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INTSORMIL

Fighting Hunger with Research ... a team effort

[redacted]

Five Year Work Plans

1990 - 1995

Funding Support through Agency for International Development Grant: DAN-1254-G-SS-5065-00

Germplasm Enhancement and Conservation

Pearl Millet Germplasm Enhancement for Semi-Arid Regions

KSU-101
W.D. Stegmeier, T.L. Harvey and B. Khaleeq
Kansas State University

Collaborating Institutions

Host Countries

Botswana

Dr. Douglas Carter, KSU/INTSORMIL, Sebele Agricultural Research Station, Gaborone, Botswana
Mr. Louis Mazhani, Sorghum/Millet Breeder, Department of Agricultural Research, Gaborone, Botswana

India

Dr. John Witcombe and staff, Millet Breeding, ICRISAT, Patancheru P.O., Andhra Pradesh 502 324, India
Dr. M.H. Mengesha and staff, Germplasm, ICRISAT, Patancheru P.O., Andhra Pradesh 502 324, India
Dr. P. Soman, Physiology, ICRISAT Patancheru P.O., Andhra Pradesh 502 324, India
Dr. Stan King and staff, Millet Pathology, ICRISAT Patancheru P.O., Andhra Pradesh 502 324, India

SADCC countries

Dr. S.C. Gupta, SADCC/ICRISAT Southern Africa Regional Sorghum Millet Program, Bulawayo, Zimbabwe
Dr. Lee House, SADCC/ICRISAT Southern Africa Regional Sorghum Millet Program, Bulawayo, Zimