mosaic virus, Venezuelan strain of MDMV, strain H of sugarcane mosaic virus and maize dwarf mosaic virus A has aided in the control of these diseases and reduction of economic losses.

The International Sorghum Virus Nursery (ISVN) and the International Sorghum Virus Antiserum Bank (ISVAB) have been important worldwide in detecting virus problems and in determining virus distribution, identification, and virus relationships. Viruses were identified in Mexico, Venezuela, Tanzania, and Argentina and virus strains were compared in Southern Africa, Australia, and France. (TAM-124)

Seasonal charcoal rot incidence differences between the 1984-85 and 1985-86 growing seasons at Sebele, Botswana demonstrated that presence and absence of stress environments (high temperature, low soil moisture) at specific stages of host plant maturity are critical to development of the disease and can differ with the host crop. Cowpeas were more susceptible to charcoal rot when stressed as seedlings but sorghum and pearl millet were more susceptible when stress occurred primarily after anthesis rather than early or throughout the season.

Although foliar diseases are not currently important in Botswana, two standard Botswana varieties demonstrated good field resistance to one or more foliar pathogens in Zimbabwe in 1985 and 1986. Segaolane had good resistance to leaf blight and sooty stripe, and Town had good resistance to leaf blight but was not evaluated for sooty stripe reaction. (TAM-128)

Identification and Quantification of Nematodes in Interactions with Bacterial and Fungal Incitants in Stalk Rot Complexes of Millet

Project KSU-108

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Summary

A bacterial disease of millet in West Africa was diagnosed as *Pseudomonas rubrilineans*. *P. rubrilineans* is the causal organism of red stripe disease of sugarcane. This is the first report of this pathogen infecting millet. Pathogenicity tests reveal that corn, sorghum and sugarcane are hosts, and strains isolated from sugarcane are pathogenic on millet and vice versa. It is assumed that the bacterial pathogen is seed-borne as *P. rubrilineans* has been shown to be disseminated by rice seed.

Epidemiological studies have shown that *Pseudomonas andropogonis* (causal agent of bacterial stripe disease in sorghum) is favored by temperatures of 32-36°C. Conversely, *Xanthomonas campestris* pv. *holcicola* (causal agent of bacterial streak disease in sorghum) is favored by cooler temperatures of 20-24°C. High relative humidities (above 90%) were not as important as temperatures for maximum disease expression.

Several sources of resistance have been identified in the germplasm from the Texas A&M University Disease and Insect Nursery accessions to X. campestris pv. holcicola. The lines TX434, R1186, TX433, and R3224 are tolerant and R1185, 85L21105, 82EON112, TX7078, and 84C-7730 are susceptible. Strains of X. campestris pv. holcicola vary in virulence as the Kansas strains are more virulent than strains from Texas and Africa.

The dot immunobinding assay (DIA), an immunological test, has been adopted for use in diagnosing bacterial stripe and streak diseases of sorghum. The assay is sensitive, reliable, and relatively simple to perform. The assay has been used in Western and Southern Africa and the U.S.

Institutions

Collaborating Host Country: Niger, INRAN; Zimbabwe, ICRISAT/SADCC and CIMMYT; Sudan ARC; Lesotho, Ministry of Agriculture.

U.S.: Texas A&M University and University of Nebraska.

Linkages:

Linkages currently exist in Lesotho, Zimbabwe, Nigeria, and Kenya for pathogen identification. Cooperative projects for screening germplasm have been established with Texas A&M and the University of Nebraska. A major effort is being devoted for establishing cooperative projects with INRAN scientists in Niger. Scientific linkages with ICRISAT/SADCC in Zimbabwe are continuing for pathogen identification and evaluating germplasm for tolerance to bacterial diseases.

Ecogeographic Zones Benefited Most by Research

West Africa and Southern Africa.

Objectives, Research Procedures and Production/Utilization Constraints

Project Objectives

Determine the principal phytopathogenic bacterial incitants of foliar diseases, and stalk and root rots of millet.

Identify sources of resistance to bacterial diseases of millet.

Develop effective screening techniques for evaluating germplasm.

Study the disease etiology and epidemiology of millet pathogens.

Develop rapid and reliable techniques for identifying bacterial diseases of millet.

Ascertain if a synergism exists between nematodes and stalk rot incitants in millet.

Determine the importance of nematodes in providing portals of entry in millet roots for stalk rot organisms.

Changes in Objectives from Previous Year

An increased emphasis on millet diseases with a consequent reduction on sorghum diseases.

Collaborative research projects in Sudan and Niger have not been finalized.

Sorghum/Millet Constraints

Surveys of nematodes and plant pathogenic bacteria parasitic to millet are almost nonexistent. No in-depth research has been conducted on the interactions of stalk rot incitants, nematodes, and plant pathogenic bacteria either in the U.S. or host countries.

Drought stress has been implicated as a predisposing factor in stalk rot development. Nematode damage often mimics drought stress due to root damage. For example, "hot spots", where stalk rot problems are continuously encountered, may be the result of high nematode populations. Research data to substantiate this phenomenon, however, are negligible.

Research Procedures

Millet fields will be surveyed in host countries with cooperating investigators. Millet plant samples will be collected for processing in host country laboratories. Cultures will be shipped to our laboratory for identification, if necessary.

We are developing rapid and simple techniques for identification of bacterial pathogens of millet for surveys and screening for disease resistance. These are assays which provide specificity and simplicity and can be adopted for use in host country laboratories with minimal equipment and training.

To investigate the interaction of nematodes and stalk rot incitants, stunt and root lesion nematode populations (100, 500, and 1,000/ml), *Fusarium graminearum* and *F. moniliforme* propagules (100, 500, and 1,000/ml) and *Erwinia chrysanthemi* (1×10^6 cfu/ml) will be added to autoclaved soil in pots containing various millet accessions. The nematodes and the stalk rot incitants will be added singly and in all possible combinations. After

60 days (anthesis), roots will be washed, weighed, and assigned a numerical value based on root disintegration. The stalks will be split longitudinally and evaluated for lesion development.

Preliminary data from our experiments reveal that some strains of Xanthomonas campestris pv. holcicola are more pathogenic than other strains. The Kansas strains are more aggressive than those from Texas or Southern Africa. This is an important parameter when reporting results from germplasm evaluations. We are presently screening the Texas A&M University Disease and Insect Nursery accessions by using various strains of X. campestris pv. holcicola.

We have reported that X. campestris pv. holcicola can be distinguished from other sorghum and millet bacterial diseases. However, the antiserum is not specific and cross-reactions are observed when tested against other X. campestris pathovars including translucens and vasculorum which infect millet. To simply, reliably, and sensitively identify these bacterial pathogens, we are adopting DNA restriction endonuclease analysis (REA, synonym: restriction fragment length polymorphism [RFLP] mapping) and Sodium dodecylsulfate-polyacrylamide gel electrophoresis (SDS-PAGE). In the REA, total DNA from a homogenous population of bacteria is digested with a restriction enzyme and the fragments produced are separated by gel electrophoresis. The number and location of restriction sites along the DNA strand are unique for each genome. Each fragment forms the specific restriction patterns, or fingerprints, of individual isolates.

Problems Regarding Achievement of Objectives

Relatively little is known about the effect of cultural practices or the cropping sequence of sorghum following millet or vice versa on nematode populations. In other crops affected by nematodes, crop rotation has been valuable in reducing nematode populations.

In general, most millet and sorghum pathologists are virologists and mycologists with limited or no expertise in bacteriology. Due to these limitations, techniques for identification of bacterial millet pathogens have lagged behind those of other disease combinations.

Bacterial diseases are often incorrectly identified due to limited or no training of scientists in host countries in this subject matter. For example, symptoms of bacterial diseases may closely mimic gray leaf spot, local lesions of downy mildew, acremonium wilt or early symptoms of

anthracnose, making diagnosis difficult. Further, symptoms caused by the various bacterial incitants are very similar.

Project Output

Research Findings for Immediate Use

Pseudomonas rubrilineans was determined to be the causal agent of a bacterial disease of millet in West Africa. It has not been determined if yield or grain quality is affected. Due to the widespread occurrence, it is assumed that the bacteria are seed-borne. Other researchers have shown that P. rubrilineans is seed-borne in rice.

Experimental data show that the optimum temperature for disease expression in sorghum by Pseudomonas andropogonis is 32-36°C and cooler temperatures of 20-24°C favor X. campestris pv. holcicola.

Preliminary data from gel electrophoresis reveal that X. campestris pv. holcicola and the gumming disease pathogen of sugarcane, X. campestris pv. vasculorum are identical. This is not uncommon as numerous examples exist where sugarcane and sorghum are hosts for the same pathogen. The synonymy of these two bacterial pathogens suggests that sugarcane would serve as a host during the seasons in which sorghum is not grown.

We have developed testing procedures for differentiating between Pseudomonas andropogonis, the causal organism of bacterial stripe disease, and X. campestris pv. holcicola, the incitant of bacterial streak disease, from sorghum stalk and leaf tissue. The dot immuno-binding assay (DIA) is adaptable for use in host countries where scientists can complete the entire procedure in their laboratory or return the nitrocellulose strip (3 X 5 cm) and our laboratory will conduct the final tests. With the latter choice, problems are encountered with the Animal and Plant Health Inspection Service as the strips may contain pathogens, or perhaps insects that have not been detected in the U.S.

Research Progress

We have identified several sources of resistance in germplasm from the Texas A&M University Disease and Insect Nursery accessions to X. campestris pv. holcicola. The accessions TX434, R1186, TX433, and R3224 are tolerant whereas R1185, 85L21105, 82EON112, TX7078, and 84C-7730 are susceptible to

the Kansas strains. Additional data are being generated concerning the germplasm reaction to diverse strains of X. campestris pv. holcicola and to various temperature regimes under growth chamber conditions.

Preliminary results indicate that Pseudomonas andropogonis is carried in sorghum seed. Our data show that 12 percent of the infested seed resulted in bacterial stripe infected plants. Experimental results from seed infested with X. campestris pv. holcicola were inconclusive. Research is in progress to investigate the role of seed transmission of bacterial diseases of sorghum and the potential role of millet seed in transmission of P. rubrilineans.

Determination of the effect of temperature and relative humidity on disease expression in sorghum is nearly completed. In general, relative humidity is not as important as temperature. P. andropogonis was unable to incite infections at temperatures of 16-20°C, however, at 32-36°C, the pathogen was very aggressive and infections were noted within two days. X. campestris pv. holcicola was favored by temperatures of 20-24°C and was nearly inhibited by high temperature.

The characterization of an additional bacterial pathogen of millet is nearly complete. This bacterial pathogen is a species of Xanthomonas and the pathovar has not been determined as polyacrylamide gel electrophoresis tests show that it does not belong to the translucens or vasculorum pathovars. It is likely that a new pathovar will be named. Pathogenicity tests are nearly complete with corn and sorghum as additional host plants.

Networking Activities

- Research Investigator Exchanges

Dr. Tunde Obilana, Sorghum-Millet Improvement Program, Bulawayo, Zimbabwe visited Kansas State University from September 20 through September 23, 1986.

- Germplasm and Research Information Exchange

Sorghum accessions were received from Dr. D.T. Rosenow, Texas A&M University.

Millet accessions were obtained from D.J. Andrews, University of Nebraska and from Dr. Glen Burton, University of Georgia, Tifton. Fungal isolates were sent to R.T. Hanlin, G.C. Bergstrom and T.A. Toussoun.

- Assistance for Host Country Researchers

Numerous millet and sorghum samples have been diagnosed for researchers in Lesotho, Kenya, and Zimbabwe.

Disease compendia, books, and scientific information have been sent to researchers in Ghana, Zimbabwe, Lesotho, and the People's Republic of China.

Travel

- Lesotho and Zimbabwe. March 6-21, 1986. Survey for plant diseases of various commodities in Lesotho; determine the causal agents of bacterial diseases affecting millet and sorghum; and discuss future research projects with Ministry of Agriculture officials in Lesotho and ICRISAT/SADCC personnel in Zimbabwe.

Publications

Leach, J.E., B.A. Ramundo, D.L. Pearson, and L.E. Claflin. 1986. Dot-immunobinding assay for detection of Xanthomonas campestris pv. holcicola in sorghum. Plant Disease (accepted).

Leach, J.E., B.A. Ramundo, and L.E. Claflin. 1986. Dot-immunobinding assay for detection of bacterial pathogens of sorghum. In Proc. Int. Conf. Plant Pathol. Bact., College Park, MD (in press).

Claflin, L.E. 1986. Sections on Fusarium stalk rot, nematodes, and bacterial diseases affecting grain sorghum. In: R.L. Frederiksen, ed., Compendium of Sorghum Diseases. 82 pp.

Changes in Year 8

No changes are anticipated.

Sorghum and Millet Disease Control, Disease Resistance, Host-Parasite Biology, and Diagnosis

Project TAM-124

Richard A. Frederiksen and Robert W. Toler

Texas A&M University

Host Country Principal Investigators

Dr. Omer Hilu, ARC, Pathologist - Sudan

Dr. Dan Meckenstock, INTSORMIL, Plant Breeder - Honduras

Dr. Walter de Milliano, ICRISAT, Pathologist - Zimbabwe

Dr. Lewis Mughogho, ICRISAT, Pathologist - India

Other Researchers

Host Country

Mr. A.S. Ferreira, EMBRAPA, Pathologist - Brazil

Mr. Carlos Casela, EMBRAPA, Plant Breeder - Brazil

Mr. Edilson Paiva, EMBRAPA, Biochemist - Brazil

Mr. Jesus Narro, INTA, Pathologist - Mexico

United States

Dr. D.T. Rosenow, Texas A&M, Plant Breeder

Dr. Gary Odvody, Texas A&M, Plant Pathologist

Dr. J. Craig, USDA/ARS, Texas, Plant Pathologist

Dr. Lloyd Rooney, Texas A&M, Cereal Chemist

Dr. Ralph Waniska, Texas A&M, Cereal Chemist

Dr. Fred Miller, Texas A&M, Plant Breeder

Dr. Gary Peterson, Texas A&M, Plant Breeder

Mr. Lucas Reyes, Texas A&M, Plant Breeder

Dr. L. Claflin, Kansas State University, Plant Pathology

Dr. R. Duncan, University of Georgia, Plant Breeder

Dr. M. Bonde, USDA, Maryland, Plant Pathology

Summary

Sorghum has many different diseases, each caused by a specific pathogen. These pathogens can be submicroscopic such as viruses, or macroscopic parasitic plants. Because sorghum/millet research crosses many geopolitical barriers, considerable effort goes into restricting the movement of pathogens without restricting the movement of germplasm. Sometimes these safeguards are more important than others, for example,

differences among isolates of the downy mildew pathogen threaten established host resistance programs and force breeders to reevaluate their strategies in defensive crop improvement. Work done during this past year indicated that there are sorghums with resistance to all known pathotypes of the sorghum downy mildew pathogen. Similarly, the high rate of variability of the pathogen causing anthracnose and maize dwarf mosaic can be identified using a uniform system that is available to all sorghum workers. Resistance to such diseases as grain mold and stalk rot appears much less affected by variation in the pathogen and probably results from physiological factors in the plant. Understanding the parameters affecting disease development actually permits better designs for control. Work done on downy mildew epidemiology has a direct influence in the areas of distribution and factors affecting the disease in Honduras as well as in Southern Africa. Key parameters include soil temperature, soil texture, soil moisture and pathogen concentration. Factors affecting these parameters also affect the amount of disease that will develop in a particular growing season.

High populations of susceptible plants permit the rapid increase of diseases such as downy mildew. Intercropping with non-host plants, crop rotation, and host resistance all can be used to reduce the potential damages of this and many other sorghum diseases.

Several thousand sorghum entries were evaluated for endemic diseases in South Texas. Susceptible materials are either discarded or produced for areas with less of a disease threat.

The International Sorghum Virus Nursery (ISVN) has been instrumental in virus detection world wide and is expanding. The International Sorghum Virus Antiserum Bank (ISVAB) had aided in determining international virus distribution and identification as well as virus relationships.

The ISVN and ISVAB have contributed to specific virus identification in Mexico, Venezuela, Tanzania, and Argentina and aided in the comparison of strains in Southern Africa, Australia, and France.

The new strain of MDMV, designated O, in general produced less severe reactions to most of the sorghum differentials. It produced the same level of reaction as MDMV-A in PI35038, RTx7078, ATx623 x RTx430 and Tx2786. QL-11 and QL-3 were immune to strain O.

The identification of host resistance to brome mosaic virus, Venezuelan strain of MDMV, strain H of sugarcane mosaic virus and maize dwarf mosaic

virus A has aided in the control of these virus diseases and reduction of economic losses.

Sources of resistance were found to MDMV strains A and B in sudangrass accessions.

Immuno-electron microscopy was coupled with immuno-gold decoration to differentially label virus particles of two strains of MDMV. The purpose of pursuing this technique is for the study of mixed infections of MDMV and/or sugarcane mosaic virus strains. MDMV-A and anti-MDMV-B IgG were used to trap approximately equal densities of MDMV-A and MDMV-B particles from infected sudangrass sap. Colloidial gold (14.5) nm), stabilized with protein A and conjugated to IgG specific to one strain of the virus, was used to specifically label virus particles of that strain in the mixture attached to the grids. The grids were then stained with PTA and examined under the electron microscope. Optimum labeling resulted in an average of 10 to 15 gold labels per homologous virus particle.

Institutions

Collaborating Host Countries: Sudan, Agricultural Research Corporation; Honduras, Ministerio de Recursos Naturales; Brazil, EMBRAPA; Mexico, INTA.

U.S.: Texas A&M University; Agricultural Experiment Station, Georgia; Agricultural Experiment Station, Kansas.

Linkages:

In Sudan, our work with Dr. Hilu is continuing. Progress is being made on the epidemiology of long smut and charcoal rot. The work is in collaboration with Dr. D.T. Rosenow.

Research on diseases and disease management in Honduras was summarized in a dissertation by G. Wall. This research represents a vital program to provide information on the disease constraints present under traditional cropping systems and the type of problems that may be introduced by new cultivars or changing cultural practices.

In Mexico, Jose Sifuentes, INTSORMIL graduate student, is completing a first year's research on managing leaf blight of sorghum. Part of the work includes selection for host resistance, pathogen race identification and damage evaluation.

In Brazil, several efforts are being made to define new sources of resistance to anthracnose. The approach with Carlos Casela is to select for

dilatory (horizontal) resistance as well as conventional approaches. In cooperation with Edilson Paiva, a new proposal to NSF/CNPq is being prepared to continue work on the biology of C. graminicola in the U.S. and Brazil.

Ecogeographic Zones Most Benefited by Research

East Africa, Southern Africa, West Africa, South America and Central America.

Objectives, Research Procedures, and Production/Utilization Constraints

Year 7 Objectives

Identify sources of resistance to disease.

Assist in the incorporation of multiple sources of resistance to disease.

Determine inheritance of resistance.

Improve disease screening methods.

Complete biology of disease where needed.

Organize, maintain, and distribute (with TAM-121 and 122) the International Sorghum Disease and Pathogen Identification Nurseries.

Produce antiserum to sorghum sudan and millet viruses for under-developed countries.

Determine amino acids (AA) peptide maps, and AA sequences of maize dwarf mosaic virus strains to determine their relationships and pathogenicities.

Organize and maintain international sorghum virus nursery for world-wide distribution.

Study the effects of MDMV-O on grain sorghum and development.

Identify and isolate resistance to MDMV-A and MDMV-B in sudangrass.

Identify, catalog, and evaluate sources of resistance to the different viruses, strains, and biotypes of viruses that infect sorghum.

Develop and release new virus resistant sorghum germplasm and inbreds.

Sudan:

Charcoal rot

Describe the best growing conditions to minimize incidence of disease.

Identify sources of resistance.

Long smut

Identify sources of resistance.

Identify plant traits leading to disease escape.

Study survival of the pathogen.

Evaluate the role of wild sorghums in pathogen survival.

Assess economic importance of disease in rain fed production areas.

Anthracnose

Identify resistant genotypes.

Evaluate elite genotypes in Sudanese breeding programs for disease reaction.

Characterize pathogen populations.

Honduras:

Survey sorghum production areas for distribution and severity of diseases.

Evaluate disease losses and rank importance of disease.

Compare disease development in traditional and introduced sorghum growing methods.

Establish a regional disease nursery program.

Develop or assist in developing methodologies for breeding for disease resistance in Honduras.

Brazil:

Characterize pathogen populations of Peronosclerospora sorghi and Colletotrichum graminicola as to specific race groups.

Evaluate new methods of selecting for stable sources of resistance to anthracnose.

Collaborate in developing anthracnose/head blight resistant populations. (Texas, Georgia, Mexico, Brazil, Puerto Rico)

Initiate studies on biocontrol of sorghum downy mildew.

Mexico:

Define races of various pathogens including strains of virus present in sorghum growing regions of Mexico using the International Sorghum Virus Nursery (ISVN) and the Antisera Bank.

Collaborate in development of head blight resistant sorghum populations.

Determine the inheritance of resistance to sorghum downy mildew.

India:

Study of virulence patterns of the sorghum downy mildew pathogen from Africa, Asia, South and North America.

Philippines:

Identify and evaluate sources of resistance to foliar diseases.

Botswana:

A graduate research program to study survival of nematodes Pratylenchus spp. and their damage to sorghum roots.

Mali:

A graduate program to determine factors affecting sorghum and millet root infection by Macrophomina phaseolina and to determine levels of host reaction to root infection.

Venezuela:

Evaluation of sorghum virus strains using both the ISVN and the Antisera Bank.

Culture of several advanced sorghum disease nurseries for host reactions and estimates of pathogen variability.

Changes in Objectives from Previous Year

Year 7 was one of the most active for TAM-124 and because of budget cuts will be reduced in Year 8. Different emphases are being projected. More attention is being directed toward grain mold, anthracnose, foliar diseases, stalk rot and head smut because of the progress in reducing losses caused by sorghum downy mildew. Virus identification will continue as a major component of the project.

Sorghum/Millet Constraints

There is a vast array of sorghum/millet pathogens, varying from parasitic plants such as Striga to viruses, and including nematodes. This complex of microorganisms and phanerogams represents at times limiting constraints to sorghum/millet production. This is particularly true when attempts are made to increase sorghum production by changing cultural practices or cultivars from subsistence levels. For example, development of earlier maturing sorghums in Sahelian Africa may be improbable because of grain mold. Decreasing plant height to increase grain/stem ratio increases levels of foliar disease. Many high yielding hybrids are inherently more susceptible to lodging, consequently, continued effort is necessary to address many different kinds of disease problems often as a result of changing agronomic procedures.

Research Procedures

Research procedures used during Year 7 were presented in the plan of work. For the most part, they are conventional and were done by graduate research assistants. G. Wall's work was conducted in Honduras, and part of M. Pawar's research was done at the USDA Biological Containment facility at Frederick, MD. This required cooperation of several agencies, particularly ICRISAT, for the shipment of critical isolates of the sorghum downy mildew pathogen.

Problems Regarding Achievement of Objectives

The stationing of two new ICRISAT plant pathologists in West and Southern Africa will help in our overall collaboration with these regions; however, few plant pathologists from national programs are actually working on sorghum/millet disease control. An objective of the 1988 Zimbabwe Conference on sorghum diseases will be to identify more of the cultivars and attempt to find ways to assist in the research.

Project Output

Research Findings for Immediate and Future Use

The work done by M.N. Pawar has demonstrated the extent of variation in *Peronosclerospora sorghi* when isolates from around the world can be evaluated at a single site. This research also provides evidence that certain types of international plant pathology require close cooperative effort because without the collaboration of the USDA and ICRISAT along with several host country contributors, this work would have been impossible. As a part of this research, ten sorghum cultivars with resistance to isolates of *P. sorghi* from seven countries are now included in breeding programs. Dr. Pawar also describes some possible experimental errors in interpreting host plant resistance as well as establishing an international set of differentials.

Disease damage or extent often cannot be forecast accurately; however, the parameters for downy mildew infection are based on oospore distribution/concentration and physical factors such as soil moisture, temperature, and texture, according to studies done by Dr. W. Schuh. For example, sorghum planting dates which are followed by saturated soils, at temperatures below -20 C (or soils with a sand content of less than 20%) can be classified as "disease suppressive". Selected weather data alone could account for 42

percent of the variation in downy mildew incidence over a four year period in south Texas. Many of these observations support the notion that diseases such as sorghum downy mildew are less likely to develop in more temperate regions. Even conditions in Texas are not ideal for the disease and as a consequence can be managed in part by site selection and planting date. When soil structure and previous inoculum are considered, the probability of disease incidence becomes even less.

Data from collaborators working in Brazil indicate that there are sorghum lines with dilatory resistance to anthracnose. This type of resistance, by definition, is not affected by changes in the pathogen population. The extent of variability in Colletotrichum graminicola, the pathogen causing anthracnose, is one of the greatest of any known pathogen. Development of more stable forms of resistance to anthracnose represents a major contribution to improving sorghum in LDC's. This concept has an immediate application in testing procedures and a potential for further improving disease resistance for LDC growers.

Twenty-one sorghum diseases were identified in different regions of Honduras. Eight of these cause major or represent major yield constraints: sorghum downy mildew, acremonium wilt, maize dwarf mosaic, gray leaf spot, ladder spot, smut, anthracnose, oval leaf spot and zonate leaf spot.

Grain mold and charcoal rot probably represent diseases that will need to be addressed more under different cropping systems. For the most part, disease damage can be assessed with multiple regression models using plant height, panicle length, and disease severity. Different cropping systems lend themselves to different disease situations and therefore different management tactics may be needed. Dr. George Wall, working in Honduras, demonstrated that maize dwarf mosaic becomes a major disease in sorghum-maize intercropping, whereas most other diseases are common in monocropping of sorghum. Some foliar diseases are much more damaging in dwarf plants than in the taller traditional land race cultivars. Host plant resistance was the best overall strategy for disease control.

The mechanisms of resistance to grain mold are complex. Specific polyphenols appear to develop in response to infection by grain molding fungi, but the highest level of resistance is conditioned by grains with a testa, also high in polyphenols. The work to date suggests that moderately high levels of grain mold resistance are possible in non brown sorghums.

Maize dwarf mosaic virus (MDMV) is one of the polyviruses whose strain relationships have not been clearly defined. Many of the characteristics which have been traditionally used in the strain definitions are now known to be unreliable. By replacing these characteristics of the capsid protein, new strain relationships were revealed.

Serological analysis by immunoblot provided an easy and convenient method to analyze these strains. By utilizing regression analysis, the relative epitope concentration and the relative epitope compatibility could be determined. This analysis provided clear distinction between strains A, B, E, and O. Strains D and F could not be distinguished from MDMV-A. Strains D and F are no longer strains but are the same as MDMV-A.

Networking Activities

East African Sorghum Workers Conference, June 1985, Frederiksen.

Brazilian Corn and Sorghum Biennial Meetings at Belo Horizonte, Brazil, August 1986, Frederiksen.

American Phytopathological Society Annual Meetings, August 1986, Toler and Frederiksen.

R.A. Frederiksen spent the academic year at Cornell University as a visiting professor in the Department of Plant Pathology. Served on the T.C. and as chairman of the plant pathology discipline.

Established nurseries for leaf blight research in Mexico, June - October, 1986, Jose Sifuentes.

Collected disease data from sorghum winter nurseries in Puerto Rico, December 1985 and March 1986, Kitty Cardwell de Castillo and Carrie Brown.

- Research Investigator Exchanges

  Dr. Zana Sanago, Mali.

  Moriba Konate, Mali.

  Felix Torborda, Universidad de Zulia, Venezuela.

  Dr. Jan Kisgeci, University of Novi Sad, Yugoslavia.

  Joe Mushonga, Sorghum Breeder, Zimbabwe.

- Germplasm and Research Information Exchange

  Distribution of Disease Nurseries

The International Sorghum Virus Nursery	1	Mexico
The International Disease and Insect Nursery	3	Egypt, Mexico, Zimbabwe
The Sorghum Downy Mildew Virulence Nursery	3	Mexico, Zimbabwe, Honduras

The Uniform Head Smut Nursery	2	Egypt, Mexico
The Grain Weathering Test	1	Mexico
The All Disease and Insect Nursery	2	Mexico, S. Africa

Travel

- Soroti, Uganda. June 1985. R.A. Frederiksen. East African Sorghum Workers Conference.
- Belo Horizonte, Brazil. August 1986. R.A. Frederiksen. Corn and Sorghum Biennial Meetings.
- Orlando, Florida. August 1986. R.A. Frederiksen and R.W. Toler. American Phytopathological Society Annual Meetings.
- Celaya, Mexico. June - October, 1986. J. Sifuentes. To establish nurseries for leaf blight research.
- Puerto Rico. December 1985 and March 1986. K. Cardwell and C. Brown. To collect data from disease nursery.

Publications and Presentations

Publications

Forbes, G.A. and D.C. Collins, G.N. Odvody, and R.A. Frederiksen. 1985. A seedling epipytotic of sorghum in South Texas caused by Pythium arrhenomones. Plant Dis. 69:726

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Schuh, W., R.A. Frederiksen, and M.J. Jeger. 1986. Analysis of spatial patterns in sorghum downy mildew with Morisitas index of dispersion. Phytopathology 76:446-450.

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Schuh, W. and R.A. Frederiksen. 1985. Spatial distribution of systemic downy mildew, caused by Peronosclerospora sorghi in sorghum fields. Phytopathology 75:1342.

Pawar, M.N., R.A. Frederiksen, L.K. Mughogho, and M.R. Bonde. 1985. Survey of virulence in Peronosclerospora sorghi isolates from India, Ethiopia, Nigeria, Texas (USA), Honduras, Brazil, and Argentina. Phytopathology 75:1374.

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Pawar, M.N. Pathogenic variability and sexuality in Peronosclerospora sorghi, and comparative nuclear cytology of Peronosclerospora species. May 1986.

Presley, D.M., R.G. Henzell, R.S. Greber, D.S. Teakle, and R.W. Toler. 1985. Use of a set of differential sorghum inbred lines to compare isolates of sugarcane mosaic virus from sorghum and maize in nine countries. Plant Dis. 69:1046-1049.

Toler, R.W. 1985. Maize dwarf mosaic, the most important virus disease of sorghum. Plant Dis. 69:1011-1015.

Toler, R.W. 1986. Diseases caused by viruses and viruslike organisms. In Compendium of sorghum diseases. R.A. Frederiksen, ed. The American Phytopathological Society. 82 p.

Alexander, J.D., and R.W. Toler. 1985. A technique for the differentiation of strains of individual maize dwarf mosaic particles in a mixed preparation. Phytopathology (Abstr.) 75:1323.

Vann, S.R., R.W. Toler, and F.R. Miller. 1985. Greenhouse and field screening of sudangrass accessions for resistance to strain A and B of Maize Dwarf Mosaic Virus. Phytopathology (Abstr.) 75:1337.

Langham, M.A., and R.W. Toler. 1985. A molecular weight analysis of the protein capsid proteins from Maize Dwarf Mosaic Virus strains. Phytopathology (Abstr.) 75:1357.

Langham, M.A., R.W. Toler, and L.M. Giorda. 1985. Detection of Maize Dwarf Virus by Immuno-blot. Phytopathology (Abstr.) 75:1357.

Presentations

Frederiksen, R.A. 1986. Enfermedades de sorgo: posibles formes de Central Proc. VI Congreso de la Asociacion Colombiana de Fitopathologia L Ciencias Afines (Ascolfi) Santa Marta, Magdalena. May 30-June 2, 1984.

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Frederiksen, R.A. 1986. Transitions in the Practice, Theory, and Experimentation in Plant Pathology. Key note address 24th Annual Plant Pathology Congress. South African Society for Plant Pathology.

Changes in Year 8

In part because of reduction in budget, more emphasis will be placed on laboratory approaches to solving disease problems. The extent and size of field nurseries will be reduced and fewer graduate students can be supported. The reduction represents a minor scaling down of the program and will permit more deliberate focusing of the research.

Development of Control Programs for Millet and Sorghum Diseases in Semiarid Southern Africa

Project TAM-128

Gary Odvody

Texas A&M University

Principal Investigators

United States

Gary Odvody, Project Leader

J.B. Mott, TAES, Plant Pathology, Corpus Christi, Texas

Host Country

B. Motalaote, Plant Pathologist, Sebele Experiment Station, (GOB), Sebele, Botswana

W. deMilliano, Plant Pathologist, SADCC/ICRISAT, Bulawayo, Zimbabwe

Other Researchers

United States

R.A. Frederiksen, Plant Pathologist and Project Leader, TAM-124

R.W. Toler, Plant Pathologist, Principal Investigator, TAM-124

D.T. Rosenow, Sorghum Breeder and Project Leader, TAM-122

D.J. Andrews, Millet and Sorghum Breeder, Project Leader, NU-115

L.V. Withee, Project Leader, KSU-107

Zimbabwe

J.N. Mushonga, Sorghum Breeder and F. Muza, Millet Breeder, Crop Breeding Institute, Harare (Cooperative through SADCC/ICRISAT)

Summary

Seasonal charcoal rot incidence differences between the 1984-85 and 1985-86 growing seasons at Sebele, Botswana demonstrated that presence and absence of stress environments (high temperature, low soil moisture) at specific stages of host plant maturity are critical to development of the disease and can differ with the host crop. Cowpeas were more susceptible to charcoal rot when stressed as seedlings but sorghum and pearl millet were more susceptible when stress occurred primarily after anthesis rather than early or throughout the season.

Although foliar diseases are not currently of importance in Botswana, two standard Botswana varieties demonstrated good field resistance to one or

more foliar pathogens in Zimbabwe in 1985 and 1986. Segaolane had good resistance to leaf blight (Exserohilum turcicum) and sooty stripe (Ramulispora sorghi) and Town had good resistance to leaf blight but was not evaluated for sooty stripe reaction.

Sorghum and pearl millet disease slide sets and commentary have been produced and are being distributed to key scientists in the SADCC region for use as disease identification aids and for educational use in the classroom and in extension or other publications.

Institutions

Collaborating Host Country: Zimbabwe - SADCC/ICRISAT, Bulawayo Crop Breeding Institute, Harare and Botswana - Department of Agricultural Research, Sebele, Botswana.

U.S.: Kansas State University - KSU-107 and University of Nebraska - NU-115.

Linkages:

Botswana - Primary linkage is through Baikabile Motalaote who returned to Botswana in late 1985 after completing her M.S. degree in plant pathology at Texas A&M University.

Zimbabwe - W. deMilliano was appointed in early 1986 as the SADCC/ICRISAT plant pathologist and is located in Bulawayo, Zimbabwe. He represents a critical element for TAM-128 INTSORMIL activities because of his continuing interaction with pathologists throughout the SADCC region. W. deMilliano has developed an affiliation of plant pathologists from several SADCC countries and involves them in training, information exchange, and collaborative research. TAM-128 collaboration with Dr. deMilliano is being developed so we can make contributions to a greater number of SADCC scientists than is possible through separate programs.

Ecogeographic Zone Benefited Most by Research

Southern and East Africa.

Objectives, Research Procedures, and Production/Utilization Constraints

Year 7 Project Objectives

Cooperatively determine and establish or plan specific soilborne disease increase nurseries for sorghum to include long smut, covered kernel smut and sorghum downy mildew.

Establish disease nurseries of variable germplasm to evaluate presence, incidence, and variability of several sorghum and millet pathogens.

Determine possible role and identity of pathogens involved in the poor stand establishment of millet and sorghum.

Begin search for naturally occurring biocontrol organisms and evaluate a commercially available Bacillus sp. as a biocontrol seed treatment to increase stand establishment in millet and sorghum.

Develop good visual aids for instruction and education in recognizing and identifying sorghum and millet diseases.

Research Procedures

Botswana - B. Motalaote finished her M.S. degree work too late to return for the 1985-86 planting season in Botswana so efforts were concentrated on determining TAM-128 involvement in development and support of her project upon return to Botswana. More specific collaboration and support were determined during a March-April 1986 trip to Botswana by the TAM-128 project leader. Many Year 7 objectives are proposed for initiation in Year 8 through B. Motalaote and her association with W. deMilliano, the SADCC/ICRISAT plant pathologist located in Bulawayo, Zimbabwe.

Germplasm exchange will be conducted for agronomic and disease evaluation purposes but also to conduct specific disease research and to monitor and characterize pathogen populations in Botswana.

Zimbabwe - TAM-128 involvement in Zimbabwe and other SADCC countries will primarily be through the SADCC/ICRISAT project of W. deMilliano and consists of U.S. based research support, development of educational support materials, and acquisition and transfer of other existing educational materials.

Germplasm exchange of millet and sorghum is being conducted through W. deMilliano and T. Obilana (SADCC/ICRISAT sorghum breeder).

Slides of common sorghum and millet diseases were collected and evaluated for use in developing duplicate slide sets with appropriate commentary for use by scientists in Southern Africa. W. deMilliano will assist in identifying scientists to receive these sets and help improve the future scope and quality of the slide sets.

Project Output

Research Progress

Seasonal charcoal rot incidence differences between the 1984-85 and 1985-86 growing seasons at Sebele, Botswana, demonstrated that presence and absence of stress environments (high temperature, low soil moisture) at specific stages of host plant maturity are critical to development of the disease. Sebele had minimal rainfall throughout the 1984-85 season and there was little or no charcoal stalk rot observed in sorghum or millet, but some charcoal rot damage occurred in cowpea seedlings which are more susceptible in the seedling stage than sorghum or millet. In 1985-86, favorable early season moisture conditions were followed by late season stress. There was high incidence of charcoal rot in sorghum and pearl millet, especially in cultivars whose maturity coincided with the onset of the stress environment soon after heading and pollination. The contributions of these three crops to soilborne sclerotial inoculum of M. phaseolina and the possible physiological specialization of the pathogen between hosts are viable areas of research as is the exploitation of the Sebele environment to screen for resistance to charcoal rot in these crops.

At the present, foliar diseases of sorghum are not a problem in Botswana but may have been in the past as two of their most widely used cultivars have excellent resistance to some foliar diseases. Segaolane maintained green leaves amidst a sooty stripe and leaf blight epiphytotic that killed many other cultivars being evaluated by the TAM-128 project leader at a Zimbabwe location in 1985. In 1986, W. deMilliano in Zimbabwe confirmed the high levels of leaf blight resistance in Segaolane and also noted its existence in the variety Town. These results show the importance of multi-location testing of germplasm throughout the SADCC region and the potential need for disease resistance not currently regarded as important in Botswana or other SADCC locations.

Although chemical seed treatments are not presently viewed as an important component of sorghum and millet production in Southern Africa they may become increasingly important if we demonstrate their utility in increasing stand establishment and seedling vigor. All seed provided to Botswana farmers by the Seed Multiplication Unit of the GOB is treated with Captan but the actual benefits of treatment need to be better documented. Our research in the U.S. has shown that seed treatment with some pesticides

can increase certain diseases of sorghum and that some seed-treatment fungicides can reduce the infection of sorghum seedlings by beneficial endomycorrhizae. Both beneficial and negative contributions of seed treatment need to be considered because of the high vulnerability of sorghum and millet seedlings and the current seedling establishment problem in Botswana.

Networking Activities

A 50-slide set of sorghum and millet diseases was selected and high quality duplicates were made for 40 slide sets and an appropriate commentary to accompany the slides was developed. The slide sets are being distributed to key personnel in Southern Africa for use in their research programs as a disease identification aid and for other appropriate educational purposes including extension and other publications.

Drought resistant germplasm from D.T. Rosenow (TAM-122) was sent to Botswana and evaluated by D. Carter (KSU-107) and by the TAM-128 project leader. L. Mazhani (sorghum breeder, GOB) has requested additional materials from Rosenow's program. B. Motalaote and L. Mazhani have provided germplasm to TAM-128 which will be utilized for agronomic evaluation and for U.S. based plant pathology research.

Millet germplasm was received from W. deMilliano for evaluation against Fusarium spp. that caused premature stalk and plant death on these lines at Matopos, Zimbabwe. T. Obilana sent requested sorghum germplasm and additional cultivars from his program for evaluation in U.S. sorghum environments.

TAM-128 helped plan and organize T. Obilana's trip to the U.S.A. to view many of the U.S. sorghum breeders' INTSORMIL programs with special emphasis on all INTSORMIL and other Texas A&M sorghum programs at College Station and Lubbock and some interaction with commercial seed company representatives. Obilana's activities were coordinated by J. Craig at College Station and D.T. Rosenow at Lubbock.

Through consultation with B. Motalaote, her major professor, J.L. Starr, and her immediate supervisor, Dr. B.S. Jones (GOB), some equipment and supply needs were determined and these items including camera, soil sampling equipment, soil sieves, and other supplies are being sent to Botswana in the fall of 1986. Other equipment needs and supplies are being further determined with special emphasis toward developing a laboratory

functional in nematology research. A trip to Botswana by J.L. Starr is being planned (on another grant) to (a) assess some of the final laboratory needs, (b) help B. Motalaote establish the laboratory, (c) determine the critical areas where nematode research is needed, and (d) evaluate current damage that may possibly be attributed to nematodes in the major crops of Botswana.

Travel

- Botswana, Zimbabwe and Zambia. March 22-April 9, 1986. Gary Odvody. To develop collaborative research programs with B. Motalaote (Botswana) and W. deMilliano (SADCC/ICRISAT) and to assess sorghum and millet disease incidence in all three countries.

Publications

Motalaote, B. 1985. Pathogenicity of the lesion nematodes on sorghum. M.S. Thesis. Texas A&M University. 37 pp.

Odvody, G.N. and J.B. Mott. 1986. Systemic fungicides used as seed treatments to control systemic sorghum downy mildew. Fungicide and Nematicide Tests. Volume 41.

Craig, J., R.A. Frederiksen, G.N. Odvody, and J. Szerszen. 1985. Effect of seed safeners on incidence of sorghum downy mildew. pp. 42-48. Proceedings of the 40th Annual Corn and Sorghum Industry Research Conference, Chicago, Ill. December, 1985.

Forbes, G.A., D.C. Collins, G.N. Odvody, and R.A. Frederiksen. 1985. A seedling epiphytotic of sorghum in South Texas caused by Pythium arrhenomanes. Plant Disease. 69:726.

Schuh, W. 1986. Epidemiological aspects of sorghum downy mildew caused by Peronosclerospora sorghi. Ph.D. Dissertation. Texas A&M University.

Changes in Year 8

Most Year 7 objectives were long term objectives carried over to Year 8 for continuation and initiation. An additional objective regarding endomycorrhizae in seedling roots of millet and sorghum is included for Year 8.

Trips to Southern Africa in 1985 and 1986 have helped TAM-128 and in-country scientists to assess and identify major disease problems in some areas of Southern Africa and how best to structure our collaborative

research programs. For instance, some of the diseases initially proposed as researchable entities for given areas of Botswana (head smut and foliar diseases) have been proposed for other SADCC regions or deleted from our research plans. The development of standard millet and sorghum disease nurseries for the SADCC Region through cooperation with W. deMilliano and SADCC country scientists is an important part of a continuing disease assessment and monitoring program.

Socioeconomics

Executive Summary

Grain sorghum production is technically feasible in the Philippines, but its economic feasibility remains uncertain. Work during Year 7 of this project initiated collection of data which will provide the basis for an economic assessment of the potential for producing and marketing Philippine grain sorghum. Subsequent research will employ cost synthesis, linear programming, MOTAD and other procedures in analyzing costs and risks associated with sorghum production and a market structure approach in evaluating the performance and needs of the feed grains marketing system. (NU-117)

Collaborative work in Burkina Faso demonstrated the high economic return to the combination of a water retention device (tied ridges) and moderate chemical fertilization. Whole farm modeling was necessary to indicate the importance of seasonal labor availability in constraining the area in tied ridges. Field testing and economic analysis of an animal traction implement to do the ridging were undertaken. This technology of tied ridging-moderate fertilization is expected to have wide applicability in the heavier soils in the Sahelian region where the tied ridges will not easily be blown down or washed away. On lighter soils in semiarid regions the same principles of looking for the combined effects of improved water retention techniques and moderate chemical fertilization are also expected to be a field research area with a potentially high payoff. (PRF-105)

Research in the Dominican Republic dealt with several issues involving sorghum and millet and improvement of the conditions of life of limited-resource farmers. One issue is whether sorghum can be substituted for maize -- the traditional crop -- in intercropping rotations. The evidence of two seasonal trials on mountain farms indicates that sorghum outperforms maize in the rotations. It can be used as feed for animals, and limited trials indicate its possible use as human food. Since technical constraints are minimal, price policies are decisive.

In studies of southern Honduran communities, the first issue is the nutritional status of children of families who raise sorghum. Although the average diet is adequate, there is considerable variability with the least

adequate diets found in the largest families. Energy rather than protein is most deficient, leading to the recommendation that in breeding programs higher yields rather than grain quality should have the highest priority.

Another issue relates to the way sorghum research should consider the role of women in production, marketing, food processing and consumption. In Honduras, women are primarily processors of sorghum as food, rather than producers as in Africa, and they are involved in marketing. It should be recognized that sorghum quality as well as quantity thus are primary interests of women.

In Mexico, the research has been concerned with the changing interest in sorghum production in response to governmental economic policies. Commercial farmers in irrigated areas have shifted to sorghum during periods when it has had a comparative price/profit advantage. Policy makers must decide between feed grain and food grain policy objectives. In rainfed areas, important technical problems must be solved to make sorghum a competitive crop.

In Sudan, farmers were found to be responsive to environmental and price changes in crops and varieties planted. Kinship networks and markets were found to be the dominant networks of communication among both men and women farmers. (KY-101 and 102)

Sociocultural Constraints in the Production, Distribution and Consumption of Grain Sorghum and Pearl Millet in Less Developed Countries

Projects KY-101 and 102

C. Milton Coughenour

University of Kentucky

Principal Investigators

Host Country

Dr. David Barkin, UAM - Xochimilco, Department of Economics, Mexico

Dr. Jose Carlos Escudero, UAM - Xochimilco, Department of Social Medicine, Mexico

Dr. Guilleromo Perez Jeronimo, UAM - Xochimilco, Department of Agronomy, Mexico

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Sr. Fernando Cruz, Instituto Hondureno de Antropologia e Historia, Honduras

M. Issa Mahame, INRAN, Niger

United States

Dr. Lawrence Busch, University of Kentucky, Department of Sociology

Dr. Milton Coughenour, University of Kentucky, Department of Sociology

Dr. Larry Burmeister, University of Kentucky, Department of Sociology

Dr. William Lacy, University of Kentucky, Department of Sociology

Dr. Billie DeWalt, University of Kentucky, Department of Anthropology

Dr. Kathleen DeWalt, University of Kentucky, Department of Behavioral Science

Dr. Dan Meckenstock, Texas A&M University, Department of Agronomy

Dr. Tareke Berhe, Kansas State University, Department of Agronomy

Other Researchers

Host Country

Dr. Khalil El Medani, University of Khartoum, Department of Anthropology

United States

Dr. Richard Cock, Washington State University, Department of Veterinary Medicine

Dr. Trent Bunderson, Washington State University, Department of Range Science

Mr. Timothy Frankenberger, University of Arizona, Arid Lands Institute

Dr. Brian D'Silva, U.S.D.A., Foreign Agriculture Service

Summary

Research during Year 7 related to the first and third objectives: constraints to the production, distribution and consumption of sorghum and millet and to the communication of information to farmers, respectively. The research on the first objective -- farming systems -- related to two sites in the Dominican Republic, several sites in Southern Honduras, and five sites in Mexico. Work relating to information communication -- the third objective -- involved data collected in Kordofan, Sudan.

The research dealt with several issues involving sorghum and millet and improvement of the conditions of life of limited-resource farmers. One issue is whether sorghum could be substituted for maize -- the traditional crop -- in intercropping rotations. The evidence of two seasonal trials on mountain farms in the Dominican Republic indicates that sorghum outperforms maize in the rotations. It can be used as feed for animals, and limited trials indicate its possible use as human food. Since technical constraints are minimal, price policies are decisive.

In studies of Southern Honduran communities, the first issue is the nutritional status of children of families who raise sorghum. Although the average diet is adequate, there is considerable variability with the least adequate diets found in the largest families. Energy rather than protein is most deficient, leading to the recommendation that in breeding programs higher yields rather than grain quality should have the highest priority. The second issue concerns the consequences for communities neglected by rural development programs. Since living conditions have deteriorated in these communities, the urgency of developing appropriate new sorghum varieties for mountain farms is increased. The third issue relates to the way sorghum research should consider the role of women in production, marketing, food processing and consumption. In Honduras, women are

primarily processors of sorghum as food, rather than producers as in Africa, and they are involved in marketing. It should be recognized that sorghum quality as well as quantity thus are primary interests of women.

In Mexico, the research has been concerned with the changing interest in sorghum production in response to governmental economic policies. Commercial farmers in irrigated areas have shifted to sorghum during periods when it has had a comparative price/profit advantage. Policy makers have substantial control of farmers' production decisions, and, therefore, must decide between feed grain and food (grain) policy objectives. In rainfed areas, important technical problems must be solved to make sorghum a competitive crop.

The issue on which research in Sudan was focused is the dynamism of farm techniques among traditional farmers and the traditional networks of information diffusion. Farmers were found to be responsive to environmental and price changes in crops and varieties planted. Kinship networks and markets were found to be the dominant networks of communication among both men and women farmers.

Institutions

Collaborating Host Country: Secretaria de Recursos Naturales, Honduras; Instituto Hondureno de Antropologia e Historia; Universidad Autonoma Metropolitana, Xochimilco, Mexico; Instituto Nacional de Investigaciones Agricolas, Mexico; Centro de Ecodesarrollo Consejo Nacional de Ciencias y Technologia, Mexico; Western Sudan Agricultural Research Project, Sudan; Secretaria del Estado de Agricultural, Dominican Republic; Institut National de Recherches Agronomiques du Niger.

U.S.: Kansas State University, Texas A&M University and U.S. Department of Agriculture (ERS/IED).

Linkages:

Through contacts with Dr. Khalil, plans were developed for future collaborative work with the Department of Anthropology, University of Khartoum. This might involve farming systems research and/or evaluation of the utilization of new sorghum and millet varieties.

In March 1986, David Barkin (UAM) and Dr. B. DeWalt worked on a book

relating to the research in Mexico. During June of 1986, B.R. DeWalt visited the Centro de Ecodesarrollo to work on the effects of sorghum cultivation on small scale farmers.

In June 1986, with the sponsorship of the evaluation division of USAID, Lawrence Busch and William Lacy with scientists in India and Brazil developed a scope of work and plan of implementation for studies of the impacts of colleges of agriculture on Indian and Brazilian development.

Dr. Larry Burmeister made contact by letter and long distance telephone with both Dr. Deuson, USAID/Niger and Dr. Mahame, INRAN/Niger to arrange a site visit to develop a social science research program in Niger.

Ecogeographic Zones Benefited Most by Research

Central America, Mexico and the Caribbean and East Africa.

Objectives, Research Procedures, and Production/Utilization Constraints

Year 7 Project Objectives

Farming Systems

Mexico - (1) link the microeconomics of sorghum production with the macroeconomic situation in Mexico; (2) identify agronomic constraints to the production of sorghum and other potential crops; (3) determine the nutritional implications of the substitution of cash crops for corn for home consumption.

Honduras - (1) Identify the farming strategies of small farmers growing sorghum; (2) identify constraints to agricultural production and recommend research approaches; (3) identify factors influencing consumption of sorghum and preferred grain quality characteristics.

Niger - (1) Identify farming strategies; (2) identify constraints to increased production; (3) identify factors influencing consumption; (4) assess organizational structures in which sorghum is produced and marketed and constraints.

Sudan - (1) refine and detail farming strategies of farmers producing sorghum and millet; (2) identify factors influencing consumption of sorghum and millet and the preferred grain qualities.

Dominican Republic - (1) Describe farming strategies of small farmers; (2) Identify constraints and the potential role of sorghum in the farming system.

Extension and communication constraints

Sudan - (1) Describe sources, channels, and barriers to communication of information about sorghum and millet within villages; (2) develop effective knowledge utilization programs for farmers in the Western Sudan.

Changes in Objectives from Previous Year

Year 7 objectives relating to farming systems in Mexico, Honduras, Sudan, and the Dominican Republic are consistent with Year 6 objectives and reflect the further analysis of data collected in these countries in earlier years. Objectives for Niger reflect the research which was expected to be initiated during Year 7. The objectives for Year 7 for Extension and Communication in Sudan represent expansion of the analysis of data collected during Year 6 in two villages.

Sorghum/Millet Constraints

In Mexico and the Dominican Republic pricing policy and the availability of suitable grain quality food sorghum are major constraints. In the Sudan, weak extension programs and market infrastructure for distributing new seed have been identified as constraints as well as the lack of farmer knowledge about hybrid sorghum.

Research Procedure

Farming systems methods used in field surveys and standard qualitative and quantitative methods used in data analysis.

Project Output

Research Findings

A study of nutritional status and sorghum use in Honduras indicates: (1) considerable variability among families in the dietary adequacy of energy and protein with the largest families having the least adequate diets; (2) sorghum is often used in tortillas in the diet but is avoided by lactating women; (3) sorghum is most often used by poorer families, and (4) efforts to increase the quantity of grain rather than its nutritional quality, should have the highest priority. In a related study, it is found (5) that levels of living in communities that are outside areas targeted for rural development have worsened, increasing the urgency of developing higher yielding sorghums.

The study of the role of Honduran women in the processes of production and consumption reveals: (1) among semisubsistence producers, women are heavily involved in processing food for consumption but little involved in its actual production; (2) financial decisions are usually made by the husband and wife jointly; (3) women are involved in raising gardens and small animals and in household and child care. (4) An important role is played by women in intra- and inter-village trade/market of agricultural products which they control to a considerable extent.

In Mexican communities, sorghum production has expanded until recently. Although the communities studied differ in their ecological characteristics, farmers turned to sorghum production due to its higher price and mechanization. Even the small farmers raise sorghum on their irrigated land.

There are two consequences. One is to encourage the raising of higher valued crops (eventually shifting from sorghum to vegetable crops or, in Sinaloa, wheat), and the other is the jobs provided for migrant laborers.

Farmers lacking irrigation also lack access to sorghum technology appropriate to their situations. In the rainfed areas sorghum ought to outperform maize as well as most other cash crops. Yet new varieties of sorghum must be developed, and research along this line promises to provide the greatest benefits to these poor farmers.

Within small, ethnically homogeneous villages in North Kordofan, information about agricultural innovations is transmitted: (1) through groups composed of close kin; (2) to women farmers from close relatives; and, (3) from opinion leaders to others within the close-kin network. (4) The opinion leaders often, but not invariably, have high social status, e.g., as sheik or village merchant; (5) function as "bridges" between groups of close-kin. (6) Neither the opinion leaders nor the ordinary farmer had had any contact with extension agents, and the service had not had influence in spreading agricultural innovations.

Research Progress

Verification trials in the Dominican Republic on the substitution of sorghum for maize in intercrop rotations in mountain villages confirmed its superior performance and the potential utility of the crop both as human

food and as grain for animals. Due to the lack of institutional commitment to improving the living conditions of the farmers, the findings have not yet been implemented.

Networking Activities

Efforts were made to expand and develop relationships with potential collaborating social scientists in Sudan. Dr. Khalil El Medani who recently completed a Ph.D. in social anthropology at the University of California-Riverside was invited to campus to discuss possible collaborative research. This was followed up with later contact in Los Angeles. Dr. Khalil has returned to a faculty position at the University of Khartoum and is collaborating in work on the Sudanese agricultural economy.

Dr. Norberto Muniz, Vicosa, Brazil spent a Fulbright year at the University of Kentucky during which plans were initiated for joint involvement in a USAID funded evaluation study of four agricultural universities in Brazil.

Travel

International

- Rabat, Morocco. January 15-February 10, 1986. Lawrence Busch. Member of USAID team evaluating the research program of the Agricultural and Veterinary Institute.
- Guatemala and Mexico. October 27-November 5, 1985. Billie R. DeWalt. Attended meeting of Latin American Sorghum Researchers in Guatemala and then to Mexico City to meet with research collaborators.
- Mexico City. June 3-17, 1986. Billie R. DeWalt. To meet with research collaborators and close out research project.

Domestic

- Washington, D.C. July 23-24, 1985. Lawrence Busch. To participate in a USAID Special Seminar on Agricultural Research in Less Developed Countries.
- Harbor Springs, MI. October 11-13, 1985. Lawrence Busch. To attend International Conference on Crop Productivity.
- Washington D.C. June 20, 1986. Lawrence Busch. To appear before the Joint-Economic Committee of the U.S. Congress.
- Monterey, CA. July 1-August 15, 1986. Larry Burmeister. Attending French language school.

- Manhattan, KS. October 13-18, 1985. Larry Burmeister, Milton Coughenour (Participant) and Paul Marcotte. To attend the Fifth Annual Farming Systems Research Symposium.
- Evanston, IL. April 18-20, 1986. Milton Coughenour (Participant) and Saadi M. Nazhat. Sudan Studies Association meetings.
- Washington, D.C. December 4-12, 1986. Billie R. DeWalt. Participate in the meetings of the American Anthropological Association.
- Champaign, IL. April 10-12, 1986. Kathleen M. DeWalt. To attend meetings of the Economic Society for Anthropology.
- Blacksburg, VA. August 20-24, 1985. Paul Marcotte. To attend meeting of the Rural Sociological Society.

Publications and Presentations

Publications

Barkin, David and Billie R. DeWalt, 1985. "La crisis alimentaria Mexicana y el sorgho." Problemas del Dessarollo 61:55-85.

Barkin, David and Billie R. DeWalt, 1985. "El sorgo en el Sur de Honduras." Pp. 153-67 in Compton L. Paul and Billie R. DeWalt (eds.), El Sorgo en Sistemas de Produccion en America Latina. Mexico: INTSORMIL/ICRISAT/CIMMYT.

Busch, Lawrence, 1985. "Government/Industry/University Interactions." In Crop Productivity: Research Imperatives Revisited. (Edited by Martin Gibbs and Carla Carlson). An international conference held at Boyne Highlands Inn and Arlie House.

Coughenour, C. Milton, Timothy Frankenberger, and Elizabeth Skartvedt, 1985. "Women farmers in rural settlements in North Kordofan, Sudan" The Ahfad Journal 2:9-22.

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DeWalt, Billie R., 1985. "Un panorama de la produccion del maiz y sorgo en el Hemisferio Occidental." In Compton L. Paul and Billie R. DeWalt (eds.), El Sorgo en Sistemas de Produccion en America Latina. Mexico: INTSORMIL/ICRISAT/CIMMYT.

DeWalt, Billie R., 1986. "Economic assistance in Central America: Development or improvishment?" Cultural Survival Quarterly 10:14-18.

DeWalt, Billie R. and David Barkin, n.d.. "Seeds of change: the effects of hybrid sorghum and agricultural modernization in Mexico." In H. Russell Bernard and Pertti J. Pelto (eds.), Technology and Social Change. 2nd Ed. Waveland Press.

DeWalt, Billie R. and Kathleen M. DeWalt, 1985. El Contexto Socioeconomico para la investigacion sobre el sorgo en el Sur de Honduras." Pp. 57-67 in Compton L. Paul and Billie R. DeWalt (eds.), El Sorgo en Sistemas de Produccion en America Latina. Mexico: INTSORMIL/ICRISAT/CIMMYT.

DeWalt, Kathleen, 1986. "The dietary correlates of change in agricultural strategy in a Mexican community." In Carol Hill (ed.), Alternative Health Care Policies: An Applied Social Science Perspective. Athens, GA: University of Georgia Press.

Duda, Susan, 1986. Development and Destruction: Interrelated Biological, Socioeconomic, and Nutritional Change in Southern Honduras. Lexington, KY: University of Kentucky, Unpublished Ph.D. Dissertation.

Fordham, Miriam A., Billie R. DeWalt, and Kathleen M. DeWalt, 1985. Farming Systems Research in Southern Honduras. Report No. 3. Lexington, KY: Department of Anthropology, University of Kentucky and INTSORMIL.

Lacy, William, M. Hansen, L. Busch, and J. Burkhardt, 1986. "Plant breeding and biotechnology: New technologies raise important social questions." BioScience 36:29-39.

Lacy, William, 1985. "The roles of sociologists in two AID programs" and "The role of social scientists in INTSORMIL" The Rural Sociologist 5(4):273,285-289.

Lacy, William and L. Busch, 1986. "Food security in the United States: Myth or Reality?" In New Dimensions in Rural Policy: Building Upon Our Heritage. Pp. 222-233 in Subcommittee on Agriculture and Transportation, Joint Economic Committee of Congress, Washington, D.C.

Marcotte, Paul, 1986. Sorghum Adoption for Smallholder Self-Sufficiency in the Dominican Republic. Lexington, KY: Department of Sociology, University of Kentucky and INTSORMIL.

Marcotte, Paul, 1986. Farming Systems Research as a Method for Introducing Sorghum in the Dominican Republic: A Synthesis of the Positivist and Critical Paradigms. Lexington, KY: Unpublished Ph.D. Dissertation.

Paul, L. Compton and Billie R. DeWalt (eds.), 1985. El Sorgo en Sistemas de

Produccion en America Latina. Mexico: INTSORMIL/ICRISAT/CIMMYT.

Thompson, Karen S., Kathleen M. DeWalt and Billie R. DeWalt, 1985. Farming Systems Research in Southern Honduras, Household Food Use in Three Rural Communities. Report No. 2. Lexington, KY: Department of Anthropology, University of Kentucky and INTSORMIL.

Van Willigen, John and Billie R. DeWalt, 1985. Training Manual in Policy Ethnography. AAA/SFAA Special Publication No. 19, Washington, D.C.

Presentations

Busch, Lawrence, July 23-24, 1985. "Evaluating agricultural research in less developed countries." Presented at USAID Special Seminar.

Burmeister, Larry, August 21-25, 1985. "Accountability in international research: Structural limitations." Presented at Rural Sociological Society.

Burmeister, Larry, October 21-25, 1985. "Agrarian structure and the developmental state: South Korea in comparative perspective." Presented at the Mid-Atlantic Asian Studies Association.

Burmeister, Larry, February 18, 1986. "The future of Korean agriculture." Presented at the Korean Studies Center, University of Hawaii.

DeWalt, Billie R., September 1985. "The nutritional consequences of agricultural development in Mexico." Cornell University International Nutrition Program.

DeWalt, Billie R., October 1985. "Social science research in agricultural development in Central America: Some needs." Comision Latinoamericana de Investigadores en Sorgo: Guatemala.

DeWalt, Billie R., October 1985. "Mexico's Second Green Revolution: Some implications for agricultural research." Invited paper at the University of Connecticut.

DeWalt, Billie R., December 1985. "Agricultural development in Mexico and Honduras: Micro and macro aspects." American Anthropological Association meetings, Washington, D.C.

DeWalt, Billie R., February 1986. "Agricultural development in Mexico." Invited paper York University, Toronto, CANADA.

DeWalt, Billie R., March 1986. "Mexico's Second Green Revolution: Some implications for planning." Cornell University Department of City and Regional Planning, Ithaca.

DeWalt, Billie R., April 1986. "The cattle are eating the forest: Ecological aspects of agrarian change in Honduras." Invited paper State University of New York, Binghamton.

DeWalt, Billie R., April 1986. "Interactions between biological and social agricultural sciences in INTSORMIL work in Honduras." Cornell University International Agricultural Program, Ithaca.

DeWalt, Kathleen M., April 1986. "Including food consumption and nutritional goals in agricultural research and development: The case of INTSORMIL." Presented at the meetings of the Economic Society for Anthropology.

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Lacy, William, 1985. "Values, goals and agricultural research: Conflicting ideologies and strategies." Presented at the annual meeting of the American Association for the Advancement of Science, Los Angeles, CA.

Lacy, William, 1985. "Social ethics, agricultural change and agricultural research." Presented at the meetings of the American Association for the Advancement of Science, Los Angeles, CA.

Marcotte, Paul, August 20-24, 1985. "Social science and farming systems research." Presented at Rural Sociological Society, Blacksburg, VA.

Changes in Year 8

In accordance with the Administrative Board decisions, project objectives have been reduced to the following:

Develop plans for, and initiate, a study of the farming system/consumption/nutritional status of limited resource farmers in Niger.

Complete analysis and reporting of findings of (a) farming and consumption systems in Sinaloa, Mexico, and (b) social networks for the communication of agricultural information in Sudanese villages.

Training of INTSORMIL graduate students in residence.

Economic Analysis of the Potential for Growing and Marketing Grain Sorghum in the Philippines

Project NU-117

Dale G. Anderson

University of Nebraska

Principal Investigators

Dr. Lydia Oliva, Dean Graduate School, and Head Department of Agricultural Economics, University of Southern Mindanao

Dr. Dale G. Anderson, Department of Agricultural Economics, University of Nebraska

Other Researchers

Dr. Dely Gapasin, Director Division of Crops Research, Philippine Council for Agricultural Resources Research Development (PCARRD), Los Banos, Philippines

Dr. George Pfeiffer, Department of Agricultural Economics, University of Nebraska

Dr. Jerry Maranville, Department of Agronomy, University of Nebraska

Dr. Leonardo A. Gonzales, Associate Agricultural Economist, International Food Policy Research Institute (IFRRI)/International Rice Research Institute (IRRI), Los Banos, Philippines.

Dr. Jerome F. Sison, Head Department of Agricultural Economics, University of the Philippines (UPLB), Los Banos, Philippines.

Mr. Jerry Amoloza, Department of Economics, UPLB (Ph.D. graduate student at University of Nebraska)

Ms. Lillian Brion, PCARRD (Ph.D. graduate student at University of Nebraska)

Summary

While it is clear that grain sorghum production is technically feasible in the Philippines, its economic feasibility remains uncertain. Work during Year 7 of the project initiated collection of data which will provide the basis for an economic assessment of the potential for the production and marketing of Philippine grain sorghum. Subsequent research will employ cost synthesis, linear programming, MOTAD and other procedures in analyzing costs and risks associated with sorghum production and a market structure approach in evaluating the performance and needs of the feed grains marketing system.

The two Philippine students whose Ph.D. dissertation projects are central to the project completed their university course requirements, drafted final approaches to their research projects and began the data collection process in the Philippines. The students' two advisers collaborated in the latter work during a visit to the Philippines in May and June.

The project is scheduled for completion at the close of Year 8. Resulting research findings will provide policy makers with assistance in formulating appropriate feed grains programs and crop scientists with guidance toward appropriate directions in their research. Training afforded student participants will contribute to the stock of professional expertise in the Philippines.

Institutions

Collaborating Host Country: Formal agreement with PCARRD, Los Banos, Philippines. Collaborative work plans with SMARC/USM, Kabacan, Philippines.

U.S.: Department of Agricultural Economics, University of Nebraska.

Linkages:

Informal working arrangements with UPLB and IRRI, Los Banos; Integrated cooperative effort with other NU INTSORMIL projects, including NU-113 (Cropping Systems), NU-114 (Mineral Element Uptake-Tolerance) and NU-121 (Philippine Country Project).

Ecogeographic Zones Benefited Most by Research

Asian Subcontinent

Objectives, Research Procedures and Production/Utilization Constraints

Year 7 Project Objectives

Project objectives are directed specifically toward resolving the unanswered question of economic feasibility of growing grain sorghum in the Philippines. Costs and returns from sorghum production are being evaluated based on data from farm trials conducted during the 1970's, on farm trials which commenced in the fall of 1984 as part of the overall PCARRD/INTSORMIL collaboration, and on data obtained from a survey of sorghum producers in Cotabato Province. The latter survey was begun as part of more comprehensive student data-gathering activities late in year seven.

Vaguely specified marketing problems have been blamed for the limited success of earlier efforts to encourage wider production and use of sorghum. The marketing case-study, for which data collection began early in 1986, will describe and evaluate the marketing system for feed grains; it will identify constraints and, where appropriate, suggest improvements.

Objectives for Year 7 were groundwork for meeting the above overall objectives. They consisted of completion of the students' Ph.D. course program and initiation of data collection activities in the Philippines.

Sorghum/Millet Constraints

In spite of the potential advantages of sorghum in the Philippine cropping systems, its rate of adoption has been slow. Problems include marketing difficulties stemming apparently from supplies too thin to encourage development of marketing facilities and institutions; and from post-harvest processing difficulties.

Having been considered relatively recently as a potential field crop in the Philippines, research data on sorghum production under local conditions are very limited. In particular, a significant economic analysis of the potential for expanded production is critically missing. Economic analysis is needed not only to evaluate the relevance of sorghum as an alternative and complementary feed supply, but to guide future biological and physical studies. The present research addresses these needs in the context of the particular circumstances which may attend production and marketing of grain sorghum in the Philippines.

Research Procedures

Close cooperation has been effected between the technical and economic components of the project. Cropping systems to be analyzed were chosen largely on recommendations of U.S. and Philippine crop scientists. Field trials established during Year 6 continued through Year 7 at sites in North Cotabato. These trials provide part of the data needed for the production analysis. Surveys of farmers and marketing intermediaries initiated during Year 7, along with a variety of secondary sources complete the data set.

Cost estimates are being derived from field trial results, adjusted for local conditions, and from farm survey results. A hybrid of sources must be used, with cost synthesis (economic engineering) procedures serving as an integrating mechanism. Costs and risks associated with sorghum production

are being compared with costs and risks associated with alternative crops and cropping systems to determine whether sorghum is indeed the best cropping enterprise under conditions thought by crop scientists to be favorable to its production. Costs of sorghum production must be compared with those for maize production since maize is the major competitive feed grain. It is important that technology appropriate to local farm sizes, resource combinations and financial capabilities of local farmers be the focus of cost comparisons. Linear programming may be a useful analytical tool for the research. Risks associated with sorghum and its alternatives will be evaluated using MOTAD procedures.

Since very little grain sorghum is presently grown and since marketing procedures and channels for sorghum apparently parallel those for maize, the marketing system for maize is by necessity the focus of much of the marketing study. Special attention is being given to discerning any circumstances unique to the marketing of grain sorghum. Cotabato Province, a major producing area and the site of SMARC field trials, is the major focus of the marketing study although coordination with USAID-supported survey activities undertaken by SMARC collaborators may enable limited assessment of marketing problems in selected locations in Luzon as well.

The marketing study has a market structure orientation, and much of the data-gathering activity begun during Year 7 was directed toward describing the structure of the industry, from the assembly of grain from farms through its final distribution as feed to livestock producers. Each of the major intermediate activities, including transportation, storage, processing, and the role of government (pricing, grades and standards) is being given attention. The ultimate purpose for the research is an assessment of the structure of the performance of feed grain marketing activities. In this connection, it is necessary to estimate the costs of services provided at each stage of the marketing sequence and to relate these costs to estimated marketing margins. Economic-engineering cost-finding procedures will be used for this part of the analysis. Data-gathering activities initiated during Year 7 emphasize scale relationships and the implications of projected future feed grain demands for unit costs.

Problems Regarding Achievement of Objectives

The major problem encountered during Year 7 was a delay of the two students in completing their comprehensive examinations. Preparation for

these examinations which must now be undertaken during Year 8 will slow progress toward completion of the research. Additionally, data collection in the Philippines has, as expected, been a challenging activity.

Project Output

Research Findings for Immediate Use

The project was not designed to produce significant results until late in its life, after in-country data collection and preliminary evaluation activities have been accomplished. Year 8 will see completion of the latter work and the publication of final results.

Research Findings for Future Use

Work undertaken in Year 7 provides the basis for completing data collection and evaluation activities in Year 8. Ultimate results will help to establish the economic feasibility of sorghum under alternative circumstances. A basis will be provided for improved sorghum policy decisions and for guidance for plant science research.

Networking Activities

- Research Investigator Exchanges

Anderson, Maranville and Pfeiffer assisted the two students in their data collection and preliminary evaluation work and coordinated project activities and plans with Philippine counterparts and others during a May/June trip to Manila, Los Banos and numerous sites in Cotabato.

- Germplasm and Research Information Exchange

Anderson and Maranville participated in meetings of the Technical Council.

- Assistance to Host Country Researchers

Collaborated with Professor L. Oliva, counterpart researcher at SMARC in North Cotabato, in planning project activities.

TRAVEL

- Chicago, IL. October 2-3, 1985. INTSORMIL TC meetings.
- Kansas City, Mo. January 13-15, 1986. INTSORMIL TC meetings.
- Kansas City, Mo. March 18-19, 1986. INTSORMIL TC meetings.

- Manila, Los Banos and Kabacan, Philippines. March 25, 1986. The two Ph.D. students supported under the project traveled to the Philippines to undertake data collection and evaluation activities. Lydia Oliva, USM/SMARC, Kabacan, is their principal advisor and collaborator.
- Manila, Los Banos and Kabacan, Philippines. May 9-June 7, 1986. Anderson and Pfeiffer assisted students with their research; principal collaborator was Lydia Oliva at USM/SMARC.

Publications and Presentations

Publications

Anderson, Dale G., Jerry Maranville and George Pfeiffer, Trip Report, INTSORMIL, Philippines, May 9-June 6, 1986. 11 pp.

Presentations

Informal presentations of project objectives, procedures and progress were made during Philippine trip to collaborators, sponsors and other interested parties at PCARRD, USM, SMARC, USAID, IRRI, UPLB and elsewhere.

Economic Evaluation of New Technology in Sorghum and Millet Production in Developing Countries

Project PRF-105

John H. Sanders

Purdue University

Principal Investigators

Dr. John Sanders, Department of Agricultural Economics, Purdue University

Dr. Joseph Nagy, Economist and then Director of the SAFGRAD/AID/Purdue Farming Systems Project, Burkina Faso.

Dr. Philip Abbott, Department of Agricultural Economics, Purdue University

Other Researchers

Ms. Linda Ames, Ph.D. Candidate doing field work in Burkina Faso.

Ing. Sibiri Sawadogo, Director of Farming Systems Research in IBRAZ, Burkina Faso.

Ing. Mehamene Issa, Director of DECOR in INRAN, Niger.

Summary

The main activity during this year was finishing up the research in Burkina Faso. Linda Ames spent eight months in the field there. Various earlier conference papers were published. Numerous papers were written analyzing new technology developments there.

The high economic return to the combination of a water retention device (tied ridges) and moderate chemical fertilization was demonstrated. The whole farm modeling was necessary to indicate the importance of seasonal labor availability in constraining the area in tied ridges. Hence, field testing and economic analysis of an animal traction implement to do the ridging were undertaken.

This technology of tied ridging-moderate fertilization is expected to have wide applicability in the heavier soils in the Sahelian region where the tied ridges will not easily be blown down or washed away. The same principle of looking for low cost agronomic solutions to the water retention-soil fertility constraints is believed to be more relevant to much of the Sahel than relying on breeding for all these objectives. If the breeders can concentrate on yields, diseases, and tastes for the moderately

improved agronomic environments, they are expected to be much more successful than attempting to breed for all of the above plus tolerance to drought and low soil fertility. From the research planning perspective, it is not only important to observe present farmer practices and input use but also to make some reasonable assumptions about future agronomic improvements including moderate increases in input utilization.

Institutions

The principal institutional relationship in Burkina Faso was with SAFGRAD. This regional program is responsible for coordinating research-training activities to develop new technologies for cereals production in semiarid regions of Africa. This project continued collaborative work with them on the economic analysis and modeling of new technologies. This analysis and the results should be immediately useful or adaptable across a wide part of the semiarid region. Also in Burkina Faso there was collaborative work with IBRAZ, the national agricultural research institution. In Niger the main collaborative institution was INRAN, the national agricultural research institution. Contacts were also made with ICRISAT and TROPSOILS researchers in Niger.

The research in Year 7 was entirely concentrated in West Africa but it is being extended to East Africa with the inclusion of the Sudan in Year 8.

Objectives, Research Procedures, and Production/Utilization Constraints

Year 7 Objectives

Undertake farm level studies of the profitability and fit of new technologies into farmers' systems of production;

Collaboration with other scientists on farm level studies to help define research priorities;

Evaluation of the farm level impacts of agricultural policies in combination with the introduction of new technologies;

Evaluation of macroeconomic impacts of agricultural policies in combination with the introduction of new technologies;

Training of researchers from West Africa in the economic evaluation of technological change and agricultural policies.

Changes in Objectives from Previous Year

One main change in objectives was the shift to farm level analysis and micro modeling in Year 7. The earlier concentration on macro modeling was

phased out as Mike Roth finished his Ph.D. thesis on an agricultural sector model for Burkina Faso, Kimsey Savadogo finished his Ph.D. thesis on urban food consumption in Ouagadougou, Burkina Faso, and Ann Bukowski finished her marketing margin analysis for a M.S. thesis. The last two were no longer supported by this project in Year 7.

Sorghum/Millet Constraints

The principal constraints analyzed in the farm level analysis were:

a) water availability;

b) soil fertility;

c) seasonal labor shortages.

Research Procedure

The principal research procedure was whole farm modeling (linear programming). The incorporation of risk into the modeling was begun in Year 7 with Linda Ames' fieldwork. There was substantial interaction with the agricultural scientists in developing the coefficients for this analysis. Moreover, the results in Years 6 and 7 have been influencing the research strategies of the agricultural scientists in Burkina Faso.

Problems in Achieving Objectives

The principal problems are a) logistical, and b) human capital.

Collecting the basic data and getting it into micro computers has taken a long time in the field. Moreover, much educational activity is necessary to demonstrate to agricultural scientists the importance of rapid economic and whole farm analysis of potential new technologies as they become available. There are presently very few trained Sahelian economists working with the agricultural research institutions, so more workshops and specific training activities are necessary to build up the economic understanding and for the economists to obtain more advanced training.

Project Output

There was substantial publication of the Burkina Faso field and model results in Year 7. Many of these papers emphasized the profitability of the combined innovations of a water retention technique (tied ridges) with low levels of inorganic fertilizers. The whole farm modeling illustrated the further constraint of the seasonal labor availability for constructing the tied ridges. In the summer of 1985, 45 mechanical ridge tiers were made

available to Burkinaba farmers. This implement had been adapted for animal traction from the tractor implement used for furrow diking in the Southern Great Plains (see Crops and Soils Magazine, Nov. 1984, p. 27) by a Peace Corps volunteer working with IITA. The economic analysis of this implement combined with tied ridges and moderate fertilization indicated the labor savings, profitability, and the potential to extend the area in tied ridges (see Nagy, Ohm, et al., 1986 for details). For the heavier soils in the Sahel as on the Central Plateau, the combined technologies of tied ridges-moderate levels of chemical fertilizers-and the animal traction ridger are immediately available. Governmental policy support would probably be necessary to facilitate the introduction of this complex, combined technology.

These innovations would substantially improve the agronomic potential of the environment for the development of new cultivars. This would help resolve the breeders' dilemma of trying to develop cultivars for very adverse conditions, i.e., tolerance to low soil fertility and drought as well as the other more conventional breeding objectives of high yields, disease and insect resistance, and eating qualities. Since it has been difficult to develop new sorghum and millet cultivars in the SAHEL, it may be necessary to first moderately improve water availability and soil fertility in order to obtain a return to the breeding activities.

In areas with sandier soils, especially in much of Niger with less than 550 mm of rainfall per year, it will be necessary to look for other water retention measures besides tied ridges. Collaborative work in Niger is now beginning with Dr. Jerry Eastin on this project. It is expected that in the next two to five years some alternative economic strategies for the sandier soils will be identified.

Also in the final report on Burkina Faso (Nagy and Sanders, 1986) and in the Nairobi drought conference a review of the technologies evaluated on the Central Plateau was undertaken. One still unresolved policy dilemma is the need to combine agronomic improvements to obtain an economic return in contrast with the observation that Sahelian and other developing country farmers tend to adopt one input at a time. Several strategies for governmental policies were suggested to facilitate the introduction of various combinations of the new technologies.

Networking Activities

The conference papers mentioned last year were published this year. John Sanders provided the economic planning and wrote two papers for the Ouagadougou conference on "Appropriate Technologies for Farmers in Semi-Arid West Africa." (See the Publications section.) Also, papers were presented in the Nairobi drought conference of SAFGRAD, the Kansas Farming Systems conference, the American Agricultural Economics Annual Association meeting, and John Sanders gave several seminars in Niger to the INRAN researchers.

Information on on-farm trials and economic analysis was interchanged at these various meetings. The concentration with the INRAN scientists was on the potential for the adaptation of the Burkina Faso results showing the high returns to the combined water retention-moderate inorganic fertilizer input technology. Also the importance of whole farm modeling to identify the constraints to increasing cereal production was stressed.

Travel

- Burkina Faso. July 30, 1985-April 1, 1986. Linda Ames. To work in the SAFGRAD-AID-Purdue Farming Systems project to do the fieldwork for her Ph.D. thesis on the whole farm modeling of new technologies on the Central Plateau of Burkina Faso. This research is relevant to a wide area in the Sahel countries where SAFGRAD works.
- Niger. Three weeks during Sept.-Oct. 1985. John Sanders. Funded by the Niger Cereals Project to lay the groundwork for increased collaboration with DECOR (the economic unit) in INRAN (the national agricultural research institute). The objective was to build working relationships with the economists and other agricultural scientists working in this Institute.

Publications and Presentations

Publications

Adesina, Akin, "A Mathematical Programming Analysis of Cereal Production, Marketing Policy in Niger and the Cross-Border Grain Trade with Nigeria," Unpublished M.S. Thesis, Purdue University, December 1985.

Jaeger, W.K. and J.H. Sanders, 1985, "Profitability of Animal Traction: Field Study in Burkina Faso," in H.W. Ohm and J.G. Nagy (eds.), Appropriate Technologies for Farmers in Semi-Arid West Africa, Purdue University, West Lafayette, Indiana, pp. 291-307.

Nagy, J.G., H.W. Ohm, L.L. Ames, and L.D. Schaber, 1986, "Analysis of the IITA/SAFGRAD Mechanical Ridge Tier," International Programs in Agriculture Staff Paper, Purdue University, February.

Nagy, J.G. and J.H. Sanders, 1986, "Cereal Technology Development in the West African Semi-Arid Tropics--A Farming Systems Perspective", Final Report of the Burkina Faso Project, Purdue University, West Lafayette, Indiana.

Roth, M., 1986, "An Economic Evaluation of Agricultural Policy in Burkina Faso, West Africa: A Sectoral Modeling Approach," Unpublished Ph.D. dissertation, Purdue University, West Lafayette, Indiana.

Roth, M., P. Abbott, J. Sanders, L.McKinzie, 1986, "An Application of Whole Farm Modeling to New Technology Evaluation, Central Mossi Plateau, Burkina Faso," IPIA Staff Paper, Purdue University, West Lafayette, Indiana.

Sanders, J.H. and M. Roth, 1985, "The Development and Evaluation of New Systems of Agricultural Production: Some Field and Model Results from Burkina Faso for Tied Ridges and Fertilization," in H.W. Ohm and J.G. Nagy (eds.), Appropriate Technologies for Farmers in Semi-Arid West Africa, Purdue University, West Lafayette, Indiana, pp. 326-337.

Sanders, J.H., 1986, "Agricultural Technology Development in Burkina Faso," in Chapter 12 of Y. Moses (ed.), Proceedings African Agricultural Development Conference: Technology, Ecology, and Society, California State Polytechnic University, Pomona, California, pp. 97-99.

Sawadogo, K., 1986, "An Analysis of the Economic and Socio-Demographic Determinants of Household Food Consumption in Ouagadougou, Burkina Faso," Unpublished Ph.D. dissertation, Purdue University, West Lafayette, Indiana.

Sawadogo, K., 1985, "Food Consumption Analysis and Related Parameters for Ouagadougou, Burkina Faso," in H.W. Ohm and J.G. Nagy (eds.), Appropriate Technologies for Farmers in Semi-Arid West Africa, Purdue University, West Lafayette, Indiana, pp. 338-350.

Presentations

Nagy, J.G., L.L. Ames and H.W. Ohm, 1985, "Technology Evaluation, Policy Change, and Farmer Adoption in Burkina Faso," Paper presented at the Farming Systems Symposium, Kansas State University, Manhattan, Kansas.

Nagy, J.G. and L.L. Ames, 1986, "Evaluation of New Technologies in Burkina Faso Using Whole Farm Modeling," Paper presented at the Annual Conference of American Agricultural Economists.

Nagy, J.G., J.H. Sanders, H.W. Ohm, and L.L. Ames, 1986, "Technology Development to Increase Cereal Production in the WASAT," Paper presented at a SAFGRAD Conference on Strategies for Drought, Nairobi, Kenya.

Changes in Year 8

In Year 7 the principal emphasis was on finishing the field research in Burkina Faso. In Year 8 field research efforts are being shifted to the two INTSORMIL priority countries of Niger and the Sudan.

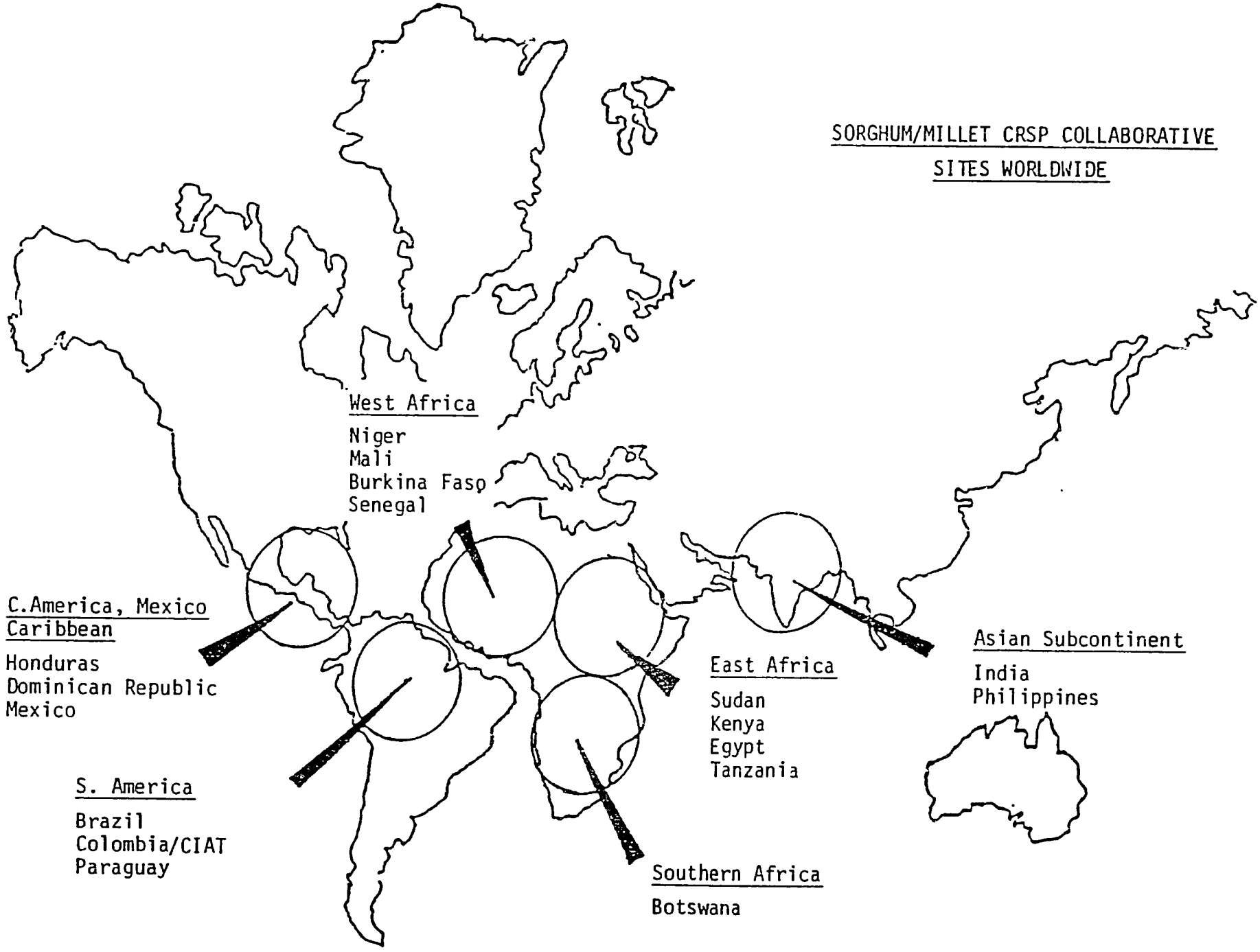
1986 Country Reports

The Sorghum/Millet CRSP has developed a structure by which a U.S. Principal Investigator serves as a country coordinator. The country project carries with it a budget which is passed through to the national program in support of local research and short term training activities. The country program concept was developed to encourage multidisciplinary collaboration at each of the international sites. The country coordinators are responsible for encouraging and developing this multidisciplinary cooperation.

Funds from the country project budgets have been very useful in providing support for host country collaborators to visit counterpart programs in the United States, to obtain scarce research supplies in support of host country research, to purchase equipment to facilitate collaboration and to provide some limited recurrent research costs necessary to implement CRSP research in the country.

The country research progress reports also document the level of research collaboration that is taking place within a country program. It is significant to note the level of collaboration that is taking place. It is also important to note that the country reports in this document reflect joint planning, joint implementation of research and joint publication of research results.

The progress in this program is reflective of the interest and cooperative spirit that has developed between the U. S. researcher and the Host Country researcher under the collaborative mode.


SORGHUM/MILLET CRSP COLLABORATIVE
SITES WORLDWIDE
West Africa
Niger
Mali
Burkina Faso
Senegal
C.America, Mexico
Caribbean
Honduras
Dominican Republic
Mexico
S. America
Brazil
Colombia/CIAT
Paraguay
East Africa
Sudan
Kenya
Egypt
Tanzania
Southern Africa
Botswana
Asian Subcontinent
India
Philippines

ASIA

David J. Andrews
University of Nebraska

Collaborative Program

Sorghum and pearl millet are major food cereals in India and Pakistan and have some potential as food or feed crop components in cropping systems in drier areas in east Asia, Indonesia, and the Philippines. Production levels are low in India/Pakistan. The main constraints are lack of nutrients, limited and untimely cultivation practices, pests and diseases and sometimes moisture shortage.

Opportunities to develop bilateral research projects exist using USAID (Delhi) and FERRO funding.

Sorghum/Millet Constraints Researched

None undertaken in Pakistan and India (apart from those with ICRISAT).

Mutual Research Benefits

Mutuality would depend on project selected, but would be emphasized.

Institution Building

Host Country Scientist Visiting U.S.

- Dr. Dely Gapasin, Director, Crops Research PCARRD, Los Banos, Philippines, visited the University of Nebraska and Purdue University.

U.S. Scientists Visiting Host Country

- Dr. Jerry Maranville, sorghum physiologist, NU-121, Philippines.
- Dr. Dale Anderson, agricultural economics, NU-117, Philippines.
- Dr. George Pfeiffer, agricultural economics, NU-117, Philippines.
- Dr. Jerry Eastin, sorghum physiologist, NU-116, ICRISAT, India.
- Mr. Bill Stegmeier, millet breeder, KSU-101, International Millet Workshop, India.
- Mr. David Andrews, millet breeder, NU-118, International Millet Workshop, India and USAID-Delhi.
- Dr. Lloyd Rooney, sorghum and millet grain quality, TAM-126, International Millet Workshop, India.

Networking

Results in India would be disseminated via all India coordinated sorghum and millet projects, in the Philippines via PCARRD.

General Comments

INTSORMIL scientists need to act on USAID Delhi's offer of funding travel to India to develop mutually appropriate research projects with Indian scientists, which USAID (Delhi) and the FERRO office are interested in funding.

Philippines projects are reaching term and there are no furtner plans for funded research.

Many research findings, particularly those developed in north India, are relevant to Pakistan.

BOTSWANA

L.V. Withee

Kansas State University

Collaborative Program

Sorghum/millet production is a risky enterprise in Botswana because of the scant and variable rainfall. During Year 7 rainfall was less than half of average - about 200 mm - at the principal research site. Drought is frequent; five to seven years out of ten rainfall is 250 mm to 400 mm. Traditional production practices reflect the high risk-low yield expectations of the farmers. Because crop production is risky, capital invested in agriculture usually goes for cattle production. A great deal of the work required to produce crops is done by women while the men are involved with the cattle enterprise or seeking labor remote from the home.

Memorandum of Understanding

The Memorandum of Understanding was completed in 1983 and stipulated that INTSORMIL would supply a senior and a junior scientist for collaborative research with the Department of Agricultural Research (DAR), G.O.B. According to the terms of the MOU, two scientists, Douglas Carter and Wayne Youngquist, have served in Botswana since April 1984 supported by INTSORMIL, DAR and by the Agricultural Technology Improvement Project (ATIP), a farming systems research/extension project with Kansas State University as the lead institution. Youngquist and his wife Joan, a graduate research assistant supported by the NU-113 project, completed their service in Botswana and returned to the University of Nebraska in April 1986.

In June 1986 L.V. Withee traveled to Gaborone and arranged for an amendment to the MOU that would provide for a second scientist to be placed in Botswana. The position that Wayne Youngquist occupied was originally planned to terminate after two years.

Other Opportunities

In retrospect it might have been more effective to have one scientist in Botswana for the initial one or two years to deal with the problems of initiating studies under new circumstances and in new environments and then to have two scientists there to continue the work. The presence in Botswana of ATIP is a fortunate circumstance. There are two agronomists on the ATIP

team with whom INTSORMIL personnel have collaborated. The experience of ATIP personnel with close collaboration with farmers gives them insight into constraints to sorghum and millet production which are shared with INTSORMIL personnel.

Sorghum/Millet Constraints Researched

The drought of the previous four years continued into Year 7 and as a consequence yields of grain were, with few exceptions, less than 500 kg/ha. As an example, in one experiment at one site average yield of sorghum for all treatments was 140 kg/ha. At another site only sorghum stover was harvested and average yield was 502 kg/ha. Under the low rainfall conditions prevailing, experimental results have been very variable. Nevertheless some generalizations may be drawn from the data.

Applications of manure and/or crop residue (stover) which influence the intake of rainfall and availability of soil water increased yields. Manure by itself was effective and in combination with stover was more effective than when used alone.

Under moisture stress conditions studies of dates of planting and of plant populations gave erratic results.

Short season varieties of sorghum appeared to be advantageous.

A popular local variety, Segaolane, gave larger yields than other local varieties and demonstrated drought tolerance. It may be an important variety in the breeding program for years to come.

With deficient soil moisture the effects of rotation were negligible but where moisture was more nearly adequate, i.e., where average yields were greater, the beneficial effects of rotation were measured. The same was true for response to nitrogen fertilizer.

Local varieties of sorghum differ in their potentials for producing grain and stover and the two potentials are not correlated.

Mutual Research Benefits

Botswana is an excellent place to screen sorghum varieties for drought tolerance and may be a source of germplasm with drought tolerance as well as other desirable agronomic characteristics. Given time, the collaborative relations between personnel of the Agricultural Technology Improvement Project will prove mutually beneficial with ATIP identifying problems for research and INTSORMIL doing more intensive research than is possible with

the production experimentation of ATIP. In turn, relevant research by INTSORMIL may benefit grain producers in Botswana and also provide experience for scientists such as Douglas Carter and Wayne Youngquist who plan professional careers in which they will probably serve elsewhere on agricultural development type projects.

Institution Building

During Year 7 a Mettler balance with accessory equipment for automated recording of data was purchased. Software and books were purchased to increase the capability to process data.

On the staff at ARS Sebele as technical officers are the following whose education in U.S. universities was sponsored by INTSORMIL: Lucas Gakale, Ph.D., Agronomy, University of Nebraska, now serving as acting chief of Arable Crops Research Division, DAR; Chris Manthe, Ph.D., Entomology, Texas A&M University; Baikibile Motalaote, M.S., Plant Pathology, Texas A&M University; Elijah Modiakgotla, M.S., Agronomy, Kansas State University, serving with ATIP at Mahalapye.

Drs. Richard Vanderlip, KSU-106, and Max Clegg, NU-113, were in Gaborone January 6-20, 1986 to consult with INTSORMIL and ATIP personnel.

Dr. Gary Odvody, plant pathologist of TAM-128, traveled to Gaborone, Botswana; Lusaka, Zambia; and Harare and Bulawayo, Zimbabwe March 22-April 9, 1986.

Mr. David Andrews, millet breeder of NU-115, traveled to Gaborone, Botswana; Lusaka, Zambia and Harare, Zimbabwe March 22 - April 3, 1986.

Dr. L.V. Withee was in Gaborone, Botswana and Bulawayo, Zimbabwe June 1-14, 1986, consulting with Dr. Doug Carter and personnel of DAR, ATIP and USAID/Botswana about a second INTSORMIL position at ARS Sebele. He also consulted with Dr. Martin Kyomo, Director of SACCAR, at Sebele and with Dr. Leland House of ICRISAT Bulawayo regarding an INTSORMIL, ICRISAT, SACCAR joint regional workshop in April 1987.

NU-115/118 Year 7 Activities in Botswana

David Andrews met with Louis Mazhani, sorghum and millet breeder at Sebele research station, who outlined his breeding objectives. As a result of previous visits under Project NU-115 and the Botswana sorghum collection previously sent to Dr. Ross, we were able to complement the breeding objectives in the area of development of adapted seed parents by sending

segregating material from crosses made at the University of Nebraska between U.S. B-lines and Segaolane -- a widely popular Botswana food quality variety which itself is a B-line. Some 36 selections were made out of the 119 F_2 and F_3 populations sent to Sebele in October 1985. Further material is being developed to support the Botswana breeding program, including the provision of very early maturing, cold resistant germplasm for the situations where planting rains come too late for normal varieties to mature. Plans for more rapid improvement of the released pearl millet variety Serere 6A, which now contains a considerable level of introgression with local varieties, were developed with Louis Mazhani to use the off-season facilities now available from the ICRISAT regional center at Bulawayo, Zimbabwe.

Networking

Two pathways for spread of research results exist. The first is through the Ministry of Agriculture (MOA); both the Department of Agricultural Research and the Department of Field Services (Extension) are in the MOA and customary procedures prevail for transfer of information. The second pathway is through ATIP which works directly with groups of farmers in two locations. ATIP also has a Research Extension Liaison Officer, Dr. Curtis Trent, within the MOA whose responsibility it is to improve the flow of information from researchers to extension field men and to farmers. Hence collaboration of INTSORMIL with ATIP provides a pathway for extension of results.

General Comments

By fortunate coincidence, Dr. Martin Kyomo, Director of SACCAR, is located at ARS Sebele in an office provided by DAR. Dr. David Gollifer, Director of DAR, is also at Sebele and is Chairman of the Consultative Technical Committee consisting of directors of research in SADCC countries. By means of these connections INTSORMIL can relate to the ecogeographic zone and the host country. Two circumstances should be borne in mind. INTSORMIL has, at present, only one scientist in Botswana with plans for a second to be located there. Research in Botswana is at locations where the climatic constraints of low and erratic rainfall and high potential evapotranspiration make crop production a marginal enterprise. Other sites should be considered.

Located at Bulawayo, Zimbabwe is the ICRISAT satellite station devoted to research on sorghum and millet, particularly the breeding of these crops. ICRISAT has planned a training program both for the graduate education of new scientists and for continuing education of technicians and scientists working with sorghum and millet in SADCC countries. INTSORMIL cooperates with ICRISAT in this training endeavor and plans to continue to sponsor the graduate training.

BRAZIL

R.A. Frederiksen

Texas A&M University

Collaborative Program

Collaborative research is being done in the areas of mineral nutrition, host resistance to acid soils, insect resistance, disease resistance and plant breeding.

Memorandum of Agreement

The Memorandum of Agreement, drafted 12 August, 1983, calls for cooperation in all possible ways to further mutual interest and objectives. It was also agreed that a specific plan of work and budget would be drafted and approved on an annual basis. In 1985-86 there was a breakdown in communications with Brazil and this is to some extent continuing. No small part of the problem was caused because R. Frederiksen was on sabbatical leave during 1985-86 and did not travel to Brazil until August 1986. Since then the program appears to be returning to normal. The temporary termination of funding for programs in Brazil should stimulate new sources of funding because there are many mutually beneficial goals.

Other Problems and Opportunities

In Brazil there are great opportunities to evaluate new and different levels of disease resistance in sorghum. The most valuable will be the detection of dilatory resistance to anthracnose. Anthracnose can be a major disease in most of the more humid sorghum growing tropical and semi-tropical areas of the world. Since new races of the pathogen appear at regular intervals, much better types of resistance are necessary for the breeding programs. We propose to select for dilatory resistance in Brazil and evaluate it in Texas, Puerto Rico, and Georgia as well as in regions of Eastern and Southern Africa. The gravity of rust and ladder spot, two other foliar diseases, will permit extended work on selection for resistance and evaluation of resistance to these diseases as well.

Sorghum midge damages sorghum in the major sorghum growing regions of the U.S. and in most sorghum growing countries of the world. Jose Waquil, a recent Texas A&M graduate now working at Sete Lagoas with EMBRAPA, will permit a natural extension of collaborative work on this key pest.

Brazil has more hectares of acid soils than any other country in the world. The improvement of sorghum as both a grain and forage for some of these soils has tremendous potential for Brazilian agriculture and of course is a natural extension of the INTSORMIL work done in Colombia at CIAT.

Sorghum Constraints Researched

Carlos Casela and Alexandre Ferreira (EMBRAPA) reported on the detection of horizontal resistance of sorghum cultivars to anthracnose. This was achieved by growing several different cultivars in several locations in Brazil with anthracnose. Those resistant at all locations were declared to have horizontal resistance. Ferreira and Casela also report that there are several races of Colletotrichum graminicola in Brazil. These are identified using essentially the same set of differential varieties as used previously.

Jose Waquil and G.L. Teetes (EMBRAPA and Texas A&M), reported on the damage caused by the sorghum midge. Sorghum midge is a key pest of sorghum in the U.S. and Brazil. Information on the extent of damage and losses provides the necessary thresholds both for evaluation of host resistance and for the application of pesticides to avoid economic losses.

Pedro Furlani and C.R. Bastos (Campinas) have learned that the inheritance of resistance to acid soils in sorghum is simple. This suggests that breeding for aluminum resistance in sorghum may be quite simple, particularly considering the variety of new sources identified by INTSORMIL workers in Colombia.

Institution Building

Most of the funds allocated for research in Brazil were spent on special equipment and supplies not available in Brazil for research in recombinant DNA and other biotechnical areas. This equipment will provide new techniques for studying constraints that are of mutual interest. Jose Waquil has returned and is working on sorghum midge in Brazil. Both A. Ferreira and C. Casela, visitors in 1985, are continuing their collaboration on sorghum diseases. P. Viana, currently the EMBRAPA counterpart to INTSORMIL's country coordinator, was a visitor on two occasions in 1985. R. Furlani, a plant nutrition graduate, and visitor, has a major interest in research in sorghum tolerance to aluminum. These are exceptionally capable and dedicated scientists working toward the reduction of sorghum

constraints. Lynn Gourley and Catalina I. Flores visited with several Brazilian workers in August of 1985.

Networking

The Brazilian Congress of Sorghum and Maize workers has provided an excellent format for the dissemination of technical information on these sorghum research areas for Latin America.

General Comments

One of the most valuable aspects of INTSORMIL is the opportunity to include all sorghum workers in a global framework. This aspect is different from research collaboration in that we benefit from research done in Brazil as well as do other collaborators in LDC's. Much of the work on stress resistance in Brazil has great potential benefit for other regions, just as research done in the U.S. benefits other sorghum production programs.

Clearly, the Brazilian researchers do not need "expert" advice from the U.S., rather they collaborate on a very equal basis and to some extent are supplying a greater proportion of their energy toward solutions to agricultural problems. Our modest involvement with EMBRAPA in particular is an extremely beneficial method of disseminating this enthusiasm and success to other regions of the world, particularly Africa.

BURKINA FASO

John Sanders
Purdue University

Collaborative Program

Production and Utilization Constraints

Water availability

Soil Fertility

Seasonal labor availability

The above constraints are interrelated. Introducing a series of technologies to simultaneously remove these three constraints has been demonstrated in Burkina Faso to have a very high return. There is a practical difficulty of introducing a series of technologies together since farmers normally adopt one thing at a time. Hence, some governmental policy intervention would probably be necessary to facilitate the combined introduction of a series of new technology components.

With the introduction of these technologies, there would be an improvement in this normally harsh environment of irregular and often inadequate rainfall and low soil fertility. Combining tied ridges with moderate fertilization would reduce the riskiness of the latter and their combined effects have been shown to have a large effect on yields and profitability. Thus, breeders could concentrate on objectives other than drought and low soil fertility tolerance. The final report for the Burkina Faso project discusses those constraints and governmental policy alternatives in considerable detail.

Memorandum of Agreement

INTSORMIL Project PRF-105 was being phased out of Burkina Faso in Year 7. The priority countries are now Niger and the Sudan following INTSORMIL emphasis and other political factors. The main importance of Burkina Faso to the INTSORMIL Economics (PRF-105) project in Year 7 was the relevance of the research results to a wide range of the Sahel area. Since farm-level research on new technologies has been going on for over five years in Burkina Faso, it was considered critical to continue and publish these results because of their relevance to the Sahel. In the future, it may be possible to resume the close ties with IBRAZ (the national agricultural research organization of Burkina Faso).

Sorghum/Millet Constraints Researched

Research Progress

The research focus was on the profitability and the fit into farmers' systems of production of new technology components to overcome the three principal constraints mentioned in the first section. Tied ridges with moderate fertilization and the use of the animal-traction ridger turned out to be a highly profitable innovation. The water-retention device reduced the riskiness of the chemical fertilizer use. The animal-traction ridger overcomes the seasonal labor constraint for tying the ridges during the first weeding period. The effects of the individual components and different strategies that host country governments might implement to facilitate the introduction of these technologies were also systematically evaluated.

Economic modeling helped identify the critical constraints and influenced the research strategies. The modeling was standard linear programming with some sensitivity analysis.

Mutuality of Research Benefits

The applicability to U.S. research is in the relevance of simple modeling evaluation of new technologies. Also the separate vs. combined impact of the various new technologies is a relevant problem in evaluating the impact of potential technologies in other regions.

Institution Building

Equipment, Materials

A microcomputer was left by Mike Roth in the Ministry of Agriculture of Burkina Faso. The Purdue Farming System Project in Burkina Faso also left vehicles and equipment for the SAFGRAD regional unit in Burkina Faso.

Trained Host Country Researchers

Baya Toe, M.S.

Paul-Francois Campoare, M.S.

Kimsey Savadogo, Ph.D.

All three Burkinaba Agricultural Economists had most of their training paid for by the Purdue Farming Systems Project but all benefited from INTSORMIL research activities and Kimsey received some INTSORMIL research support. Baya and Paul are presently in the Ministry of Agriculture in Burkina Faso. Kimsey has returned to the University of Ouagadougou.

Networking

The principal method for networking the improved agronomic technologies was the Ouagadougou conference on developing appropriate technologies in semiarid West Africa. Researchers from major institutions all over West Africa came to this conference (see the references in the report on the INTSORMIL Economics Project, PRF-105).

Also intensive distribution of conference papers and other field reports was undertaken to a large mailing list in West Africa and to U.S. government officials and academics concerned with Africa.

General Comments

Recommendations for Future Collaboration

With the present political situation, it is extremely difficult to continue research or even contacts in Burkina Faso. When this situation changes, it should be possible to resume contacts with IBRAZ and the University of Ouagadougou.

Relevance of Burkina Faso Research

The prime country in this region is Niger. In most of this country there is less rainfall and soils are sandier than in much of Burkina Faso. Hence, the research results on tied ridges and moderate fertilization are more relevant to large areas of Mali and some of Senegal where the rainfall is between 550 to 800 mm/year. Nevertheless, the same concept of first looking for the agronomic improvement technique to retain or conserve more water, then using moderate chemical fertilization is considered to be relevant in the lower rainfall regions (< 550 m) as in most of Niger.

Moreover, after extensive testing of alternatives to inorganic fertilizers in Burkina Faso, we believe that these technologies tend to be either infeasible technically or economically. This is considered to be relevant to the continuing research on such alternatives to organic fertilizers as: mulch, manure, "green manure", rotations with legumes.

The major emphasis, however, is to first search in the semiarid regions for moderate economic improvements in water availability and soil fertility. Then the breeding program should be aimed at these improved environments. Trying to find a breeding solution to all the conditions of the harsh environment of the Sahel has not been very successful in the last 20 years of breeding work for cereals and is not expected to be very successful in the future.

COLOMBIA

Lynn M. Gourley
Mississippi State University

Collaborative Program

Production and Utilization Constraints

Outside of the fertile mountain valleys, the major sorghum production constraints in Colombia are drought in the northern Atlantic coastal states and acid, infertile soils in the eastern plains. Colombia has about 70 million hectares of acid soils or 57% of the total land area. These unproductive soils contain toxic levels of aluminum (Al) high enough to inhibit the growth of all major cereal crops. These soils contain inadequate quantities of N, P, K, Ca, Mg and several trace elements for normal crop production. Traditional high-input agricultural practices have not been successful in the acid soil areas of Colombia due to the high cost and inequitable supply of production inputs for resource-poor farmers. Low-input technology requires the use of Al-tolerant cultivars and careful management of the types and quantities of soil amendments used.

Birds are probably the second most serious constraint to sorghum and millet production. Bird resistant, high tannin cultivars are used in most areas of Colombia. Pearl millet is not presently grown in the country, but birds will be a problem if the area planted to this crop is increased.

Sorghum diseases are a potential production constraint. Sorghum downy mildew is not found in Colombia, but anthracnose, charcoal rot, grain molds and other leaf and stalk diseases can be a problem in the high rainfall areas.

Armyworms and stalk borers contribute to production losses and are potential serious constraints.

Memorandum of Agreement

Research in Colombia was formally initiated by a Memorandum of Intention signed by the Directors of INTSORMIL, ICRISAT and CIAT in 1981. CIAT invited INTSORMIL to conduct research at its facilities after the question of mandated crop species had been cleared with ICRISAT. A Memorandum of Agreement between the National Program of Colombia (ICA) and INTSORMIL has been prepared but not signed. A formal ICA-INTSORMIL MOA will be sought next year.

Other Problems and Opportunities

The collaborative research effort with ICA is a strong informal agreement. The National Program of Colombia would like to sign an MOA with INTSORMIL, but ICA officials have also stated that collaboration will continue even if no agreement is signed. The selection of the International Center, CIAT, as the operational headquarters for the prime site research has been ideal. The student training program and CIAT's outreach programs throughout Latin America keeps INTSORMIL's sorghum and millet research very visible.

Sorghum/Millet Constraints Researched

The major thrust of the research effort in Colombia is to screen and evaluate sorghum and pearl millet germplasm from world collections and INTSORMIL breeding programs for sources of tolerance to low levels of phosphorus and high levels of Al toxicity. Much of the research effort concerns cultural practices. Using the low-input philosophy, a higher than normal level of management is required to insure that the fertilizer inputs applied to the plant growing in this tropical environment are economically efficient.

Sorghum and pearl millet genotypes are selected based on their ability to produce an economic return of grain with a minimum input of lime and phosphate fertilizer.

Research Progress

Sufficient high yielding Al-tolerant sorghum cultivars have been found in the portion of the world sorghum collection evaluated to conduct regional acid soil yield trials. These cultivars will produce from 2-5 t/ha grain in soils of 4.5 pH and 65% Al saturation. These trials have been distributed throughout Latin America and to several acid soil areas in Africa and Asia.

Improved Al-tolerant lines are being developed to produce acid soil tolerant hybrids. Four pairs of Al-tolerant A-lines (male sterile) and B-lines (maintainer) have been released by the Mississippi Agricultural and Forestry Experiment Station as germplasm. These lines were screened and developed in Colombia by the INTSORMIL projects there.

Pearl millet is not grown in Colombia. The pearl millet germplasm evaluated for acid soil tolerance has been found to be tolerant to a higher level of Al toxicity and to a lower level of soil phosphorus than sorghum.

This finding has encouraged ICA to evaluate pearl millet as a forage and grain crop for the acid soil regions of Colombia.

Mutuality of Research Benefits

This research will benefit both Colombia and the U.S. in several ways. Al-tolerant germplasm will help increase sorghum production in acid soils in both countries with less soil amendment inputs. Al-toxic subsoils in some areas of the Southeastern U.S. are a constraint to sorghum production. In Colombia the problem is more severe throughout the soil profile and acid soils cover a much larger area than in the U.S.

Another major benefit to the U.S. will probably be through commercial seed companies. Multinational seed companies will use the proven Al-tolerant germplasm for hybrids in their overseas operations. Spinoff improvement of U.S. hybrids will come if there is a large enough market demand. The demand for the improved varieties and hybrids in Colombia and throughout Latin America should be large for these food and feed grain deficient countries.

Institution Building

Research support funds provided to ICA have been limited due to a limited operations budget. Both MSU-111 and MSU-104 have provided travel funds to ICA sorghum workers for planning meetings, short-term training and visits to breeding nurseries. Tours for sorghum researchers from national institutions and private seed companies in South America have been conducted to the Al-tolerance field screening nursery at CIAT-Quilichao. Project MSU-111 donated 20 bags of fertilizer to ICA for research at the La Libertad station. Soil analyses for ICA are being conducted at CIAT via INTSORMIL for the collaborative research.

Five Colombian students are in training at INTSORMIL universities, two at Mississippi State, two at Nebraska and one at Purdue. None have completed their training.

The ICA Sorghum Coordinator, Dr. Hernan Gaviria E., visited sorghum research sites in Texas. The principal ICA acid soil sorghum breeder, Mr. Cesar Ruiz, started his M.S. training at Mississippi State University. Dr. Charles Berry, Cargill, consulted with MSU-111 PI about INTSORMIL research

in Colombia. Lynn Gourley, MSU-104 PI, made three trips to Colombia this year to conduct winter nursery activities and to coordinate prime site research.

Three students in the INTSORMIL training program have or are conducting research in Colombia for their advanced degrees. This type of training in the host country will be increased in the future.

Networking

INTSORMIL is informally linked with every country in South America in which CIAT conducts research. The project PI for MSU-111 has participated in CIAT training programs which provide free educational linkages with students throughout Colombia and other countries. We have cooperative research linkages established with ICA-Colombia, EMBRAPA-Brazil, FONAIAP-Venezuela and INIPA-Peru in the major acid soils areas. Through these associations and INTSORMIL staff visits germplasm and information are exchanged. The MSU-111 PI attends field days at commercial and ICA research sites in Colombia, visiting with farmers and other sorghum workers about INTSORMIL and our research objectives in Colombia. ICA National Program staff and CIAT farming system specialists further spread the word about our work.

The ICRISAT/INTSORMIL Identification Handbooks on insects and diseases (Spanish version) are being distributed to sorghum researchers and students throughout Central and South America. The Acid Soils Sorghum Workshop proceedings will soon be published in Spanish and English and made available to Latin American and other sorghum scientists around the world.

A potential problem with networking in Latin America is not a lack of networking activities, but the lack of time to visit all of the sites requesting assistance. Some countries feel they are being left out or not getting their share of INTSORMIL's time and attention.

General Comments

INTSORMIL as an international organization is better able to become the collaborative glue holding the Latin American National programs in a loose cooperative, directed program than any other organization. Occasional workshops provide researchers in National Programs the opportunity for recognition among their peers. This helps create enthusiasm and the possibility to attract outside funding for their fund-starved programs and

perhaps leverage our INTSORMIL funds. More bright young scientists can be spotted for advanced training with this approach. The two best, most long lasting efforts to improve collaborative research are workshops and advanced degree training.

Another recommendation would be contacts with regional organizations such as the Andean Pact and Southern Cone country meetings. Even joint agreements with these organizations might help provide funds for more regional efforts. A signed MOA with ICA would also formalize the collaborative effort with this Prime Site National Program.

Colombia is not a perfect host country or prime site, but her National Program staff will aid us in our efforts and her industrious farmers will apply INTSORMIL germplasm and technology if it produces an economical return. Colombia is a developing country that wants our help. The National Program, ICA, is willing to share any germplasm that is developed jointly with INTSORMIL with other countries in the Zone. The Seed Unit at CIAT has agreed to increase and process seed for the region. Colombia is a very good site for acid soils research.

Some of the sorghum diseases observed in Brazil, Venezuela and Peru are not known to exist in Colombia. Brazil should be retained as a collaborator for pathology research and EMBRAPA scientists are also good collaborators for the acid soils research.

DOMINICAN REPUBLIC

Ralph Neild

University of Nebraska

Principal Investigator

Ralph Neild, University of Nebraska

Other Researchers

Joanne Logan (U.S.) stationed in Dominican Republic

Rafael Perez Duverge, Host Country

Collaborative Program

Institutions Involved

Collaborating Host Country: Dominican Republic, Secretary of Agriculture

U.S.: University of Nebraska

Linkages:

C.E.S.D.A. Southern Agricultural Research Center, Secretary of Agriculture, Dominican Republic

Ecogeographic Zones Benefited Most by Research

Caribbean Basin - Tropics East Asia

Project Output

Research Findings

Field tests have identified six white sorghum varieties well suited to the Dominican Republic. They are being multiplied and distributed to various extension organizations.

An appropriate technology package has been developed for small farmers who wish to produce white sorghum. Included are plant densities, fertilization rates, and cropping systems with legumes such as cowpeas.

Agroclimatic procedures have been developed to determine and evaluate the growing seasons for sorghum and the potential for sorghum as a relay or sequence crop in multiple cropping systems.

Networking

- Workshops

Workshop on Agroclimatology and Meteorology October 14-17, 1985 sponsored by INTSORMIL, Peace Corps and Secretary of Agriculture at San Cristobal, D.R. has been published in Spanish.

- Research Investigator Exchanges

Trip by Rafael Perez Duverge to CLAIS meeting in Costa Rica.

Trip by Lorenzo Aceves-Navarro - NU-8 student from Mexico to present his M.S. thesis results in D.R.

- Germplasm and Research Information Exchange

Trips by David Andrews, NU-115, to winter nursery in D.R., resulting in germplasm exchange and training in plant breeding strategies with staff of CESDA.

- Research equipment and support

1985 Dodge Ram Charger, a head thresher, plot thresher, IBM-PC Computer, plant breeding supplies, sorghum extension publications and subscription to a scientific journal have been provided at CESDA.

Software program and training have been provided on the operation and use of the IBM-PC Computer.

Travel

- Dominican Republic. October 1985. Lorenzo Aceves Navarro. Workshop.
- Costa Rica. November 1985. Rafael Perez Duverge. CLAIS meeting.
- Dominican Republic. February 1986. David Andrews NU-115. Sorghum winter nursery.
- Dominican Republic. March 1986. Ralph Neild. Project review.
- U.S. Joanne Logan. November 1986. Present paper at Agronomy Society meeting.

Publications and Presentations

Twelve monthly reports by Joanne Logan to administration of INTSORMIL and Nebraska Agricultural Experiment Station.

First National Workshop on agroclimatology.

Agrometeorology - INTSORMIL, Peace Corps and Secretary of Agriculture, D.R., October 14-17, 1985. San Cristobal - Organized by Ron Block, Peace Corps and Joanne Logan, INTSORMIL - in Spanish.

Phenology of sorghum cultivars and agroclimatology.

Lorenzo Aceves Navarro - in First National Workshop on agroclimatology and agrometeorology, October 14-17, 1985, San Cristobal, D.R.

Utilization of best units in agroclimatic studies in Mexico - Lorenzo Aceves-Navarro in First National Workshop on Agroclimatology and Agrometeorology, October 14-17, 1985, San Cristobal, D.R.

Agroclimatic studies and data in agricultural investigation, Joanne Logan and Ron Block in First National Workshop on agroclimatology and agrometeorology, October 14-17, 1985.

General agroclimatology of the Dominican Republic, Joanne Logan in First National Workshop on agroclimatology and agrometeorology, San Cristobal, D.R.

Methods for Developing Useable Projects from climatic variables. Joanne Logan in First National Workshop on agroclimatology and agrometeorology October 14-17, 1985, San Cristobal, D.R.

The Operation and Germplasm Exchange of a Winter Nursery for Sorghum Improvement in a Third World Country, Joanne Logan. David Andrews and R.E. Neild, annual meeting of the American Society of Agronomy, December 1-4, 1986, New Orleans, Louisiana.

Changes in Year 8

Project terminated December 31, 1986.

Training Output

Project NU-122 has:

a. Trained one Ph.D. student

b. Developed and sponsored two National Workshops in the Dominican Republic

c. Trained high school students and agricultural technicians in field plot techniques

d. Trained experiment station staff in the field and analyzed data with a PC Computer

e. Provided training in the breeding selection and increase of improved sorghum strains.

Summary

During Year 7 NU-122:

a) identified six white sorghum strains adapted to the Dominican Republic, b) developed an appropriate technology package to assist small farmers in the production of white seeded food sorghum, c) trained agricultural high school students in field plot techniques, d) trained experiment station

technicians in methods for improving sorghum production through plant breeding and selection, and e) trained researchers in the operation and use of a PC Computer.

EGYPT

Jerry D. Eastin
University of Nebraska

Cooperation with Egyptian scientists consists primarily of germplasm exchange. Funding limitations currently confine INTSORMIL activities in Egypt to germplasm and technical advice if requested.

HONDURAS

Darrell T. Rosenow

Texas A&M University

Collaborative Program

Institutions Involved

Secretaria de Recursos Naturales (SRN), Honduras

USAID Mission, Honduras

Panamerican Agricultural School (EAP)

Texas A&M University

Mississippi State University

ICRISAT/CIMMYT, Mexico

Latin American Commission of Sorghum Investigators (CLAIS)

CENTA, El Salvador

University of El Salvador

Collaborators Involved

Honduras

Ing. Gerardo Reyes, Head, Dept. of Agric. Res., SRN (through March)

Dr. Leopoldo Alvarado, Head, Dept. of Agric. Res., SRN (April 1)

Ing. Antonio Silva, Asst. Head, Dept. of Agric. Res., SRN (April 1)

Ing. Rigoberto Nolasco, Head, National Sorghum Program, SRN, Choluteca

Dr. Fransisco Gomez, Sorghum Breeder, National Sorghum Program, SRN (late 1986)

Ing. Lindolfo Fernandez, Agronomist, National Sorghum Program, SRN, Comayagua

Ing. Humberto Mejia, Agronomist, National Sorghum Program, SRN, Olancho

Dr. Dan Meckenstock, Sorghum Breeder, TAM-131, Principal Investigator of Project; Sorghum Improvement in Honduras and Central America

Dr. Keith Andrews, Entomologist, Head of Integrated Pest Management Project (MIPH), EAP, Zamarano

Ing. Roni Munoz, Asst. Professor, EAP, Zamarano (late 1986)

Other Countries

Ing. Rafael Reyes, Entomologist, CENTA, El Salvador

Ing. Leopoldo Serrano, Entomologist, University of El Salvador

Dr. Compton Paul, Agronomist, ICRISAT, Mexico (CIMMYT), and CLAIS Coordinator

Agr. Rene Clara, Sorghum Breeder, ICRISAT, Mexico (CIMMYT)

Ing. Edgar Ramiro Salguero, Agronomist, ICTA, Guatemala

United States

Texas A&M University (TAMU)

Dr. Darrell Rosenow, TAM-122. Sorghum Breeding. Drought tolerance and disease resistance, and Country Coordinator

Dr. Fred Miller, TAM-121. Sorghum Breeding. Tropical adaptation, food and feed type parental lines and hybrids.

Dr. Gary Peterson, TAM-123. Sorghum Breeding. Midge resistance.

Dr. Richard Frederiksen, TAM-124. Pathology. Disease resistance, identification, screening and control.

Dr. Frank Gilstrap, TAM-125. Entomology. Biological control of stemborers.

Dr. Lloyd Rooney, TAM-126. Cereal Quality. Food grain quality, tortilla and traditional food products.

Mississippi State University

Dr. Henry Pitre, MSU-105. Entomology. Fall armyworm, soil and other insects.

Graduate Student Research Collaborators (conducted their research in Honduras.)

George Wall (Salvadorian). Pathology. Received Ph.D. in 1986 at TAMU with R.A. Frederiksen.

Ronaldo Sequeira (Nicaraguan). Entomology. M.S. student with Frank Gilstrap at TAMU.

Marco Castro (Honduran). Entomology. Received M.S. in 1985 at MSU with Henry Pitre and currently Ph.D. student with Pitre at MSU.

Carlos Trabanino (Honduran). Entomology. M.S. student with Henry Pitre at MSU.

Memorandum of Understanding

Signed between INTSORMIL and the Secretary of Natural Resources (SRN) in October, 1982. A revised MOU is currently being developed cooperatively by INTSORMIL and SRN which will reflect some recent changes in the program and will clarify responsibilities of SRN and INTSORMIL in conduct of research in Honduras. After the revised MOU has been signed, a formal MOU

with the Panamerican Agricultural School (EAP) will be developed to cover the officing of Meckenstock at the School and the collaborative activities with INTSORMIL graduate students doing research in Honduras. A MOU exists between INTSORMIL and the Honduras Institute of Anthropology and History (IHAH) but has been largely inactive during the past year.

Other Opportunities

A draft of a MOU with El Salvador was prepared to cover some collaborative research, but was put on hold due to budget constraints. It is believed that a MOU with El Salvador should be developed, hopefully with some USAID/ES funding, to cover collaborative research in the country which will not require extensive PI travel or expenditure of funds. The Salvadorians have requested a collaborative program with INTSORMIL, and it has been supported by USAID/ES. The Mission has supported some Salvadorian travel to U.S. and some research in El Salvador.

As Dr. Fransisco Gomez develops his breeding program for Honduras, there will be opportunity for the INTSORMIL person in Honduras to reduce breeding efforts and to devote more time to networking activities with other countries in Central America and in the Central America, Mexico, Caribbean Ecogeographic Zone. A strong networking of activities in the area is highly desirable due to the small size of countries, the direct application of improved breeding materials and cultivars developed in Honduras to other countries, and the existing excellent cooperation among national scientists in the area through regional programs such as CLAIS, PCCMCA, and ICRISAT.

Sorghum Constraints Researched

Major emphasis is on improving sorghum production in the small farm steep hillside agriculture where tall, photoperiod sensitive sorghums (Maicillos criollos) are intercropped with maize. Major constraints to production and utilization are low yield, diseases, insect problems, drought, and good food grain quality. Of lesser importance, but also a priority in the area are the lowlands and areas of larger landholdings, where shorter, photoperiod insensitive sorghums work well. Similar constraints exist in these areas. Seed production of improved cultivars is also a constraint to increased production.

Research Progress and Results

Breeding of improved cultivars

Releases - a dual purpose photoperiod insensitive sorghum variety, Sureño was released in late 1985, for use both for grain and forage. The variety has high grain yield and is resistant to downy mildew and other foliar pathogens. The grain possesses resistance to grain mold, weathering, and to the rice weevil, and has excellent tortilla quality. The stalks are juicy and sweet.

Maicillos criollos breeding - Improved photoperiod sensitive dwarf maicillo types have been developed from crossing Maicillos with U.S. sources of disease resistance, drought and lodging resistance, weathering and grain mold resistance, high yield potential, and good food grain quality. Improved dwarf Maicillos nurseries were developed of F_5 and F_6 lines and evaluated and selected at several locations in Honduras as well as in El Salvador, Guatemala, and Mexico. Some lines were entered in cooperative CLAIS trials which were planted over the region. Some of these trials include intercropping with maize, and on-farm trials in 1986. Data from 1985 indicated that some of the improved maicillos lines had higher yield potential, higher downy mildew resistance, and better weathering resistance than the Maicillo checks, and were shorter in height and slightly earlier in maturity.

Tortilla nursery - A 23 entry nursery was developed of food type varieties, selected for tortilla quality and adaption from U.S. and ICRISAT derived lines. It was evaluated in Honduras, El Salvador, Guatemala, Costa Rica, Mexico, and U.S.A.

Maicillo collection - Over 200 have been collected in the area, with 60 introduced to the U.S., and 28 have been entered into the cooperative TAES-USDA Sorghum Conversion Program. A derivative of the original conversion cross involving a local Maicillo, San Barnardo, showed superior yield, adaptation, and tortilla quality traits in hybrid combinations in Texas, as part of Fransisco Gomez's Ph.D. dissertation.

Pathology

George Wall (TAMU - Frederiksen, TAM-124) completed his Ph.D. dissertation in 1986 with research done in 1983-85 in Honduras on disease

identification, screening, and loss assessment. The major diseases of different parts of Honduras were defined and sources of resistance identified.

A downy mildew screening site at Comayagua has been developed for commercial hybrids being sold in Honduras, and all breeding materials.

Entomology

The MSU-105 project (Marco Castro-Ph.D. candidate, and Carlos Trabanino-M.S. candidate - Pitre, major professor) has identified, with the collaborative efforts of agricultural research and extension personnel of the Department of Agriculture, Natural Resources, the major soil inhabiting pests of sorghum seed and seedling plants in the sorghum producing areas of southern Honduras. These pests include mainly white grubs, wireworms, ants, rootworms and termites. The complex of insect pests, diversity of species and population dynamics varies depending on cropping systems utilized, region and topography and environment. In polycropping investigations in central and southern Honduras, research emphasis is on soil inhabiting insect pests of seed and seedling sorghum plants, as well as on insect pests feeding in or on the foliage, stalk and panicle (developing seed). Pest control tactics evaluated for practical utility in these areas have included the development of specific cropping practices (planting systems), the selection and/or development of host plant resistant sorghums for insect population suppression, the practical utilization of biological control agents in routine subsistence farming systems, and the use of chemical application for insect control. Factors associated with the plants (mechanisms of insect resistance) in various stages of growth and development are under investigation. Successes have been achieved in all areas, however, the more simplistic use of insecticide, using specific application techniques suitable for subsistence farming, appears to show the most promise for the short term. Cultural practices and biological control show some promise as tactics for implementation in subsistence farming operations, but as with the utilization of host plant resistance, there is need for more research to provide a better understanding of the relationships between plants, pests and the utility of the control tactics. Additional attention is being given to the development of these low income, farming in-put insect control tactics for use on subsistence farms in Honduras.

Ronaldo Sequeira (M.S. candidate with F. Gilstrap, TAM-125) conducted research in Honduras and El Salvador from May 1985 through January 1986. Studies were completed in Honduras identifying stemboring pyralid pests, associated parasites, and crop losses due to stemborers at several locations; quantifying the effects of four different sorghum cropping systems on the population dynamics of several pests of sorghum and maize; and the effects of releases of an exotic parasite of stemborers. The data are undergoing analysis and the results will be prepared as a Master of Science thesis. Parasites of stemborers have been and are continuing to be sent to Honduras and El Salvador for release and permanent colonization. To date about 90,000 parasites have been sent and plans are to send about 50,000 more parasites before the end of calendar year 1986. These parasites are called Cotesia (=Apanteles) flavipes and are proven extremely efficient in Texas and Caribbean countries where already established. All work not yet published will be submitted for publication in the near future.

Food Quality

Tortilla nursery - A 23 entry nursery was developed and distributed for evaluation and use.

Research was conducted by Fransisco Gomez (for Ph.D. with F. Miller, TAM-121) in Texas on agronomic, grain, and food quality evaluation of food grain genotypes with special emphasis on tortilla making and tortilla quality. He found that white seeded types with tan plant color, a thick, non-staining pericarp which removes easily, intermediate textured endosperm and with good weathering resistance were the best for making tortillas. He identified one male parental line, SC1207-2, derived from the cross, 77CS2 (Tx2817) X San Barnardo (a local Maicillo), as producing the best hybrids, both in grain production and food quality traits. This line also performed exceptionally well in Niger in 1985. This indicates the potential of the Maicillos for breeding in the U.S. and other parts of the world for improved food quality sorghums.

Institution Building

Research Supplies and Support

One vehicle was purchased for INTSORMIL scientist and graduate student use (another to be purchased in late 1986), along with computer equipment,

software (SAS), and air conditioner for computer room, all for SRN use.

Through efforts of the INTSORMIL representative in Honduras, the USAID Mission contributed in 1986, $82,500 worth of local currency directly to SRN for use in the National Sorghum Program, as well as $45,000 to Dr. Meckenstock (through SRN and EAP) for support of his overall activities and INTSORMIL graduate student activities.

Training of Host Country Researchers

Fransisco Gomez completed his Ph.D. in Plant Breeding (with Dr. Fred Miller, TAMU) at Texas in late 1986 and returned to Honduras where he assumed a position of sorghum breeder in the Honduran Sorghum Program (SRN). His support and salary will be funded through USAID counterpart support funds through SRN. Gomez will be the primary Honduras sorghum researcher, and has been designated as the liaison with international programs such as INTSORMIL.

Marco Castro (Ph.D. student) and Carlos Trabanino (M.S. student) conducted their entomology research in Honduras this past year. Both work with Henry Pitre at Mississippi State University.

Ronaldo Sequeira (Nicaraguan) (M.S. student) conducted entomological research in Honduras and El Salvador in 1985 and 1986 (with Frank Gilstrap at Texas A&M University).

George Wall (Salvadorian) (Ph.D. student) finished his Ph.D. in pathology research in Honduras, 1983 to 1985 (with R.A. Frederiksen, TAMU).

Host Country and U.S. Visits by Scientists

Dan Meckenstock, Ronaldo Sequeira, Gary Peterson, and Billie DeWalt to Annual CLAIS meeting, Guatemala.

Dan Meckenstock and Ronaldo Sequeira to PCCMA XXXII Meeting, El Salvador.

Rigoberto Nolasco, Wilfredo Diaz (former SRN administrator), and Rene Clara (Salvador) to SICNA and INTSORMIL PI Conference, 1985.

Rene Clara (Salvador) to Texas, Summer 1985 for short term training in breeding.

Rafael Reyes (Salvador) and Leopoldo Serrano (Salvador) to Texas for short term training in Entomology.

To Honduras:

Henry Pitre, Carlos Trabanino and Marco Castro, Mississippi State

University

Darrell Rosenow, Gary Peterson, Ed Runge and George Wall, Texas A&M University.

Glen Vollmar, INTSORMIL Management Entity.

Networking

In-Country. Research activities, sharing research results, and development of research plans are coordinated through frequent visits and meetings with Recursos Naturales (SRN) researchers and regional and national administrators. Extension personnel are used to help identify problems and research needs and assist in on-farm research. An Annual Report of research data for all SRN and INTSORMIL activities is prepared for SRN. Coordination is also done with the Seed Production branch of the government regarding seed increase of newly released cultivars. Graduate student studies are planned through visits of U.S. principal investigators with appropriate collaborators and institutions in Honduras.

Regional. Networking on a regional basis is done in several ways. One is through direct contacts at regional meetings such as CLAIS, PCCMCA, and the Latin American Workshops at CIMMYT (co-sponsored by INTSORMIL and ICRISAT). Also, research results, through improved breeding lines and materials, are disseminated through regional nurseries and tests, such as those developed by CLAIS and PCCMCA. PI's from the U.S. also attend and participate in these meetings and workshops, and further collaborative networking activities through direct contacts and presenting research results at such meetings. Another method of developing networking activities is by direct visits to countries such as El Salvador and Guatemala, with specific research activities developed through such visits.

General Comments

The INTSORMIL/Honduras program has developed well. The recent placement of Dr. Leopoldo Alvarado, who has a Ph.D. from Nebraska, into the major administrative position responsible for research within Recursos Naturales, and the return to Honduras of Dr. Francisco Gomez into a sorghum breeding position in Recursos are both very encouraging signs in the development of a strengthened Honduran National Sorghum Program. Strengthening the Honduran contribution in collaborative research would be desirable as would Honduran input into development of annual work plans for

collaborative research. The program is multidisciplinary, but it lacks INTSORMIL activities in the areas of cropping systems, agronomic research and physiology. PI's with expertise in those areas are encouraged to become involved.

The Honduras research relates very well to surrounding countries and to the entire Central American, Mexico, Caribbean Zone as outlined in the Global Plan. The concentration of research in Honduras on the Maicillos criollos complements very well the other research activities of the area which are aimed primarily at photoperiod insensitive, commercial type hybrid and varietal work done by ICRISAT, Mexico, and commercial companies. The INTSORMIL collaborative research in Mexico on food type sorghums, with emphasis on use of sorghum for tortillas and good tortilla quality type sorghums, has very direct application to Honduras. The INTSORMIL/Honduras program has developed good working relationships with the regional programs in the area such as CLAIS, CATIE, PCCMCA, and ICRISAT, and has participated actively in meetings and workshops in the Zone. It is hoped that INTSORMIL/ Honduras can host a Zone Workshop in late 1987, with emphasis on all aspects of Maicillos criollos production and utilization.

KENYA

John A. Mann
Texas A&M University

Collaborative Program

Memorandum of Agreement

In spite of an expressed desire on the part of INTSORMIL and the Ministry of Agriculture to formalize our relationship with a Memorandum of Agreement, the continued uncertainty of the status of USAID's new project has delayed the signing of such a document.

In spite of the lack of an official agreement, collaborative work has continued at full clip. This includes trials at five locations twice a year, assistance to local programs, short-term training in the U.S., and short-term technical assistance in Kenya by INTSORMIL scientists. A signed memorandum is desirable, but the lack of one has not impeded progress to date.

Sorghum/Millet Constraints Researched

Sorghum. A number of constraints exist for sorghum production and utilization in Kenya. Poor general adaptation of improved lines to the environment is chronic, due at least in part to the sources of germplasm used. New and diverse germplasm, especially with drought tolerance and good tropical adaptation, is essential. A second constraint to production is the "bird" problem, which is at once a problem of inadequate human resources and the perception that birds are a serious pest. As discussed in the Year 7 TAM-132 annual report, birds are a problem only on a local scale, as Kenya nor any other East African country has ever recorded nationwide losses in excess of 5 percent. A third constraint, especially in the western zone, is Striga. It is especially prevalent in the lake basin, affecting maize, sorghum, millet and sugar cane.

Pearl millet. Pearl millet suffers from many of the constraints that plague sorghum. The major problems are again a lack of good germplasm and birds. ICRISAT materials are poorly adapted, and Ugandan materials are somewhat limited in diversity. INTSORMIL (i.e., Kansas and Nebraska) material and West African materials need introduction and testing to expand the germplasm base. Birds are a problem on millets but because of millets' higher market price, labor is often used to prevent damage.

Utilization. The chief utilization constraint is associated with the presence of a pigmented testa on much of the sorghum grown in Kenya. (It should be noted that millets are highly preferred for "uji" and do not suffer as does sorghum from utilization constraints.) While many of the local types grown in traditional growing areas such as Western Province have a testa present, they have a reputation for getting "sweeter" as they mature, and for producing an acceptable food product. The testa on improved types is different, at least to the farmers, and these cultivars suffer the reputation of producing a bitter food product and having poor storage characteristics. This difference appears to be due to the locals having a purple testa and the exotics having a brown testa.

Research Progress

Research in Year 7 has been concentrated on producing sorghum germplasm suitable for the Kenyan environment and farmer. Work has concentrated on "food quality" sorghum types, but now more emphasis has been placed on high tannin types, as they are preferred in the western zone. Research in the past year has established that three different zones exist in the country as far as sorghum and millet are concerned, and has provided at least partial answers as to what types of sorghums will fit where. In the lowlands (below 1000m) lines such as TX629, TX623, RTAM428, etc., are very well adapted. In the high drylands (>1000m, <1000mm), such lines as TX7000, B35, etc., are best. In the wet midlands (8-1200m, 1-2000mm) many of the Kafirs and such lines as A155, and SC326-6 are suitable.

Mutuality of Research Benefits

The crosses of elite lines onto TP24 to incorporate the Ms3 gene into the elite lines have had two results which should be useful to the U.S. as well as Kenya. The full-sib offspring of these crosses and backcrosses have provided some very productive lines which are now included in the TAES pedigree program, and some which may well be released in Kenya. The sterilized elite lines will also be very useful to those breeders in the U.S. who use population breeding techniques in their programs; this in addition to the production of synthetics for Kenyan conditions. Even though this project is entirely oriented towards Kenya and East Africa, many potential benefits to the U.S. are being produced by the project.

Institution Building

During Year 7 $450 was spent by the project for supplies for various sorghum and millet programs in Kenya. This included pollination bags, envelopes, tags, pencils, etc., and proved to be the only source for these materials during the year. In addition, $1200 was given for research support to maintain programs at Alupe, Katumani, Kiboko and the Coast. An additional $900 was given in the first weeks of Year 8. This money has kept these programs operating in a situation where the Kenyan government has provided little or no support in the last year.

Newton Ochanda, who took an M.S. degree with Drs. Rosenow and Miller, is now the sorghum breeder for the Western Province area of Kenya. He has established a sound breeding program there, and while it needs inputs of germplasm and equipment/supplies, he is a good example of what INTSORMIL institutions can provide in the way of education and training. He has become a strong collaborator with TAM-132, and this relationship should continue to strengthen and expand. Many of the local sorghums in that area of Kenya may be useful in the conversion program, as they are characterized by having testas, yet getting "sweet" at maturity.

F. Lawrence M'Ragwa Riungu, the senior breeder in the Sorghum and Millet group, visited the U.S. during Year 7 under the sponsorship of TAM-132. He spent time with the programs of Drs. Rosenow and Miller, and about three weeks with TAM-132. In addition, he spent a week each in Kansas and Nebraska working with millet, and four days at Purdue. In addition to the field work, he spent considerable time with scientists in other disciplines, including quality/cereal chemistry, pathology and entomology.

Drs. Rosenow, Frederiksen and Mann all spent time in Kenya during Year 7, Rosenow and Frederiksen for about one week each, and Mann for a total of seven weeks on two trips. All participated in review and consulting with local scientists.

Networking

Most of the networking activity in East Africa has been through the OAU/SAFGRAD workshops, and through personal contacts with breeders in the region. The East African Regional Adaptation Trial (EARAT) was sent to Ethiopia, Sudan, Somalia, Uganda, Rwanda, Burundi and Tanzania, and was planted in three locations in Kenya. Data from these plantings will be very useful in determining what Texas material will fit where, and greatly

increase both regional cooperation and regional development. Within Kenya, networking has been greatly enhanced by the simple procedure of INTSORMIL scientists always traveling with Kenyan colleagues. These trips are all too often the only opportunity for a scientist from Katumani, for example, to visit Alupe. To date, research results are not at a stage where they can be shared with farmers, except in such ways as "farmer selection blocks". At this point, farmers have a lot more to contribute to research than visa-versa.

General Comments

Kenya offers a cadre of trained and enthusiastic personnel, good infrastructure and political stability. It is a key country in USAID's Africa strategy, and is among the targets for agricultural research development. In addition, agricultural research in the country needs assistance of the type INTSORMIL is so well equipped to provide. INTSORMIL germplasm is well adapted, there are no language barriers, and our scientists will be able to move into collaborative relationships quickly and smoothly. INTSORMIL is in good position to be involved in the USAID/Kenya Agricultural Research Project, and should use already established linkages with Kenyan institutions as a springboard for further involvement.

Because of cultural and ecogeographical similarities between Kenya and many of the other East African countries, and because of a number of dissimilarities between these countries and Sudan, it may make sense to separate out East Africa as a separate Zone, to include Ethiopia, Kenya, Uganda and Tanzania.

MALI

L.W. Rooney
Texas A&M University

Coordinators

U.S.A. -- L.W. Rooney and A.B. Onken, Texas A&M University

Mali -- Mr. M. Konate, Sorghum Breeder, IER

New Coordinators

Dr. Moussa Traore was appointed the Malian INTSORMIL Coordinator, effective July 1, 1986. Dr. L.W. Rooney was appointed INTSORMIL Coordinator for Mali in 1986 to replace Dr. Onken, Texas A&M, who resigned. Mr. M. Konate, Malian INTSORMIL Coordinator, was replaced by Dr. Moussa Traore effective July 1, 1986. Dr. Traore completed his Ph.D. at the University of Nebraska in plant physiology.

Institutions Involved

Institute of Rural Economy (IER), Mali
Texas A&M University
University of Nebraska

The program has been and continues to be an integrated effort among INTSORMIL, TROPSOILS, and ICRISAT - Mali. A farming systems project funded there has begun. The project coordinator (Dr. Robert Chase) is a member of the Texas A&M faculty. There may be opportunities to work with that program as well. Problems of communication exist; but chances for continued substantial progress are excellent. Dr. J. Scheuring, ICRISAT Plant Breeder, resigned but cooperation with Dr. Shetty, ICRISAT Agronomist, is excellent. Dr. Scheuring has provided significant support to the IER INTSORMIL efforts since 1979.

Collaborative Program

Production and Utilization Constraints

Yield stability in sorghum/millet production is of major importance where food production is marginal relative to population. Low soil fertility, drought, diseases and insects are major contributors to yield instability. They also result in changes in gran quality such that it becomes unfit or undesirable as human food. There are strong interactions between such factors as soil fertility and soil water use as well as insects and diseases and grain quality.

Soil fertility and drought resistance and tolerance are associated. Due to a lack of nutrients, principally N and P, usable water is left in the soil profile even by native range plants in the Malian Sahel. We have determined that on Alfisols in Texas (same soil family as many in SAT areas of Africa) usable water is left in soil zones of low nutrient supply. Thus, it is necessary to determine the relationship between nutrient use efficiency and water use efficiency in plants under low nutrient conditions. To make the best possible progress in sorghum production in developing countries, it will be necessary to understand the soil characteristics. The development of an effective soil analysis program in Mali is of major importance to the overall research effort.

Memorandum of Agreement

A Memorandum of Agreement to allow transfer of funds was signed in Mali on October 10, 1984. The 1985-86 workplan and budget was developed and approved by the IER in April, 1985. The third work plan and budget for 1986-87 was completed in April 1986 and signed in June 1986.

Other Problems and Opportunities

Communications between the U.S. and Mali are still difficult at best, due to unreliable telex service in Mali. Drs. Yohe and Traore are trying to implement an electronic mail and data communication system between the U.S. and IER-Bamako. When this is successful, communications will be effective.

The U.S. AID mission in Bamako continues to be a strong supporter; Dr. S.K. Reddy has aided the work very significantly. The effective interaction between TROPSOILS and INTSORMIL and IER has improved. The credibility and use of the soil testing laboratory at the Sotuba Experiment Station needs improvement. Research with crops, irrigation, cropping systems, and fertilizers is not as effective due to the lack of soil chemical characterization. The agronomic data can be interpreted correctly only when the chemical characteristics of the soil are defined. An effective plan to improve the soils laboratory should be a high priority of all agencies and programs involved in agronomic research in Mali.

Research Progress

Sorghum Improvement through Breeding and Selection

The collaborative breeding program of Dr. D. Rosenow, Texas A&M University, with Dr. O. Niangado and M. Konate (IER) continues to identify desirable characteristics of sorghums for Mali. Sorghums with open heads, hard grains, and other characteristics are required for acceptable food quality. Putting these attributes together into improved yielding varieties is requiring considerable effort. However, seven cultivars have been released from the Malian sorghum improvement program. The sorghums called Malisor 1 through 7 are shorter, early maturing and have improved disease resistance. These types have many desirable characteristics for intercropping with ground nuts and cowpeas. The tô quality varies, but, some of them (Malisor 7) have hard seed and thick pericarp which provides desirable decortication properties and excellent tô keeping quality. However, the heads are compact which can cause problems with head bugs and molds. The food quality properties are known due to extensive testing via the mini tô tests conducted in the food technology laboratory at Sotuba. Several advanced breeding lines look promising. The fact that quality testing has been done during breeding and selection activities by Malian scientists is critically important. Input from INTSORMIL on grain quality evaluation has been continued since the inception of the program in 1979. The major factors that critically affect post harvest technology of sorghum were determined and used to develop simple milling and tô quality tests. This has been done with modest equipment but with great skill by the food technology personnel.

Physiology of Drought

Mr. Verne Isbell (graduate student, Texas A&M) provided two months of technical assistance during the growing season to deliver and calibrate physiology equipment, train Malian scientists in its efficient use and maintenance and to assist with acquisition and interpretation of physiological data on sorghum drought stress. The equipment was purchased through a training grant by USAID Mali to ICRISAT. Experiments were conducted to determine why local Malian guineense sorghums have drought tolerance. Experiments were conducted in Lubbock, TX as well with Malian CSM-63 and U.S. sorghum lines. Measurements of soil water relationships suggested that the top 10 cm of soil was where most water was used for plant

growth. Dr. Traore who returned to Mali in January 1986 has secured funding through a USAID-PSTC grant for physiological research. Dr. Sullivan (NU-116S) has provided computing and other equipment to help Dr. Traore initiate his research program on drought tolerance of sorghum and millets and factors affecting yield.

Soil Toxicity

In the past, several INTSORMIL tests at Cinzana were lost because of poor stands. Preliminary tests suggested that Al toxicity is an important factor contributing to poor seedling emergence, survival and growth. Mr. M. Doumbia (graduate student, soil fertility) is conducting research on factors affecting soil toxicity at the Cinzana Station, Mali.

Mr. Doumbia completed his B.S. degree and course work for an M.S. at Texas A&M as part of TROPSOILS and INTSORMIL cooperation. Drs. Onken, (TAM-123), and Hossner, TROPSOILS, serve as co-advisors. Mr. Doumbia will complete his M.S. and Ph.D. theses research in Mali. A better understanding of the soil toxicity problem is critically important.

Soil Analyses and Characterization

A major constraint is lack of detailed knowledge of Malian soils. Dr. Onken through a strengthening grant from Texas A&M is conducting analyses on soils from Mali. This work will continue with support from TROPSOILS also. The analyses of the samples are nearing completion. Efforts to improve the effectiveness of the Malian soil analysis laboratory continues through TROPSOILS.

Food Quality

Grain quality research continues in Mali in the food technology laboratory and in Dr. L.W. Rooney's laboratory to improve methods of selecting sorghums and millets for tô quality. Personnel from the Malian food quality laboratory were given a short training program at Texas A&M University and Purdue University. Pearl millet lines from Mali, Niger, and the World Collection have been characterized for differences in kernel characteristics that relate to processing. The structure of pearl millet lines with different characteristics has been determined and related to differences in processing properties. The relationship of pearl millet kernel shape to dry milling was determined by decortication trials in Mali

and by laboratory village work elsewhere. The structure of finger millet and fonio has been determined. Sorghums that produce dark colored tô were shown to have pigmented undercoats. Chemical analyses of the composition of sorghum and millets decorticated in Malian villages was provided to IER staff. Research on production of dry alkaline cooked sorghum flours has been initiated in Mali. The concept of producing instant dry flours for tô was obtained by M. Haidara and Salimatu Coulibaly during their training program at Texas A&M. Laboratory procedures were improved. The new food quality laboratory facilities are partially constructed and equipment will be purchased this year to expand research into improvement of the past harvest technology of Malian crops.

Mutual Research Benefits

The identification of sorghums through development and use of appropriate screening techniques for drought tolerance and nutrient use efficiency will benefit both African and U.S. sorghum producers. Sorghum breeders from Mali and the U.S. have access to a much wider range of germplasm through a collaborative program than would otherwise be available. The delineation of grain characteristics responsible for various aspects of quality will have effects on utilization both in Mali and the U.S. and will furnish plant breeders in both countries with necessary information for selection of sorghum and millet types for particular uses.

Institution Building

Equipment, supplies, chemicals and other support items were transferred to Malian scientists. Major items of equipment purchased by Dr. Sullivan from NU-116 funds to aid in establishing a plant physiology program include: an IBM-PC system with expanded memory, color monitor, two disk drives, Epson FX-85 printer, constant voltage transformer, power surge controller, and all needed interfaces, extra diskettes and a case of printer paper, data base manager and MSTAT computer software programs, a Mettler electronic balance, B & L stereozoom microscope, cassette tape recorder and leads, and a cassette tape reader for use with the IBM-PC, a Kodak Ektagraphic slide projector with case and 12 extra bulbs, pressure chamber for water potentials, and a thermocouple psychrometer with digital meter, infrared thermometer, two cases of petri dishes, some chemicals and books.

Mr. V. Isbell spent two months during the growing season to train Malian scientists to operate equipment to determine physiological parameters. The equipment was purchased by ICRISAT-Mali using AID Mali funds. The technicians were carefully instructed in maintenance of the equipment as well.

Dr. Moussa Traore completed a Ph.D. (physiology) in January 1986, at the University of Nebraska. His research on physiology at Nebraska was related to Malian sorghum research needs.

Mr. L. Traore, M.S. - Agronomy, Texas A&M University, has been in charge of the SAFGRAD trials in Mali for several years.

Ms. A. Kante (former technician, IER Food Quality Laboratory) is working on an M.S. in food science and technology in the Cereal Quality Laboratory at Texas A&M University. Her research is on factors affecting tô quality of sorghum and millet.

Mr. M. Doumbia is currently in Mali conducting research on "The Soil Toxicity Problems at the Cinzana Station" as part of his thesis research on soil fertility. He works with Drs. Onken and Hossner jointly through TROPSOILS and INTSORMIL.

Mr. M. Diorte is working on an M.S. in plant pathology at Texas A&M University. His research is on charcoal rot of sorghum. Dr. Rosenow is on his advisory committee.

Short-term training

Two Malian scientists, Miriam Haidara and Salimatu Coulibaly, from the IER Food Technology Laboratory (Bamako) were provided short term training in cereal quality testing procedures at Texas A&M University and Purdue University. Mr. M. Konate, sorghum breeder, IER traveled to INTSORMIL institutions in October 1985 to review Sorghum trials, plan experiments and obtain germplasm. Director Traore and Mr. Z. Sanogo, IER, Bamako traveled to U.S. institutions to review research programs.

INTSORMIL travelers to Mali included Drs. Rosenow and Onken (Oct. 1985), Mr. V. Isbell (Sept. through Oct. 1985) and Dr. C. Sullivan (March 1986). Dr. Rosenow assisted in evaluating sorghum drought tolerance and breeding tests. Dr. Onken reviewed the INTSORMIL sponsored field experiments. Dr. Sullivan participated in the Malian research and planning conference, planned physiology research and obtained a draft work plan for 1986-87.

Networking

The Malian program complements the INTSORMIL research program in Niger very effectively. Most of the work in Mali has applications elsewhere in West Africa. The food technology work is applicable to all areas of Africa where millets and sorghums are used. Few if any other national programs have effective grain quality evaluations as part of their cereal improvement programs.

Each spring in Mali, a research review is held in which each scientist reports on the previous year's research results and discusses research plans for the next crop season. The participants include all scientists (expatriates included) conducting agronomic research in Mali. Malian scientists participate in the West African Regional Sorghum Millet Workshops sponsored by ICRISAT each year. SAFGRAD, which works closely with farmers at the village level, has representatives at each of these meetings. Scientists from Mali participate in international workshops. For example, M. Haidara and Dr. O. Niangado participated in the International Pearl Millet Workshop in India by presenting papers. Food Technology personnel have participated in workshops in Senegal where their processing research was discussed.

MEXICO

Frederick R. Miller
Texas A&M University

Collaborative Program

Institutions Involved

University of Sonora, Hermosillo, Mexico

Universidad Autonoma de Nuevo Leon, Marin, N.L., Mexico

Instituto Nacional de Investigacions Agricolas (INIA), Celaya, Mexico

Texas A&M University, College Station, Texas

University of Georgia, Experiment Station

ICRISAT/CIMMYT Center, El Batan, Mexico

Memorandum of Agreement

Memorandums of Agreement have been established separately with each of the four major entities in Mexico. Extensive interaction has been on- going with Mexico for a number of years without official MOA's. Since Mexico has had such a close history of association with several INTSORMIL institutions, establishment of a broad, sound and interactive collaborative program has been easy, but not without barbs. Funding of research activities with collaborating institutions was easily established except with INIA. Activities with ICRISAT/CIMMYT were carried out under the INTSORMIL/ICRISAT purposes.

Other Problems and Opportunities

Sorghum is important to Mexico. It is widely grown and its merits are known. Because sorghum is adapted to a much wider range of climatic conditions than maize, sorghum is gaining in popularity. Sorghum is also known in Mexico and Latin America as a livestock feed, and is not preferred as a cereal in human food. However, sorghum is being rapidly accepted as a human food resource in tortilla production, soups, cookies, etc. Because there is a shortage of maize in Mexico, sorghum is being used as a blend or replacement in many food products. Finally, because Mexico is a visible leader in Latin America, improvements made in Mexico's sorghum activities will rapidly be transferred into need areas of Central America. Mexico is a critical link between Latin America and INTSORMIL's effectiveness in moving technology to that region.

Because of budget reductions for Year 8, the ME allocation of funds to Mexico was terminated. The country coordinator for Mexico believes it is a mistake to reduce funding to the programs in Mexico because we lose the association and contact with those individual programs and also the ability to move information into the Latin America system. Mexico has served as a central site for four international workshops on sorghum. A fifth workshop on Seed Production was held in 1985. Mexico has been critically involved in these workshops, and recognizes the importance of such activities. In 1985, the "All Mexico Annual Sorghum Reunion" was established. The Second Annual Meeting was held in 1986. We have a great potential to interact with Mexico, and with Latin America through Mexico in INTSORMIL. Individual INTSORMIL PI's still collaborate with Mexican scientists as individual project funding permits.

Sorghum/Millet Constraints Researched

Sorghum is currently of major social and economic importance in Mexican agriculture and industry and millet, potentially, can be a valuable alternative for rainfed farmland with deficient rainfall and in areas with short growing seasons due to early frosts, such as the high altitude valleys. Sorghum production can be extended to other rainfed lands and through genetic improvement, grain can be obtained for direct human consumption. Drought tolerance in sorghum is known to be high and lends stability to the productivity of this major food cereal. Drought, diseases and insects are major contributors to yield instability. Furthermore, they cause changes in grain quality such that it becomes unfit or undesirable for human food. The development of the full potentials of sorghum in an alkali food system merits major involvement in resource storage, milling, processing, cooking, and product evaluation.

Research Progress and Results

Dr. Lloyd Rooney, Texas A&M University, has been working very closely with the cereal quality project at the University of Sonora. The efforts have concentrated on the development of traditional cooking procedures, design and operation of dry milling equipment, and the search for an alternative cooking technology such as extrusion cooking that would be used in LDC's to improve utilization of sorghum for human foods. Both white and red experimental sorghum hybrids have been processed in a pilot plant at the

University of Sonora. White grain from a non-tan plant color sorghum hybrid underwent drastic off-color changes when compared to white grain from a tan plant color sorghum. These white grain (tan plant) can replace 50 to 75% of maize (white or yellow) when pearled from 10 to 18% by weight. In contrast, white grain (non-tan plant) could replace 30 to 50% maize. White tortillas were produced which were rollable and with good flavor when processing conditions were: 0.8% CaO, 8 min cocking at 84C degrees, 15 min steeping and 10 to 12% pearling. The red sorghum ATx378 x RTx430 pearled at 18% was replacing 40% yellow maize. The pilot plant operation showed that sorghum can be used in a commercial tortilla plant with only minor cocking changes.

Using the environment of Mexico where high levels of diseases on sorghum exist, the project is determining the basics of disease spread and biotype change. Sorghum leaf blight is widespread in the world but occurs in high incidence in the Baja of Mexico. One option to control the disease is host plant resistance. This can be wasteful of good genes without supporting technology. Cultivar mixtures have been exploited as an inexpensive means of controlling important airborne diseases in some crops. This study will compare the incidence and development rate of the leaf blight in varying mixtures of resistant and susceptible sorghum cultivars. The study being carried out with INIA collaborators will compare yields in the presence and absence of the disease, evaluate the relative contributions of mechanisms of disease spread and measure infection frequency, sporulation rates and latent period as components of resistance for the resistant and susceptible cultivars. The results of this three year study will be applicable throughout all areas growing sorghum.

During the year, numerous trials for adaptation, genetic studies, disease and insect evaluations, food quality studies, and breeding lines were sent into the collaborating programs. Approximately 150 early generation selections were received from Mexico, and are being included in the INTSORMIL program in Texas.

Research Benefits

Because sorghum in Mexico is so nearly equal to sorghum in the U.S., the development, testing, implementation, and end-use of this crop will allow U.S. scientists to benefit from these trials. Diseases are more intense in some areas and research on behaviour, genetic evaluations, screening for resistance, etc., benefit INTSORMIL breeders and pathologists.

Because Mexico is grain deficient, much interest is expressed in using high quality sorghum in food products. Such work benefits the U.S. and Mexico as well as all who depend upon this grain. Expanded markets, new superior germplasm, new products with increased market value, etc., result from these kinds of collaborative research activities.

Institution Building

During 1985-86, $19,000 was used to fund research activities completed jointly in Mexico. In addition, numerous research supplies were provided and some equipment loaned for short-term use. Approximately 20 research trials were exchanged with various institutions involved. Germplasm selections were made in Mexico, and returned to sorghum scientists in Texas.

Currently, there are at least five Mexican graduate students studying for advanced degrees in INTSORMIL institutions. Those students who have completed studies have returned to Mexico and are involved in university research/teaching, private research, and government research.

October 13-17, 1985 at El Batan, Mexico, the Fifth Latin American Sorghum Workshop was held. The emphasis was "La Produccion de la Semilla de Sorgo en America Latina". Representatives from most Latin American countries were present. Major paper presentations were made describing sorghum seed production.

INTSORMIL scientists who were in Mexico in 1985-1986.

Fred Miller	R.A. Frederiksen
Gary Peterson	Gebisa Ejeta
Lloyd Rooney	(several INTSORMIL students)

Networking

Each year in Mexico, an "All Mexico Annual Sorghum Workshop" is held to discuss research and research plans. This meeting is an outgrowth of INTSORMIL involvement.

Mexico has served as a central site for five international workshops on sorghum (pathology, food quality, breeding, farming systems, and seed production). More than 125 scientists and workers attend these meetings, and they represent from 10 to 17 countries of Latin and South America. Since Spanish is the language, information transfer is easy and rapid. The whole Latin America and South America Ecogeographic Zones benefit from these workshops and interactions.

Where once there were many individual programs in Mexico, they are beginning to work together. The same is happening for Latin America. The involvement of Mexico in improvement and development of sorghum in Latin America is paramount. Mexico offers a unique situation because of the infrastructure which exists there and the proximity to the rest of Latin America.

Perhaps one of the most gratifying aspects of INTSORMIL activities is the opportunity to establish contact with scientists in other countries working on the same commodity, facing the same or different problems and to be able to develop a meaningful, productive, collaborative research program. Our goal is to share germplasm, methodologies and to grow more productive because of the interaction. Several of these relationships have developed in Latin America and more will develop.

General Comments

Areas of interest and cooperation which can be expanded are:

- Breeding for yield and stability.
- Breeding for disease resistance and insect resistance.
- Breeding for and understanding sorghum food quality and end product use.
- Identification of cold tolerance for early growth and anthesis as well as drought tolerance.

Because sorghum is a major cereal crop of Mexico and Latin America, and because its full food potential is not developed, it is necessary to develop and strengthen national programs working on the commodity. There is a strong base of interest and scientific expertise in Latin America that can be attracted as through involvement with Mexico. Mexico's acceptance of modern technology is high. Mexico has good scientists, and also has good credibility with the rest of Latin America. Technology can be infused into Mexico, modified, redistributed and tested, then transferred to Latin America in an easy manner. Mexico is accessible, a good place to work, and has a large array of the problems existing in other lesser developed areas also.

NIGER

John Axtell

Purdue University

Project Personnel

Katy Ibrahim, Purdue INTSORMIL Admin. Assistant

Susie Clark, In-Country INTSORMIL Admin. Assistant

Collaborative Program

Drought, insect pests, long smut and Striga are the major constraints in Niger. Extremely high soil temperature leads to difficult problems in crop establishment. Sand blasting of young seedlings is also a complicating factor. Plant breeding for tolerance to these major constraints is one of the most feasible solutions. New cultivars must be acceptable for tuwo preparation. For example, the variety L-30 has been the highest yielding sorghum variety in the Sahelien trials for the past ten years, but is not accepted by farmers because of poor food grain quality.

Institutions Involved

Purdue/Niger Cereals Research Project (NCRP)

USAID Mission

Niger Cereals Research Project (INRAN)

TROPSOILS

ICRISAT Sahelien Center (ISC)

Ministry of Rural Economy (DECOR)

Peace Corps

Purdue University

Texas A&M University

University of Nebraska

Mississippi State University

Memorandum of Understanding

Signed by INTSORMIL, Ministry of Higher Education Research in Niger, Director General of INRAN, and Director of USAID Mission in April 1983.

Other Opportunities

The collaborative millet improvement program could be greatly strengthened in Niger by the involvement of Dr. Wayne Hannah at the Coastal Plains Station in Tifton, Georgia. We are proposing to the Technical

Committee that it solicit a proposal from Dr. Hannah for research on wide crosses between wild Nigerien millets and local cultivars to transfer stress traits into the local germplasm. We propose to do this by a subcontract with David Andrews' project at Nebraska.

Sorghum/Millet Constraints Researched

Sorghum Breeding:

Collaborators - INRAN: Mousa Adamou, John Clark

INTSORMIL: Purdue - J. Axtell, G. Ejeta

Texas A&M - D.T. Rosenow, F. Miller

Nebraska - J. Eastin

Germplasm Enhancement:

The following is a list of sorghum breeding nurseries recently introduced to Niger by INTSORMIL for evaluation and selection during the 1986 crop season. In addition to the array of breeding material that Clark and Adamou had already accumulated, the pool of sorghum germplasm now available in the program looks very good. There is now sufficient germplasm base to effect a meaningful selection program.

Breeding Material	Source	No. Entries
F_1 Crosses: P-967083 x Nigerien locals	Purdue	23
F_2 populations: Exotic x Exotic	Texas A&M (F.Miller)	21
F_2 populations: Exotic x Exotic	Texas A&M (D.Rosenow)	12
F_4 progenies: Sudan Sel. x U.S. Lines	Purdue	309
F_4 progenies: P-967083 x SEPON	Purdue	498
F_4 progenies: P-967083 x P-898012	Purdue	91
Miscellaneous Breeding Lines	Purdue/Texas A&M	
(Selections from Lubbock, Zimbabwe, Sudan)		
Experimental Hybrids (Exotic x Local)	Purdue	60
Experimental Hybrids (Exotic x Exotic)	Texas A&M	40
Parental Line for Hybrids	Purdue	120
Drought Tolerance Test	Purdue/Texas A&M	15
Standard Establishment Trial	Purdue	20
Drought Obs. Nursery	Nebraska	17

It is important to note that such a large array of germplasm was not shipped to Niger indiscriminately. Some of the material was introduced only following a specific request from Clark and Adamou. The rest was based on

preliminary evaluation of smaller sets of an array of INTSORMIL nurseries evaluated in Niger during the previous (1983, 1984, and 1985) crop seasons. Only those that showed promising adaptation potential were introduced in large numbers to initiate further selection. Such an approach is cautious and effective. It protects the breeders in national programs from evaluating too many nurseries that do not have immediate utility in their program. It also helps the cooperating INTSORMIL Principal Investigators to get closely involved in developing appropriate germplasm for their collaborators as well as providing a mechanism to assess the adaptation potential of the germplasm within their program. It certainly provides for development of a true spirit of collaboration/a mutually useful cooperation.

Hybrid Development:

There appears to be good interest developing in evaluating the agronomic potential of sorghum hybrids in Niger. To properly evaluate the potential of hybrids, both local sorghums and introduced germplasm are being considered. A selected group of local sorghums, earlier introduced, was intercrossed with U.S. A-lines during the winter in Puerto Rico. Intercrosses were also made among U.S. A and R-lines. Approximately 100 experimental hybrids will be evaluated at Kollo (rainfed) and at Lossa (irrigation) to provide some preliminary information on the potential of various germplasm. At the same time some 120 R-lines identified as being superior in Sudan are also introduced to Niger and will also be evaluated at Kollo, Tarna, Bengou and Lossa. Two graduate students from Purdue are scheduled to undertake studies on experimental sorghum hybrids in Niger. Tom Tyler and I. Kapran are currently in Niger conducting the hybrid trials. Their research projects are being supervised in Niger by Dr. John Clark under the supervision of Drs. Ejeta and Axtell.

Results for these hybrid trials in 1986 are extremely encouraging. In particular, some of the hybrids using pollinator lines developed from a local variety by exotic crosses (Mousa Adamou SST lines) on TX623, TX631, and P954066 female lines are very promising (Tyler study). Also, some of the exotic x exotic hybrids from previously tested exotic parents are extremely productive in Niger. Evaluations for yield, long smut resistance, and food grain quality are currently in progress by Tyler and Kapran.

Drought Tolerance/Crop Establishment:

Two major nurseries on drought/stand establishment will be evaluated in Niger this season. The experiment on studying some factors associated with stand establishment is on its third year of testing. Twenty local and introduced drought tolerant sorghum selections will be evaluated both under irrigation and rain at Tarna and appropriate data will be collected. The other study involves characterization of sorghum lines previously identified as being drought tolerant in Africa and the U.S. Several sets of this nursery will also be evaluated at different environments: four locations in Texas by D.T. Rosenow, and one set at West Lafayette by Monyo and G. Ejeta. Agronomic field notes from all locations will be pooled to be compared with physiological notes collected at Lubbock, Texas. This study is undertaken as a basis for a Ph.D. thesis by E. Monyo, a graduate student from Tanzania.

Cereal Quality:

Collaborators: INRAN - Mousa Oumarou, J. Clark

INTSORMIL - Purdue - J. Axtell, A. Kirleis

Some useful work has been done by the Cereal Quality Laboratory at INRAN, Niamey in characterizing traditional and improved local sorghum varieties for their tuwo quality parameters. The lab also has capability for some physical and chemical analysis of sorghum grain, and these tests are done on a routine basis. These activities of the laboratory will be a useful tool as new and improved sorghum varieties from the breeding program become available. As part of the overall evaluation of the potential of experimental sorghum hybrids, it is proposed that elite hybrids, if identified, be tested for food quality preparations. The two graduate students from Purdue (T. Tyler and I. Kapran), working on sorghum hybrids for Niger will include food quality aspects in their studies. Grain from elite local and exotic hybrids will be collected for tuwo quality evaluation in Niger. Grain will also be introduced to the U.S. for physical and chemical characterization in the Cereal Quality Laboratory at Purdue. Dr. Allen Kirleis has agreed to provide such support and direction to the two graduate students.

Sorghum Entomology: Head bugs

Collaborators: INRAN - S. Maigah

INTSORMIL - Texas A&M-Gary Steck, G. Teetes, F. Gilstrap

Following his visit to Niger and Mali during 1984 and 1985, George Teetes proposed a series of entomological experiments on the head bug complex in the region. Sorghum panicle-feeding bugs were apparently first noted as serious potential pests in West Africa during the early 1980's. A group of INTSORMIL scientists evaluating sorghum in nurseries at several locations in Niger in 1983 noted an especially high abundance of headbugs. Concern over the magnitude of the bug infestation led to my first trip to Niger in the fall of 1984. Although 1984 was one of the driest years on record for the region, bugs were abundant in panicles of some local varieties and many inproved sorghum lines and hybrids. The panicle-feeding bug situation was described in the trip report and became the basis for the subsequent collaborative research and specific research objectives, and the hiring of Dr. Gary J. Steck to be stationed in Maradi, Niger during the sorghum growing seasons of 1985 and 1986. The collaborative research with INRAN during 1985 progressed very well. An excellent collection of the bug species complex was made and curated. Thirty-four species of phytophagous Hemiptera were censused on sorghum panicles in Niamey, Dosso, Tahaou, and Maradi, Niger during August-October, 1985. Eurystylus sp. and Campylomma spp. were consistently collected in large numbers. Densities of Eurystylus peaked very early and quickly at all sites. Creontiades pallidus, Nysium sp., and a pentatomid species may be considered occasional pests. The sorghum varieties most heavily infested were early maturity types such as El Mota Galmi. Much of the sorghum grown in the Konni and Galmi areas was heavily infested. Local, later-maturity varieties in the Maradi and Bengou areas were not much infested. Panicle compactness was not an important factor in determining head bug infestations in variety trials. however, the presence of very susceptible varieties harboring large numbers of bugs may be endangering nearby plants of relatively nonsusceptible types. In an experiment where head bug densities were great, seed density was significantly lowered, and average seed weight was consistently lower than where bugs were controlled with insecticides.

Head bug Research by Dr. Steck in 1986

Head bug densities were extremely high in almost all areas surveyed. Head bugs were extremely abundant in panicles of the diverse sorghum types grown for breeding and evaluation on Niger experiment stations. However, bugs were also common and abundant in panicles of most local varieties grown in farmers' fields. The head bug problem is not only an experiment station problem. On many occasions head bug damage was very apparent and will be of a magnitude great enough to cause significant losses to grain yield and quality. The species composition is similar to what it has been the previous two years. But, if anything, the damage is more common and more severe. As in previous years, long smut was very severe and may be the second most serious problem with sorghum production and improvement after head bugs. Striga was very abundant in millet, and common in sorghum in some areas.

The collaborative research with INRAN continues to progress very well. The cooperation and assistance of INRAN personnel is good, and direct collaboration with Dr. Maiga is excellent. Dr. Steck has several good experiments underway that will produce extremely valuable results. The head bug species composition is now well known (there is still a problem with identification of species level). Eurystylus sp. is for sure the more abundant and important. Creontiades pallidus and Campylomma spp. are also important components of the head bug species complex. Numerous other species occur, but are less abundant and more occasional in their occurrence. Less time will be spent in the future on species composition determination.

The experiments being conducted by Dr. Steck are of three major types. They are designed to determine bug biology, population dynamics and assess damage. Based on my observations these experiments will produce useful data and will assist in describing the head bug situation in Niger, and provide the basis for future collaborative research. It is important to note that the procedure of stationing Dr. Steck at Maradi only during the cropping seasons continues to work and is providing effective collaborative research at minimal cost. This procedure is accepted by INRAN personnel and they continued to be impressed with the amount of research conducted and the quality of the data obtained.

Sorghum Entomology: Millet Stemborer and Head Girdler

Collaborators: INRAN - S. Maigah

INTSORMIL - F. Gilstrap, Osman Youm, and G. Teetes

This year is Mr. Youm's first full research year at Kolo, Niger. He is conducting research on biological control of these two important millet insect pests. To our advantage is the fact that millet stemborers were more abundant and damaging this year than they have been in the recent past. Almost all millet was heavily infested with stemborer, and all early planted millet was heavily infested with head girdler.

Mr. Youm's experiments are of three major types. He is determining alternate stemborer hosts and parasites, determining their population dynamics, and studying parasite effectiveness as density suppressing agents. He has identified several alternate host plants of the major stemborers species attacking millet, and several parasite species. He is rearing several of these species in the laboratory. Using several plantings of millet, he has or is describing the population dynamics of the stemborer and its associated parasites. Using cages, he is determining parasite effectiveness by introducing parasites to borers on plants in some cages and excluding parasites from borers placed on millet plants in other cages. In the laboratory, he is rearing parasites and studying borer oviposition substrate preferences. His data will be of the type and quality for use as his dissertation research.

The progress that Mr. Youm has made did not come easily at first. He found himself without needed equipment and laboratory space. His own initiative and good collaboration with INRAN and the PARA project enabled him to get what he needed. He has built a small laboratory and has managed to get it at least partially equipped and supplied. My impression was that many people are most impressed with what he has been able to accomplish during his short time in Niger. He is making an outstanding contribution to INTSORMIL's efforts in Niger.

Striga:

Collaborators: INRAN - H. Hassan, D. Laycock, J. Clark

INTSORMIL - Purdue - G. Ejeta, Dale Hess

A graduate student from Purdue, Dale Hess, is stationed at INRAN as a research associate in 1986, undertaking studies on various aspects of Striga. Mr. Hess is working on characterizing known Striga resistant

sorghum varieties for biochemical and morphological attributes. He also made intercrosses of these lines at Purdue. In Niger he is conducting studies on inheritance as well as some basic and applied studies that would contribute towards better understanding of the mechanisms of Striga resistance in sorghum.

An excellent Striga infestation was obtained by Hess at the Konni Station in 1986. Very significant differences between resistant and susceptible parents were observed in 1986 and extensive notes on number of plants in each plot were collected by Hess. The three resistant parents, SRN39, P967083, and IS9830 had substantially less Striga infestation than the susceptible local varieties, Bagoba, L-30, and Babadiafara. SRN39 had almost no Striga plants in an otherwise very heavily infested field. Prospects are extremely good for the Hess inheritance study of Striga resistance in 1987.

Economics:

Collaborators: INRAN - Lysamba, Maliki Kadi
INTSORMIL - J. Sanders, Akin Adesina
NCRP - R. Deuson, M. Krouse, B. Shapiro, C. Reddy

Akin Adesina's principal objective was the improvement of DECOR's technical capacity to conduct whole-farm modeling. The LINDO computer package purchased by INTSORMIL will facilitate the use of linear programming in DECOR's research beyond the present simple partial budget analysis of farm-trial results. In less than a month after Akin's departure, the junior economist at Maradi had already produced a whole-farm model.

INTSORMIL/NCRP Sorghum and Millet Research: Experiment Station and On-Farm Trials

Presently there is an INTSORMIL breeding emphasis in Niger on developing hybrid sorghums especially for the irrigated regions. There are two M.S. students, Tom Tyler and Issoufou Kapran (Nigerien), engaged in this research with Dr. John Axtell and Dr. Gebisa Ejeta. Since ICRISAT has been concentrating on non-hybrid cultivar improvement for dryland conditions, this INTSORMIL research fills a gap and is most relevant for the long run when West African countries are able to develop their own seed industries.

The concern with putting sorghum into irrigated regions results from the problems often encountered with alternative crops in the irrigation

projects. Rice is maintained by the Nigerien government at a price substantially above the world price. On the irrigation projects the parcels have been divided into very small units so the farmers also have their dryland areas. Barry Shapiro will be analyzing the allocation of labor between the irrigated and the dryland areas. Moreover, there have been some problems with the repeated cultivation of rice. Rice yields have been falling.

In AID the predominant interest was in finding higher-value crops. This interest extended from the Ambassador on down. This concern apparently stems principally from the extremely low price presently for millet, cited at 10 to 20 cfa/kg. The exchange rate is 332 cfa/dollar. There have been two reasonably good years for millet production in 1985 and 1986. 1985 was slightly below normal and 1986 was a good year. In 1985 there was minimal cowpea harvest for grain among traditional long-season cultivars, but in 1986 farmers were again able to harvest cowpeas for grain.

With the concentration on the irrigated zones for sorghum, it is important to remember that there are approximately 800,000 ha of sorghum produced in Niger as compared with 3 million ha. of millet. (For these area estimates see R. Deuson, Issa Mamene, and J. Clark, "Proposal to Test Sorghum Hybrids Under Irrigation," DECOR, INRAN, fall 1985, mimeo.) Sorghum is concentrated on the better soils in the dryland regions, the alluvial soils, and the heavier clay or loam soils. Sorghum is also found in very small parcels on many predominantly millet farms where it is found beneath the acacia ("gao") tree or in the recession from a water source.

On the heavier soils in Burkina Faso, crusting has often occurred, thereby reducing infiltration and increasing runoff. In these circumstances chemical fertilization becomes even riskier. One basic factor apparently explaining the success of the tied ridges in these heavier soils is the reduction of runoff associated with the crusting. The tied ridges - moderate chemical fertilizer - seem to be a relevant technology for much of the sorghum area, especially in the Maradi region. In some regions of Maradi with heavier soils, the farmers already make ridges between rows with the first weeding. It would be a simple modification to just tie or close these ridges. Then the riskiness of moderate chemical fertilization would be reduced and its profitability increased.

In 1986 tied ridges were utilized on the Kolo Station in agronomic trials and in some of the regular sorghum breeding there. They appear to have performed very well. For the 1987 on-farm trials in the Maradi region, tied ridges-moderate fertilization treatments with and without the new sorghum cultivars are being discussed. If sorghum productivity is increased where sorghum is already produced on the heavier soils, then it will not have to compete with the high-valued crops on the irrigation areas such as rice, wheat, and vegetables. Rice and wheat have high governmental price supports.

A more difficult research challenge will be to improve the agronomic environment on the various sandy or dune soils. One apparent advantage of these soils is that water infiltration is excellent. On these dune soils the principal crops are millet and cowpeas. It has been suggested that Niger may be the center of origin for millet. The local millets are able to germinate in extremely high soil temperatures. Most imported millet, especially the Indian cultivars, do very poorly at these high temperatures.

Water-use efficiency and yields have been shown to be substantially increased with fertilization alone on these sandy soils even in very low rainfall years such as 1984 (ICRISAT-Sahelian Center, Annual Rept. 1984, p. 42). DECOR in INRAN-Purdue has also been doing farm trials with intercropping of millet and cowpeas and fertilization on these dune soils. With the high infiltration of the soils and an improved organic-matter content from the rotation of millet and cowpeas, the probability of an economic return to chemical fertilization on the dune soils should be increased. DECOR has been doing partial budgeting analysis of the profitability of chemical fertilizer in various regions with the data from the on-farm trials. The ICRISAT Sahelian Center also has been doing research on ridging with animal traction on these sandy soils.

The ICRISAT research on fertilization of millet and with the ridging seems to be very promising and is being continued by the Sahelian Center. DECOR can take advantage of some of these ideas in its on-farm trials in 1987 in the dune areas.

Research Progress and Results:

Germplasm Enhancement - INTSORMIL has contributed significantly to the availability of sorghum germplasm in Niger. Many well adapted lines have been obtained primarily from the Texas A&M and Purdue programs.

Survey of Head bugs and Stemborers in Niger - Dr. Gary Steck and George Teetes surveyed head bugs in Niger in 1986. A regular schedule of sampling was undertaken in three major sorghum production areas (Maradi, Konni and Gaya) and at the Kollo Station. Taxonomic collections were made of all species of head bugs encountered. These will be used to verify identifications and establish a complete reference collection. Sampling also yielded detailed information on species composition, distributions, relative abundances and seasonal phenology. Youm and Gilstrap have an excellent stemborer study in progress in 1986 and 1987.

Drought Tolerance - Several lines selected by Gebisa in Sudan have proven to also be drought tolerant in Niger and will be useful germplasm sources for the INRAN breeding program.

Hybrid Sorghum - Hageen Dura-1 seems to be well adapted after two years. There is strong interest in this and other hybrids in Niger for utilization on irrigated farms. Several additional hybrids were tested at three locations in Niger during the off season and evaluated with Hageen Dura-1 in 1986.

Mutual Research Benefits

Drought tolerant lines identified in Sudan and Niger are now an integral part of the U.S. sorghum breeding programs at Texas A&M and Purdue. These were sources of drought tolerance which were previously unknown in the U.S.

Information gained on local processing of sorghum flour in Niger and Sudan are providing useful insights into the problem of lower digestibility of sorghum grain in U.S. feedlots.

Germplasm with tolerance to stemborers and head bugs is potentially valuable in the U.S. and in many other areas of the world.

Institution Building

Research Supplies

Laboratory supplies from INTSORMIL have been provided to the INRAN Cereal Quality Lab at Kollo.

Several boxes of scientific journals have been sent to the INRAN Library at Niamey.

A Toyota Land Cruiser and a Toyota Corolla Station Wagon were purchased in 1986 in time for harvest. Two motorcycles have also been purchased for transportation for INTSORMIL and INRAN collaborators.

Training Host Country Researchers

Mousa Adamou, INRAN Sorghum Breeder, began Ph.D. studies at Purdue in August 1986.

Two M.S. students from Purdue (Issoufou Kapran and Sharif Ari) will be conducting M.S. thesis research in Niger during 1986.

Mousa Oumarou spent several months at Purdue, Kansas and Texas A&M cereal quality labs. He is currently in charge of the INRAN Cereal Quality Lab in Kollo.

Mamadou Ouattara is studying Soil Science at Texas A&M University.

Host Country and U.S. Visits by Scientists:

Visits by Niger Scientists to the U.S.:

Mousa Oumarou - Cereal Quality Lab (1985)

S. Maigah - Attended INTSORMIL/ICRISAT Entomology Conference at Texas A&M and returned to Texas in August 1986.

Mamadou Ouattara - from INRAN Soils Lab to Purdue and Texas (1985).

Visits by U.S. Scientists to Niger:

John Axtell, Purdue/Sorghum Breeding

Gebisa Ejeta, Purdue/Sorghum Breeding

Tom Tyler, Purdue/Sorghum Breeding

Dale Hess, Purdue/*Striga*

John Sanders, Purdue/Economics

I. Kapran, Purdue/Sorghum Breeding

Sharif Ari, Purdue/Sorghum Breeding

Woods Thomas, INTSORMIL Board of Directors/Chairman

Glenn Johnson, External Evaluation Panel Member

Brhane Gebrekidan, External Evaluation Panel Member

John Yohe, Nebraska/Management Entity

George Teetes, Texas A&M/Entomology

Gary Steck, Texas A&M/Entomology

Osman Youm, Texas A&M/Entomology

Networking

In-Country - The major activity for disseminating research results within Niger has been the INTSORMIL/INRAN/NCRP Sorghum and Millet Workshop, which was planned during Year 6 and implemented during Year 7. The Workshop was very successful for the 45-50 participants who presented papers and took part in discussions. Additional research information exchange took place through INTSORMIL scientist visits to Niger. An EEP Review was successfully conducted in October 1986.

Regional - For the past two years key INRAN sorghum and millet researchers have participated in exchange visits with neighboring countries. In Year 5 INTSORMIL/INRAN scientists visited Burkina Faso to see the Purdue Farming Systems Research and the ICRISAT West African Research Program in Ouagadougou. In Year 6 a similar exchange visit was made with the ICRISAT/Mali/USAID Program in Bamako.

General Comments

The INTSORMIL/CRSP Program in Niger is developing nicely. Continual dialogue between INTSORMIL and INRAN scientists must continue over several years in the designated research areas. Joint research planning and joint nursery visits in both the host country and U.S. are essential. French language capability among INTSORMIL principal investigators must be improved. The joint workshop planned in Year 6 and implemented in Year 7 was extremely successful in lending a positive note to our collaborative research program in Niger. The excellent support of the USAID Mission, including participation by the Agricultural Development Officer, Mission Director, and Ambassador Bogosian was very important to the success of the Workshop.

PARAGUAY

Fred Miller

Texas A&M University

Project Personnel

Dr. Fred Miller, Sorghum Breeder, Department of Soil and Crop Sciences, Texas A&M University

Mrs. Anne Spelletich-Oddone, Research Associate, Department of Soil and Crop Sciences, Ministry of Agriculture, Asuncion, Paraguay

Collaborative Program

Institutions involved

Texas A&M University

Ministry of Agriculture, Asuncion, Hon. H. Bertoni, Ing. Luis Alvarez and Ms. Mercedes Alvarez, M.S.

Colonia Menno - (Mennonite - Central Chaco), Ing. Jacob Frisean and Ing. Willy Giesbrecht

Colonia Unidas, Ing. Ramon Ledy and Ing. Tomas Horn

Colonia Minga Guaza

Cooperative Coranel

Instituto Agropec. Carlos Pfanel

Instituto Interamericano de Cooperacion Para la Agricultura

Sempar S.A. Seed Co., Ing. Pedro Kirchhofer

Peace Corps de Paraguay

USAID Mission, Hon. Clyde Taylor, Ambassador, Mr. Paul Fritz and Mr. Oscar Carvallo

Paraguayan agriculture provides 45% of the total national employment, with 60% of the population living in rural sectors. Diversification of agricultural crops in Paraguay is of major concern and importance. In the country, maize and wheat are produced in areas of higher rainfall in the south and central regions. However, there are major areas within these regions where sorghum can be used to stabilize the production of grain and forage. In more northern areas of the Chaco, neither maize nor wheat is reliable. Sorghum offers the only plausible solution to the severe grain deficiency in this area.

Because of a high population growth (2.6-3.0%) and recognition of higher quality food, more and more grain and forage is being produced in Paraguay for livestock utilization either to finish beef for market, or to

complement maize when fed to swine and poultry. Since wheat and maize are used in the food chain directly there is little of these cereals available for animal use. Because of its wide array of uses, sorghum offers Paraguayan consumers a supplement to wheat and maize directly as human food, and indirectly through animal products.

Sorghum has been produced in Paraguay on a limited basis. However, research and transfer of technology to farmers/ranchers has been limited. Because of the present high level of interest, it became evident that USAID could take this interest and multiply its existence into a major grain and forage commodity to significantly stabilize Paraguayan agriculture.

The major constraint to growth and rapid expansion of the sorghum industry in Paraguay was the availability of high quality hybrid planting seeds at an affordable price, and at the appropriate time for planting. By developing a hybrid seed industry and the necessary associated research base in Paraguay, these constraints would be overcome, and the benefits of expanded diversification in the cereal grains would lend stability to agricultural production.

Memorandum of Agreement

A Memorandum of Agreement to allow collaborative research, transfer of funds, and joint technical and scientific activities was signed in Asuncion, Paraguay on September 27, 1985. The fully signed agreement was implemented on October 25, 1985. The 1985-1986 work plan and associated budget was presented September 1, 1985, and accompanied the MOA. The United States Agency for International Development (USAID) Mission in Paraguay had commissioned a $25,000 contract to "buy-in" to INTSORMIL to provide leadership in this collaborative research effort. Mr. Paul Fritz and Mr. Oscar Carvallo were the forward thinking individuals with USAID who got this program moving.

Other Problems and Opportunities

The Paraguay INTSORMIL program has evolved over the past 2.5 years, following initial contracts by the USAID Mission for Technical Assistance. Dr. Fred Miller went to Paraguay on three occasions to provide that technical assistance. During these visits, at the request of the Mission and Ministry of Agriculture, a collaborative program was developed with these entities and INTSORMIL. Dr. Miller worked closely with the Mission

and, subsequently, the Mission obtained approval for a $25,000 contract grant to INTSORMIL.

Following appropriate guidelines, Texas A&M University hired Mrs. Anne Spelletich-Oddone, as of September 1, 1985, as sorghum breeder in Paraguay. She was assigned to carry out the mutually agreed Plan of Work with Ms. Mercedes Alvarez, the Paraguayan Sorghum Research leader.

Few problems have occurred in the operation of this project, after establishment of the general procedures. Supplies for research are very difficult to obtain, but the INTSORMIL breeder in Paraguay is very imaginative. The USAID Mission has been extremely helpful and supportive. They are hereby recognized for their outstanding support.

In Paraguay, as in similar countries, there is a need to produce concentrated energy for operation of machinery and to reduce dependence on imported fossil fuels. Technology exists to convert sugars from certain types of sorghum stems into alcohol. Brazil has implemented this technology. The INTSORMIL scientist in Paraguay is working with the Ministry of Agriculture to obtain additional funds for developing this technology in Paraguay.

Sorghum Constraints Researched

The goal of this program is to develop the production of sorghum in Paraguay to a level of adequacy for human food, animal grazing, and dry season survival, and as a response to expanded production of poultry, swine and finished livestock through private enterprise.

To accomplish this goal for Paraguay it is important to utilize the interest which exists in sorghum to alleviate the critical grain and forage deficiencies. This can be accomplished by short term introduction of existing technology from the INTSORMIL program and blending with local expertise and culture. In the longer term it will be necessary to train technicians and professionals in sorghum culture and utilization and to assist in the development of a hybrid seed industry to supply adapted productive hybrid seeds to producers in the country.

A strong interaction between the public and private sectors must be built to insure the adoption of the technology of production and utilization. In order that we establish a reasonable program, the following objectives are outlined.

Objectives

Identify and characterize the potential sale of sorghum in Paraguay agriculture.

Strengthen and assist the national research in sorghum through collaborative research sponsorship through association with the INTSORMIL-CRSP.

Develop to a maximum the involvement of private producers who have expressed interest in sorghum such as:

Association of Sorghum Producers

Association de Rurale

Mennonites at Filadelfia, Loma Plata, Leguna Capitan, and others in various regions.

Instituto Interamericano de Crebito para Agriculture in Paraguay

Various Agricultural Schools, such as:

Instituto Agropecuaria Carlos Pfanel - Coronel Oviedo

Halvetes Agri. Mech. School (Switzerland) - Valenzuela

Cooperatives especially:

Minga Guazu - Coranel

Colonia Unidas

Research Progress and Results

During 1985-1986, 13 trials or tests were planted throughout Paraguay at nine major research locations. Numerous results have been obtained which indicate that tropically adapted (TA) sorghums work very well in the country. Only the following limited discussion is chosen to demonstrate impact.

In the central part of Paraguay, south of Asuncion, Credit Agricola works closely with small holding farmers. This area was chosen because of former Peace Corps involvement. We put in comparison trials of local maize and the white food sorghum "Dorado". The maize yield was 900 kg ha^{-1}, and Dorado yielded 3800 kg ha^{-1}. Cooperators were impressed with the yield of grain and also the yield of green fodder for livestock consumption. The Extension Service was given recipes for sorghum food products to distribute. Plans were made to expand the area of involvement during 1986-1987. Approximately two tons of seed of the variety Dorado were stored for distribution to cooperators.

Servicio Agropecuario Chaco Central (Mennonite Colony) at Filadelfia has demonstrated the ability for sorghum to grow and produce economic returns under severe stress. They have identified two sorghums, VG 146 (Sureño) and ATx631 x RTx435, as materials possessing excellent quality in bread and cookie production. They are expanding their use and testing of sorghum to include evaluation in food products in the local hotel. The Mennonites have progressed well in their ability to produce hybrid seed of forages. Following two years of experience and successes they have officially named two forage sorghum hybrids. 1) ATx623 x Greenleaf Sudangrass = "Fredi" and 2) ATx623 x Local Hegari = "Chaci". The Mennonites will continue to develop their experience in the production of forage sorghum hybrids. They also collaborate in the food from sorghum experiments, evaluation of grain hybrids, and monitoring of diseases and insects. We will move into evaluation of basic agronomic practices to maximize productivity in the near future.

Basic breeding materials have been provided to the Ministry of Agriculture and are being placed into an improvement system with Ms. Alvarez, but backstopped by Mrs. Oddone.

Research Benefits

The identification of sorghums with wide adaptation, drought resistance, and food quality traits in Paraguay will increase the efficiency by which we can identify and use these materials in the U.S. The identification of sorghum grain characteristics which affect food properties and their impact on utilization in Paraguay and the U.S. will allow plant breeders and cereal chemists in both countries to select superior types for particular uses.

Institution Building

During 1985-1986, INTSORMIL funded research and support in Paraguay for $25,000.

INTSORMIL scientist, Dr. Fred Miller was in Paraguay September 20-28, 1985; February 20-March 5, 1986 and May 19-24, 1986.

A complete set of Crop Science Journals and Agronomy Journals from 1960 to the present were provided to the Research Center - Ministry of Agriculture, Caccupe.

Networking

Collaborating scientist Ms. Mercedes Alvarez has traveled to Brazil, Argentina, and Uruguay to participate in meetings to discuss sorghum production and research in Paraguay. In addition, Mrs. Anne Spelletich-Oddone accompanied Ms. Alvarez to Argentina to visit Morgan Seed Company's sorghum winter nursery site near Formosa. They discussed sorghum diseases, production practices and the availability of planting seeds.

General Comments

Perhaps the most important aspect of a program such as this is student training. At this time we have not identified a student(s) for further training. However, we have some potentials. The next best things have been implemented. Two technical support staff have been identified, and will go to Texas for two months of intensive sorghum training. This training will be placed on the potentials of sorghum for Paraguay and how sorghum must fit into a "system" of production - and on the mechanics of F_1 hybrid seed production. Such training will have direct impact on the major current limitation to sorghum's growth in the country, i.e., the availability of quality planting seeds.

Paraguay is a part of the South American Ecogeographic Zone, and results obtained in the country are transferable to Brazil and probably Colombia, but certainly into other nearby countries. The diseases and soil stresses as well as drought patterns are similar throughout the Ecogeographic Zone.

PHILIPPINES

Jerry W. Maranville

University of Nebraska

Principal Investigators (NU-121)

Dr. Lydia Oliva, Dean Graduate School and Head Department of Agricultural Economics, SMARC/USM.

Dr. D.A. del Rosario, Crop Physiologist, IPB/UPLB

Ms. Fabiola Alejandro, Sorghum Breeder, SMARC/USM

Dr. Jerry W. Maranville, Professor of Agronomy, University of Nebraska

Other Researchers

Dr. Pablito Pamplona, Professor of Agronomy and Deputy Director SMARC/USM

Dr. Dely Gapasin, Director, Division of Crops Research, PCARRD - Los Banos

Dr. Dale G. Anderson, Professor of Agricultural Economics, University of Nebraska

Dr. George Pfeiffer, Assistant Professor of Agricultural Economics, University of Nebraska

Collaborative Program

Institutions Involved

Collaborating Host Country: PCARRD, Formal agreement; IPB, Los Banos; SMARC/USM, Kabacan

U.S.: Department of Agronomy, University of Nebraska

Although sorghum is not produced extensively in the Philippines, it has potential to stabilize the feed grain production in that country since it is generally more stress tolerant than corn. The current varieties are of a feed rather than a food type and therefore offer no alternative food source such as corn might do when food supply is low. The support price for corn is also somewhat higher than for the type of sorghum currently being grown, making it economically less attractive to produce. Collaborative INTSORMIL/ Philippine research in 1985 discovered that a new variety released in Honduras through the INTSORMIL program there could substantially outyield local types in the Philippines under proper management. This variety, VG 146, also has the advantage of being a food type with good popping characteristics which enhances the desirability for utilization. It is

taller than most producers would like, however, and most likely should be shortened before it will be widely accepted.

Experiments on sorghum production following lowland rice showed that 5 to 10 days after rice harvest was the best time to plant sorghum. Germination is highest if seeds are planted 3 to 5 cm deep. It was also shown that early maturing sorghums are best fitted to the post-rice condition. Under the best conditions, sorghum yields were as high as 2.9 t/ha.

Linkages:

Informal working arrangements with IRRI. Projects NU-113, NU-114, NU-115, NU-117, TAM-121 and PRF-104B have made contributions to the research.

Ecogeographic Zones Benefited Most by Research

Asian subcontinent.

Objectives, Constraints and Research Procedures

Objectives

Investigate the potential of sorghum production following rice.

Test new selections of sorghum for yield potential in upland production.

Conduct "on-farm" trials to demonstrate the correct production practices for maximizing sorghum yields in Mindanao.

Constraints

The primary constraint to sorghum use in the Philippines may be more related to the ability to market the crop profitably than the ability to grow it. However, if yields were to improve markedly through the use of new varieties and sound agronomic practices, the low price usually received for sorghum in comparison to corn would perhaps be offset sufficiently to make the commodity more attractive to farmers. The current local variety is thought to contain some tannin/although the imported hybrids in use do not. This belief of the presence of tannin is a constraint to feed millers although INTSORMIL-linked research has shown this is not a factor in feeding efficiency, and that indeed, tannins should not be a major concern for the sorghums now in production.

Research Procedures

Sorghums for rice paddies. This research has been largely of a physiological nature and conducted at IPB. Studies on resistance to drought or flooding are being conducted in the greenhouse. Some varietal screening is being made in rice paddy conditions in the field. Studies on tolerance to acidic soils are also underway at IPB.

Varietal screening of upland production. INTSORMIL scientists from Texas A&M and Nebraska continue to furnish the bulk of the material coming to SMARC for yield testing. Some material is also made available from ICRISAT and the IPB sorghum breeding program.

On-farm demonstration trials. This is coupled to the economics project NU-117. Trials consist of several treatments including varieties, pest control procedures, and fertilizers. These serve not only as research trials, but as an extension component for the area to demonstrate sorghum use. Economic data are gathered and evaluated relative to production on these trials to complement the agronomic data.

Problems Regarding Achievement of Objectives

The research is financed largely by INTSORMIL funds. The procedure to make these funds available to the researchers in a timely fashion is often complicated and slow. Getting the necessary documents prepared and signed by all parties is a constraint to making the research funds available to the Philippine scientists.

Project Output

Research Findings for Immediate Use

The most important output from the INTSORMIL funded research was identification of variety VG 146 which is showing promise as a potential yield improving type for either feed or food use. Trials in 1985 showed the variety outproduced the local type by as much as 43% which made it economically better than corn even though the sorghum market price was lower. Variety VG 146 is the same variety as Sureño, a dual purpose grain/forage cultivar just released in Honduras and recommended for 10%-20% of the country's total acreage. In addition, VG 146 is gaining popularity as a specialty crop because it can be "popped" and consumed as food, a practice not common for sorghum in the Philippines. Since this is a variety

practice not common for sorghum in the Philippines. Since this is a variety rather than a hybrid, seed production will be relatively simple and the cost should be minimal and affordable by most farmers in the region.

The "on-farm" demonstration/research trials have been a continual source of information on production techniques to the local farmers. During the January-April 1985 cycle, three fertilizer levels were shown to be economically feasible. However, there was a strong interaction between fertilizer level and growing cycle as the March-June cycle did not require fertilizer levels similar to those of the early cycle. This was thought to be due to the dry condition of the soil during the latter cycle.

Experiments on sorghum production following lowland rice showed that 5 to 10 days after rice harvest was the best time to plant sorghum. Germination is highest if seeds are planted 3 to 5 cm deep. It was also shown that early maturing sorghums are best fitted to the post-rice condition. Under the best conditions, sorghum yields were as high as 2.9 t/ha.

Research Progress for Future Use

Varieties are in a continued phase of selection at SMARC and IPB. With the apparent acceptance of VG 146 type sorghum, an array of genotypes with similar characteristics will be made available from NU-115 for testing at both SMARC and IPB. Farmers would prefer a shorter type if it could be found. VG 146 may need to be shortened through breeding.

Networking Activities

- Research Investigator Exchanges

Drs. Anderson, Maranville, and Pfeiffer traveled to Los Banos and Cotabato for discussions and collaboration during May and early June of 1985.

- Germplasm Exchange

Projects NU-115 and TAM-121 continue to send germplasm to SMARC for testing.

Travel

- Chicago, Illinois. October 2-3, 1985 to participate in INTSORMIL TC meeting.
- Kansas City, Missouri. January 13-15, 1986 for TC meeting.

- Kansas City, Missouri. March 18-19, 1986 for TC meeting.
- Manila, Kabacan, and Los Banos, Philippines. May 12-21 for collaboration with Philippine researchers and other participants on agronomic and economic issues in sorghum production. Primary persons were Drs. Lydia Oliva, D.A. del Rosario, and Artemio Salazar (new sorghum breeder).

Publications and Presentations

Publications

Anderson, D.G., J.W. Maranville and G. Pfeiffer. Trip Report, INTSORMIL Philippines. May 9-June 6, 1986. 11 pp.

Presentations

No formal presentations. Informal presentations were made to persons at PCARRD, USM, SMARC, USAID, IRRI, UPLB, and IPB.

Changes in Year 8

None. This will be the last year of Project NU-121.

SENEGAL

David J. Andrews
University of Nebraska

Collaborative Program

Senegal is primarily a pearl millet growing country--the sorghum crop is about 1/3 in comparison. Yields of both crops are low and landrace or modified landrace varieties are used; yields are also restricted because of low fertility and limited and untimely cultivation practices, pest and diseases and sometimes moisture shortages. Millet food products are made in the traditional time consuming way and are becoming disadvantaged in comparison with rice and imported wheat flour.

Memorandum of Agreement

MOA has been negotiated with ISRA to cover collaboration on millet breeding and physiology. A separate MOA was negotiated with ITA to cover collaboration on millet food quality research.

Millet Constraints Researched

Research Progress

The basis for collaborative research in millet food quality has been drafted. New products seem possible. Establishment of quality standards can assist in breeding new varieties. Varieties sent from Hays, Kansas (KSU-101) and Lincoln, Nebraska (NU-118) performed well in comparison to local varieties in tests conducted by ISRA in the northerly drought prone area of Senegal. Such varieties can be further adapted by reselection.

Mutual Research Benefits

Food quality research can be of potential application in food or feed uses of millet in the U.S. Variety testing helps validate varieties for potential use elsewhere, especially for drought response.

Institution Building

A dehuller is being shipped to Dr. Ababacar N'Doye, ITA, Dakar.

Mr. A. Fofana is now millet breeder in ISRA, Senegal, having received his M.S. at Nebraska. Collaborative breeding is planned with him.

Dr. Ababacar N'Doye, cereal scientist, ITA, Dakar, visited the University of Nebraska for six weeks to initiate collaborative food quality work. Dr. Mbaye N'Doye, head of crop production research, CNRA, Bambey,

visited the University of Nebraska in March to discuss crop breeding research.

Dr. Chuck Walker and Janet Buck visited ITA, Dakar in November 1985 to determine possibilities for collaborative food quality research and to understand the state and direction of existing research.

Networking

Food quality research has widespread potential throughout West Africa and elsewhere where there are similar needs for new products. Variety evaluation has relevance to similar ecological low disease zones with very low rainfalls in Africa. INTSORMIL scientist workshops and existing regional networks can be used to disseminate established results.

General Comments

Variety testing can be expanded and can include some types of hybrids. Some consulting could be done on ongoing breeding projects. Senegalese breeding germplasm is of potential use in KSU-101 and NU-118 projects. NU-121 can assist in variety choice and breeding decisions in NU-118.

Varieties from northern Niger are known to be suitable in Senegal. Variety organoleptic research in Mali is complementary to food product work in Senegal.

SUDAN

Allen W. Kirleis
Purdue University

Collaborative Program

Production and Utilization Constraints

Moisture stress is the most important constraint to sorghum/millet production in Sudan. Methodologies for screening sorghum germplasm for drought tolerance are also lacking. Breeding efforts to incorporate drought tolerance with higher than average yield potential are limited by lack of a rapid field screening procedure as well as lack of knowledge of sources of sorghum germplasm possessing useful traits.

Other factors that reduce sorghum/millet yields in Sudan include insect pests, diseases, and *Striga*. Insects pests that are known to attack sorghum especially in the rainfed areas of Sudan include stemborers, American bollworm, and central shootfly. The major fungal diseases on sorghum/millet in Sudan include anthracnose, charcoal rot, long smut, and grain mold. *Striga*, a parasitic weed of sorghum in Sudan, constitutes a major constraint to sorghum production. There is very little sorghum germplasm with resistance to *Striga* and the mechanism that renders resistance to *Striga* is unknown. Knowledge of inheritance of this trait is also lacking.

One of the major factors limiting the utilization of sorghum and millet in Sudan is the fact that the high yielding varieties lack food quality acceptable to the consumer. Work is needed to develop a better definition of sorghum and millet food quality so that a rapid test can be developed for screening breeders' lines.

Institutions Involved

Host Country

Agricultural Research Corporation (ARC)

- Gezira Research Station
- El Obeid Research Station
- Kadugli Research Station
- Food Research Centre, Shambat

Sudan National Seed Administration

Regional Ministry of Agriculture and Natural Resources, Kordofan Region

ICRISAT/Sudan

Western Sudan Agricultural Research Project (WSARP)

University of Khartoum/Faculty of Agriculture
USAID Mission/Khartoum

U.S.
Kansas State University
Purdue University
Texas A&M University
University of Nebraska

Memorandum of Agreement

Agricultural Research Corporation of the the Democratic Republic of Sudan (ARC) and INTSORMIL.

Collaborators Involved

Cooperative Breeding and Genetic Evaluation of Sorghum. Scientists: Abdel Latif M. Nour/Osman Elobeid Ibrahim (ARC). Rosenow/Ejeta (INTSORMIL).

Physiological and Agronomical Research on Sorghum. Scientists: Saeed M. Farah (ARC). Eastin (INTSORMIL).

Sorghum/Diseases/Plant Pathology Research. Scientists: El Hilu Omer (ARC). Frederiksen (INTSORMIL).

Striga/Weed Control in Sorghum. Scientists: A.M. Hamdoum/A.G.T. Babikar (ARC). Ejeta (INTSORMIL).

Evaluation of Sorghum and Millet Food Products. Scientists: S.M. Badi (ARC). Kirleis (INTSORMIL).

Library Improvement.

Plant Pathology Student Training. Scientists: Mohamed El Fatih K. Ali (ARC Student). Warren (INTSORMIL, Major Professor).

Western Sudan Agricultural Research Project (WSARP) and INTSORMIL.

INTSORMIL Agronomic Work at Kadugli Research Station. INTSORMIL Agronomist Tareke Berhe.

Dr. El Hilu Omer, ARC plant pathologist, has been named as the ARC's coordinator for INTSORMIL activities. Dr. Omer's appointment has facilitated better program coordination between ARC and INTSORMIL.

Development of a Five-Year Sorghum/Millet Research Plan for Sudan

At the request of the USAID Mission Khartoum and the Agricultural Research Corporation (ARC), INTSORMIL scientists (Ejeta, Kirleis, and Rosenow) were asked to assist in developing a five-year plan for sorghum and millet research in Sudan. The first draft of the document was written in November 1985. The USAID Mission is hopeful that the five-year research plan will foster additional cooperative sorghum/millet work between ARC and INTSORMIL scientists and strengthen ARC's sorghum/millet research capability. The USAID/Khartoum Mission has agreed to help ARC obtain funding to support the research program.

Problems with Collaboration in 1985/86

Political unrest in Sudan in early 1986 prevented U.S. scientist travel to Sudan. This made ARC/INTSORMIL collaboration difficult during the 1986 crop season and caused the postponement of the Sudan/INTSORMIL Workshop planned for the Fall of 1986.

Sorghum/Millet Constraints Researched

Hybrid Seed Industry Development

INTSORMIL has had a continual involvement in the efforts of the Government of Sudan in expanding research on sorghum hybrids as well as in promoting a wide use of hybrid sorghum varieties by farmers in Sudan.

INTSORMIL sorghum breeders have been directly involved in devising breeding strategies with ARC scientists, in providing essential germplasm, and in assisting in the evaluation of sorghum breeding nurseries. INTSORMIL has also collaborated with the Sudan National Seed Administration and has provided essential technical assistance in the hybrid seed production efforts. Technical assistance provided through INTSORMIL has facilitated the hybrid seed production activity. INTSORMIL PI's and ME staff working closely with the USAID mission in Khartoum and the Government of Sudan provided the necessary momentum towards the establishment of an infant seed industry in Sudan.

Research Results from Kadugli, South Kordofan

In both on-station and on-farm trials, Ugandi millet was the earliest and highest yielder. It flowered in 45 days and matured in 70 days.

Average yields for Ugandi were 251 Kg/Ha in on-station and 569 Kg/Ha in on-farm trials. Multiplication and distribution of Ugandi should be encouraged.

Of all sorghum genotypes tested, Hageen Dura-1 was the highest yielder with a yield of 544.3 Kg/Ha and 1805 Kg/Ha for on-station and on-farm trials, respectively. The drought tolerant and early genotypes, SRN-39 (also Striga tolerant), IS-9830 (also Striga tolerant), and P898012 continue to be well adapted to the area. WSARP should consider releasing P898012 and SRN-39.

In screening for drought tolerance studies in sorghum, the following entries were found promising:

From KSU/Sudan INTSORMIL Project germplasm: Zinnaji Hirehree, Najaad Abyad, Sojib, Sodiri 1 and Sodiri 3. These five early entries yielded over 5,000 Kg/Ha.

From Dr. Jerry Eastin's (University of Nebraska) material - entries 820194, 842654, 3-17832, and 830212. The potential of these entries needs further study.

Very limited beneficial effects were observed both on sorghum and millet by the application of nitrogen in the form of urea. It is believed that the lack of response was mainly due to low rainfall and insufficient moisture regimes in the soil. Only one genotype of sorghum, IS-9830, showed good yield response to 20 and 40 Kg/Ha N applications. Continuation of fertilizer studies is not recommended for North Kordofan. The undeperdability of rainfall makes fertilizer use impractical. Work should concentrate more on the incorporation of legumes in the cropping system. N fertilizer may play a role in South Kordofan when proper time of application is used.

Intercropping trials of sorghum and millet with groundnuts showed very encouraging results in favor of intercropping. The cereals performed much better in the intercrop.

In seedling establishment studies, it was found that: pre-soaking of seeds in water for 12 hours prior to planting had no advantage over dry sowing in millet but improved seedling establishment and grain yield in sorghum, and, large seeds established better than small seeds at 9 and 12 cms depths resulting in higher grain yields. Thus, production of good quality seed should be given high priority.

All the local germplasm of cowpeas (late types) failed to flower because of drought. Only four early introductions from IITA produced yields ranging from 59 to 145 gms/20 m^2 plot. In contrast, two tepary bean entries (courtesy of Dr. Dermot Coyne, University of Nebraska) produced 296 and 339 grams.

All of the above legumes needed 65-70 days from planting to harvest. The need for selecting very early cowpea genotypes is therefore obvious.

Mutual Research Benefits to Sudan and U.S.

An effective mechanism has been developed for germplasm exchange with cooperators in Sudan. The type and extent of germplasm introductions to Sudan from INTSORMIL is decided by either specific requests from the Sudanese collaborators or based on preliminary evaluation of small sets of nurseries introduced the previous season. Such an approach has been found to be satisfactory and workable and has resulted in the introduction of improved high yielding breeding lines to Sudan. The germplasm introduced in Sudan by INTSORMIL today constitutes a significant part of the core breeding material used in the ARC sorghum breeding program. Likewise, useful local sorghums from Sudan having unique characteristics have been introduced for use in U.S. breeding programs.

Cooperative ARC/INTSORMIL crop physiology and breeding work on drought tolerance of sorghum has led to a better understanding of crop adaptation to stress. Through the work of pooled evaluations of sorghum identified as drought tolerants both in U.S. and Sudan, the range of adaptation of various sorghum types is better defined.

Work on the food quality of sorghum by ARC/INTSORMIL has shown that a fermentation process, commonly used to prepare most Sudanese sorghum foods, improved the protein digestibility of cooked sorghum products. This work has led to a better understanding of the factors that influence sorghum protein digestibility and work is now in progress to apply this new knowledge to improve the digestibility of sorghum when used as an animal feed in the U.S.

Institution Building

Research equipment valued at $23,000 to support ARC/INTSORMIL cooperative sorghum research work was purchased and will be shipped to Sudan in the Fall of 1985. Reference books valued at $1,012 have been provided to

the ARC library to support sorghum/millet research in the disciplinary areas of sorghum breeding and genetics, sorghum pathology, sorghum physiology, weed science and cereal chemistry. An INTSORMIL Agronomist was stationed at Kadugli for five months (July 1, 1985 to December 1, 1985).

Osman Elobeid Ibrahim received a Ph.D. degree in plant breeding under the direction of John Axtell (Purdue University) in May 1984. He returned to the Sudan in July 1984 and has been working at the Gezira Research Station, ARC, as a sorghum breeder since that time. Ibrahim's breeding efforts are concentrated on breeding for drought tolerance, insect resistance, and improved grain yield and food quality. During the 1985 crop season Ibrahim cooperated with several INTSORMIL scientists (Ejeta, Kirleis, and Rosenow).

ARC Scientist Travel to U.S.

October 1-29, 1985. Abdel Latif M. Nour, ARC Sorghum Breeder. Observed INTSORMIL sorghum breeding programs at Texas A&M (College Station and Lubbock), Nebraska, and Purdue Universities. Attended the INTSORMIL Workshop "Sorghum Seed Production in Latin America: Problems and Solutions," in Mexico City.

July 10-17, 1985. Saeed M. Farah, ARC Plant Physiologist. Observed INTSORMIL plant physiology program at the University of Nebraska.

INTSORMIL Scientist Travel to Sudan

October 29-November 11, 1985. Gebisa Ejeta, Allen Kirleis, and Darrell Rosenow. Assist ARC in developing a five year sorghum and millet research plan for Sudan. Evaluate INTSORMIL/ARC cooperative sorghum nurseries in Wad Medani.

July 1, 1985-December 1, 1985. Tareke Berhe. Conducted agronomic research on sorghum/millet in Kadugli, South Kordofan.

Networking

A significant networking activity involving information exchange is developing through efforts of the INTSORMIL project and its collaborators in Sudan and other parts of Africa. Using information accumulated on germplasm and environmental data from INTSORMIL collaborative efforts in Sudan, varieties and hybrids that show potential in Sudan are suggested for testing in similar environments in Africa. Research methodologies (on drought

tolerance for example) as well as new findings are also shared across countries and zones.

Farming systems research efforts used by WSARP in the El Obeid area were largely based on baseline data provided by the INTSORMIL socioeconomic research team. In addition, the INTSORMIL agronomist Tareke Berhe stationed in El Obeid initiated an active on-farm research program and provided the necessary leadership for similar efforts by the WSARP farming systems research team.

General Comments

Recommendations for improving collaborative research in Sudan.

To help facilitate better program coordination between ARC and INTSORMIL the following is recommended.

An annual research review and planning session between ARC and INTSORMIL is suggested. It is hoped that this will create a proper forum for sorghum and millet research scientists in Sudan to address key issues, review research results and plan new ones on a yearly basis.

Efficient ARC/INTSORMIL program coordination requires a good communication system. As all telex messages must now go through the USAID Mission in Khartoum, it is suggested that a modest investment be made to install a telex service at Wad Medani, and perhaps a radio communication connecting other major ARC stations.

Sudan's relation to ecogeographic zone.

Grain sorghum and pearl millet are the most important cereal crops in the Sudan. Sorghum makes up about 80% of the total. These crops are grown under both rainfed and irrigated conditions. Sudan is a vast country having a diversity of ecological zones with varying climates. Accordingly, the breeding, physiology, and agronomic work done in Sudan is relevant to the entire Eastern African Zone.

Most sorghum foods consumed by the Sudanese are made from a fermented batter. As many other countries in the region consume fermented type foods, the food quality work done on local Sudanese sorghum food can be useful to other countries in the region.

TANZANIA

Frederick R. Miller
Texas A&M University

Collaborative Program

Institutions

Tanzania - TARO (Tanzanian Agricultural Research Organization)

U.S. - Texas A&M University

Memorandum of Agreement

A Memorandum of Agreement between TARO and INTSORMIL was signed in September of 1982, and remains in force to date. The nature of the cooperation and collaboration was outlined as follows:

To bring together colleagues from all disciplines relating to sorghum and millet production, milling, transport, and consumption, and establish research priorities.

To bring together East African sorghum and millet workers through workshops or intercountry travel to encourage increased cooperation and exchange of materials and ideas.

To act as a facilitator in establishing INTSORMIL and East African sorghum/millet workers as collaborative teams.

To establish a strong sorghum breeding program in Tanzania, and develop germplasm appropriate to small farmers in the region.

Other Problems and Opportunities

Because of reduced funding and other problems associated with implementation much reduced involvement has taken place with Tanzania. Much of the germplasm which was originally introduced by INTSORMIL from Texas A&M University has been continuously grown with exceptional results. Mr. Hamis Saadan, coordinator and sorghum breeder, has recently returned to Texas A&M University to work toward a Ph.D. under SADCC funding.

With INTSORMIL activity in Kenya developing, it is hoped that much of the original work initiated in Tanzania will be resurrected. Excellent relationships remain with the sorghum/millet scientists in the program.

Sorghum/Millet Constraints Researched

Constraints

The constraints to sorghum and millet production in Tanzania are very similar to those in neighboring countries such as Kenya. Tanzania has begun

encouraging farmers to grow sorghum and millet, probably to the detriment of long term acceptance of these crops, as few suitable cultivars are available. The impression of sorghum (especially) as a "backwards" crop does exist, and many people in the country still go hungry with maize failures when either sorghum or millet would have provided good crops. In addition, the country suffers from a lack of good improved types, and work is urgently needed on breeding well-adapted, stable cultivars with good food quality. The bird resistance/poor food quality complex is a problem, even in those areas where brown sorghums are traditionally grown. In addition, much of the available "exotic" sorghum germplasm has poor drought tolerance because of its origins in the old Serere program.

Research and Constraints

Research initiated by INTSORMIL in Tanzania has been carried forward there by Mr. Hamis Saadan, although on a much smaller scale, reflecting the limited resources available to his program and the time available to do the work. Part of John Mann's work in Texas this past year has also been directed towards the problems in Kenya, which will apply directly to Tanzania. His work on synthetic varieties and food type will be useful there as well as in many other areas in East Africa. It is hoped that in the next several years, direct involvement in Tanzania will resume.

Research Progress and Results

Major activities of sorghum/millet were limited to breeding and agronomic investigations. Intercropping of sorghum, millet, and legumes at different spacings, and plant distributions were undertaken. A number of germplasm introductions from ICRISAT and INTSORMIL were evaluated for resistance to insects, particularly the stemborers, midge, and shootfly. As resistance is identified, these sources are crossed to local sorghums to transfer the resistance. Very little more was done with millet, except to maintain the germplasm.

The sorghum materials planted in 1985 consisted of selections from local sorghums and from INTSORMIL - Texas A&M. Materials from Texas A&M University in the previous season appeared to show symptoms of MDMV, but when samples were examined by Sokoine University, no virus was found, only bacteria. In 1985, we grew many selections from S_3, S_4, F_3, NaOH, A/B, R-line, TP24, TP15, etc., amounting to about 3000 lines. Many of these

materials have tremendous yield potential. Selections were made for preliminary trials in 1986, which will be at Ilonga, Homabolo, and Ukirigura. Most of these Texas A&M University materials looked so impressive in agronomic characteristics and yield potential, that very quick evaluation will lead to the release and distribution of varieties. Only site specific or genotype x environment identifications need to be made before release of new superior varieties.

The strategy of the National program, which is emerging, is summarized below.

Intercrossing within guineas. West Africa guineas were introduced and crossed with local selections (approximately 100 hand emasculations were made).

Crossing exotics to local cultivars. Previous experiences of crossing introduced lines x local have been disappointing, resulting in reduced yield, adaptation, and general loss of vigor. A program of backcrossing and three-way crossing has been initiated to attempt to pull yield genes and local adaptation back together.

Direct use of exotic materials. Based upon the success of the Texas A&M University materials in the program, we are expanding the activities to introduce similar materials directly from different institutions, and evaluate for possible considered release to farmers, if acceptable grain quality can be found in the materials.

In one other project, which merits mention, there is the considered potential for hybrids. Hybrids have not previously been employed outside experimental farms. In 1985, the brewing industry requested information on how to increase grain yield. In this industry the specific grain quality is not so critical, as with food sorghums, but more important is yield of non-brown grain in the brewing of opaque beer. ATx623 x CS3541 was chosen for initial use. The problem now will be how to produce enough seed of the hybrid, and get it to farmers who supply the brewery. This use of this hybrid may be a key to moving more hybrids into the economy.

Institution Building

During 1985-1986, there was very little activity with Tanzania. A small amount of supplies was sent to Mr. Hamis Saadan to keep him

functioning. Yield trials and breeding materials as well as a limited number of inbred parental lines were sent to the program.

Training was taken on by SADCC, and as a result Mr. Saadan returned to Texas A&M University to work toward the Ph.D. degree. Dr. Robert Mushi has completed a Ph.D. degree in sorghum breeding at the University of Nebraska and will soon be returning to Tanzania. Mr. Emanuel Monyo, a Ph.D. candidate in sorghum breeding at Purdue University will finish his degree in December 1987 and return to Tanzania to work on the sorghum program. The capabilities of these newly trained scientists will be a significant contribution to overall capabilities of TARO to carry our research in sorghum breeding.

General Comments

Collaborative research is a program built upon individual scientist interactions. Even though there was an unfortunate reduction of activities in Tanzania, there has been continuing scientist to scientist interaction. This will continue. With the opportunities developing in Sudan, the potential exists for more involvement in Tanzania.

Training

INTSORMIL gives high priority to training host country scientists who will have major responsibilities for sorghum and millet research in their home countries. Training is also provided for young U.S. scientists who plan for careers in overseas development work.

The most frequently used training system is graduate study for advanced degrees, with the students' research forming an integral part of an INTSORMIL project, or being very closely related to it.

During the year covered by this report, 127 students (82 international and 45 U.S.) were advised by INTSORMIL principal investigators. Thirty-six of the students were female and 91 male. Students funded by INTSORMIL totaled 71 (52 international and 19 U.S.). Fifty-six other students funded from other sources but working on INTSORMIL projects received varying amounts of research support. The international students came from 31 different countries.

INTSORMIL is also cooperating with ICRISAT on a 10 year special training program aimed at the Southern Africa Development Coordinating Conference countries. This program, funded principally by USAID regional funds, is independent of the training activities described above.

Following is a tabulation of Year 6 INTSORMIL training activities.

YEAR 7 INTSORMIL TRAINING REPORT

AGRONOMY/PHYSIOLOGY

Project	M.S.	Ph.D	Country	Male	Female	Funded by* INTSORMIL	Research** Support
KSU-106	1		Malawi	1			1
		1	U.K		1	1	
	1		U.S.	1		1	
NU-113		1	Botswana	1			1
		1	Bhutan	1		1	
		1	Canada	1			1
		1	Egypt	1			1
		1	Nigeria	1			1
	1		Sudan	1		1	
	2	3	U.S.	2	3	3	2
NU-114	1		Argentina	1			1
	1		Colombia		1	1	
		1	India	1		1	
		3	Philippines	2	1	2	1
		1	U.S.	1			1
NU-116		1	India	1		1	
		1	Mali	1		1	
		1	Mexico	1			1
	1		U.S.	1			1
TOTALS	8	17		19	6	13	12

PLANT BREEDING

MSU-104		1	Bangladesh		1		1
	1		Colombia	1		1	
		1	Costa Rica	1		1	
		1	Indonesia	1			1
	1	2	U.S.	1	2		3
NU-115		1	Tanzania	1		1	
		1	U.S.	1			1
PRF-103A		1	Colombia		1	1	
	1	1	Niger	2			2
	1	2	U.S.	3		2	1
PRF-107	1		Niger	1			1
		1	Tanzania	1		1	
	1	1	U.S.	2			2

PLANT BREEDING - Continued

Project	M.S.	Ph.D	Country	Male	Female	Funded by* INTSORMIL	Research** Support
TAM-121	1		Cameroon	1			1
	1		Haiti		1		1
		1	Honduras	1		1	
		1	India	1			1
	1	1	Mexico	2		1	1
		1	Senegal	1			1
	3	2	U.S.	3	2		5
TAM-122	1	1	India	1	1	2	
	1		Somalia	1			1
	1	1	U.S.	2		1	1
TAM-123	1		U.S.	1		1	
TOTALS	16	21		29	8	13	24

ENTOMOLOGY

KSU-109	1	2	Sudan	1	2		3
MSU-105	1	1	Honduras	2		2	
TAM-125		1	Botswana	1			1
		1	Brazil	1			1
	1		Colombia		1	1	
	1		Nicaragua	1		1	
		1	Senegal	1		1	
	1		Sudan	1		1	
	2	1	U.S.	2	1	2	1
TOTALS	7	7		10	4	8	6

FOOD QUALITY AND UTILIZATION

PRF-103B		1	India	1		1	
		1	U.S.	1		1	
PRF-104B		1	India		1	1	
		1	Sudan	1		1	
		1	U.K.	1		1	
		2	U.S.	1	1	1	1

FOOD QUALITY AND UTILIZATION - Continued

Project	M.S.	Ph.D	Country	Male	Female	Funded by* INTSORMIL	Research** Support
TAM-126	1		Argentina		1	1	
		1	El Salvador		1	1	
	1		Mali		1		1
		2	Mexico	1	1	1	1
	2	1	U.S.	2	1	1	2
TOTALS	4	11		8	7	10	5

PATHOLOGY

KSU-108		1	Ethiopia		1		1
TAM-124		1	Argentina		1	1	
	1		Botswana		1	1	
		1	El Salvador	1		1	
		1	Germany	1			1
		1	India	1		1	
	1		Mali	1			1
		1	Mexico	1		1	
	1	4	U.S	3	2		5
		1	Venezuela	1			1
TOTALS	3	11		9	5	5	9

SOCIOECONOMICS

KY-101/ 102		1	Iraq	1		1	
		1	Nigeria	1		1	
		1	Peru	1		1	
		4	U.S.	1	3	4	
NU-117		2	Philippines	1	1	2	
PRF-105		1	Niger	1		1	
		1	Syria	1		1	
TOTALS		11		7	4	11	

STUDENTS SUPPORTED BY INTSORMIL TO COMPLETE TRAINING FROM PROJECTS

TERMINATED IN PROGRAM YEAR 6

University	M.S.	Ph.D	Country	Male	Female
AGRONOMY/PHYSIOLOGY					
Kansas State University		1	India	1	
		1	Philippines	1	
		1	U.S.	1	
BREEDING					
University of Arizona		1	Ethiopia	1	
		1	Somalia	1	
FOOD QUALITY AND UTILIZATION					
Purdue University	1		U.S.		1
PATHOLOGY					
University of Nebraska		1	Colombia		1
		1	Philippines	1	
Purdue University		1	Ethiopia	1	
		1	Sudan	1	
STRIGA RESEARCH					
North Carolina State University		1	Sudan	1	
TOTALS	1	10		9	2

* Funded by INTSORMIL is being supported on a research assistantship.

** Research Support is support from another source (tuition, stipend, books, computer time, miscellaneous and possibly some research funds) but working on an INTSORMIL project.

Acronyms

AAA/SFAA	American Anthropological Association/Society for Applied Anthropology
ABA	Abscisic Acid
ADC's	Advanced Developing Countries
ADIN	Nursery for Disease and Insect Resistance
ADRA	Adventist Development and Relief Agency
AID	Agency for International Development
AID/ES	Agency for International Development/El Salvador
AID/H	Agency for International Development/Honduras
APHIS	Animal and Plant Health Inspection Service, U.S.
ARC	Agricultural Research Corporation, Sudan
ARS	Agricultural Research Service
ARS-Sebele	Agricultural Research Station, Sebele, Botswana
ASA	American Society of Agronomy
ATIP	Agricultural Technology Improvement Project
BIFAD	Board for International Food and Agricultural Development
BPI	Bureau of Plant Industry, Philippines
CARE	Cooperative for American Remittances to Europe, Inc.
CARS	Central Agricultural Research Station, Kenya
CATIE	Centro Agronômico Tropical de Investigaciôn y Ensemanza, Costa Rica
CENIAP-FONAIAP	Venezuela Agricultural Research Agency
CENTA	Centro de Technologia de Agricola, El Salvador
CESDA	Center for Agricultural Research, Dominican Republic
CIAB	Agricultural Research Center of the Lowlands, Mexico
CIAT	International Center for Tropical Agriculture, Colombia
CILSS	Interstate Committee for Drought Control in the Sahel
CIMMYT	International Maize and Wheat Improvement Center
CIRAD	Departement du Centre de Coopêration Internationale en Recherche Agronomique pour le Dêveloppement
CLAIS	Consejo Latin Americana de Investigadores en Sorgho
CNPQ	Conselo Nacional de Desenvolvimento Cientifico e Tecnologico
CNRA	National Center for Agricultural Research, Senegal
CRSP	Collaborative Research Support Program
DAR	Department of Agricultural Research, Botswana

DAR	Division of Agronomic Research, Mali
DECOR	Ministry of Rural Economy, Niger
DIA	Dot Immuno-binding Assay
DNA	Deoxyribonucleic Acid
DOA	Department of Agriculture, Botswana
DR	Dominican Republic
EAP	Escuela Agricola Pan Americana, Zamorano, Honduras
EARAT	East African Regional Adaptation Trial
ECHO	Educational Concerns for Hunger Organization
EDXRF	Energy Dispersive X-Ray Fluorescence
EEP	External Evaluation Panel
ELISA	Enzyme-linked Immunosorbent Assay
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuaria, Brazil
EMBRAPA-CNPMS	EMBRAPA - Centro Nacional para Maize e Sorgo
ERS/IEC	Economic Research Service/International Economic Development
FAO	Food and Agriculture Organization of the United States
FENALCE	Federacion Nacional de Cultivadores de Cereales
FHIA	Fundacion Hondurena de Investigacion Agricola, Honduras
FONAIAP	Fondo Nacional de Investigacion Agropecuaria
FRC	Food Research Center, ARC, Sudan
FSR	Farming Systems Research
FSR/E	Farming Systems Research/Extension
FSSP	Farming Systems Support Project
FSU	Farming Systems Unit, Burkina Faso
GASGA	Group for Assistance on Systems Relating to Grain after Harvest
GOB	Government of Botswana
GRA	Graduate Research Assistant
GTZ	German Agency for Technical Cooperation
HI	Harvest Index
HTS	High Tannin Sorghum
IAC	International Agriculture Center
IAN	Institute Agronomia Nacional, Paraguay
IANR	Institute of Agriculture and Natural Resources
IBRAZ	Institut Burkinahe de Recherache Agronomique et Zoologique
ICA	Instituto Colombiano Agropecuario/Colombian Agricultural Institute

ICARDA	International Centre for Agricultural Research in the Dry Areas
ICRISAT	International Crops Research Institute for the Semiarid Tropics
ICTA	Instituto de Ciencias y Technologia Agricolas, Guatemala
IDIAP	Agricultural Research Institute of Panama
IDIN	International Nursery for Plant Disease and Insects
IDRC	International Development Research Center
IER	Institute of Rural Economy, Mali
IFPRI	International Food Policy Research Institute
IFTST	International Food Type Sorghum Trial
IHAH	Instituto Hondureno de Antropologia e Historia
IICA	Instituto Interamericano de Ciencias Agricolas de la OEA
IITA	International Institute of Tropical Agriculture
INCAP	Instituto de Nutricion de Centro America y Panama
INIA	Instituto Nacional de Investigacions Agricola, Mexico
INIAP	National Agricultural Research Institute, Ecuador
INIPA	National Agricultural Research Institute, Peru
INRAN	Institute Nigerien du Recherche Agronomic, Niger
INTA	National Agricultural Technology Institute
INTSORMIL	International Sorghum/Millet, CRSP
IPA	Instituto de Pesquisas Agronomicas, Brazil
IPB	Institute of Plant Breeding, Philippines
IPIA	International Programs in Agriculture, Purdue University
IPM	Integrated Pest Management
IRAT	Institute of Tropical Agriculture and Food Crop Research
IRRI	International Rice Research Institute, Philippines
ISA	Instituto Superior Agricola
ISAVN	International Sorghum Anthracnose Virulence Nursery
ISC	ICRISAT Sahelien Center
ISRA	Institute of Agricultural Research, Senegal
ISVAB	International Sorghum Virus Antiserum Bank
ISVN	International Sorghum Virus Nursery
ITA	Institut de Technologie Alimentaire, Senegal
ITAT	International Tropical Adaptation Test
KARI	Kenya Agriculture Research Institute
KIRDI	Kenya Industrial Research and Development Institute
KSU	Kansas State University

LDC's	Less Developed Countries
LIFE	League for International Food Education
LTS	Low Tannin Sorghum
MAFES	Mississippi Agricultural and Forestry Experiment Station
ME	Management Entity
MDMV	Maize Dwarf Mosaic Virus
MIAC	MidAmerica International Agricultural Consortium
MIPH	Integrated Pest Management Project, EAP, Honduras
MOA	Memoranda of Agreement
MOA	Ministry of Agriculture, Botswana
MOALD	Ministry of Agriculture and Livestock Development, Kenya
MOU	Memorandum of Understanding
MRN	Ministerio de Recursos Naturales, Honduras
MSU	Mississippi State University
NCRP	Niger Cereals Research Project
NDFRS	National Dryland Farming Research Station, Kenya
NSA	National Seed Administration, Sudan
NSF	National Science Foundation
NU	University of Nebraska
OAU	Organization of African Unity
PAGE	Polyacrylamide Gel Electrophoresis
PCARRD	Philippine Council for Agriculture and Resources Research Development
PCCMA	Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos Alimenticios
PEG	Polyethylene Glycol
PET	Potential Evapotranspiration
PfP	Partnership for Productivity
PI	Principal Investigator
PRF	Purdue Research Foundation
PSTC	Program in Science & Technology Cooperation
PTA	Phosphotungstic
REA	Restriction Endonuclease Analysis
SACCAR	Southern African Centre for Cooperation in Agricultural Research
SADCC	Southern Africa Development Coordination Conference

SAFGRAD	Semi-Arid Food Grains Research and Development Project
SAFGRAD/IDRC	SAFGRAD/Canadian International Development Research Center
SAT	Semi-Arid Tropics
SDMVN	Sorghum Downy Mildew Virulence Nursery
SDS	Sodium dodecyl sulfate
SICNA	Sorghum Improvement Conference of North America
SIDA	Swedish International Development Agency
SMARC/UPSCM	Southern Mindinao Agricultural Research Center/University of the Philippines, Southern Mindinao
SRCVO	Section of Food Crops Research, Mali
SRN	Secretaria de Recursos Naturales, Honduras
TA	Tropically Adapted
TAES	Texas Agricultural Experiment Station
TAMU	Texas A&M University
TARO	Tanzania Agricultural Research Organization
TC	Technical Committee
TROPSOILS	Tropical Soils Collaborative Research Program, CRSP
TRPSS	Texas Reduced Phenoyl Sorghum Synthetic
UAM	Universidad Autonoma Metropolitana, Xochimilco, Mexico
UANL	Universidad Autonoma de Nuevo Leon, Mexico
UHSN	Uniform Head Smut Nursery
UK	University of Kentucky
UNISON	University of Sonora, Mexico
UNL	University of Nebraska - Lincoln
UPLB	University of the Philippines, Los Banos
US	United States
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
USM	University of Southern Mindanao, Philippines
VAM	Vesicular Arbuscular Mycorrhizae
WARS	Western Agricultural Research Station, Kenya
WASAT	West African Semi-Arid Tropics
WSARP	Western Sudan Agricultural Research Project
WUE	Water Use Efficiency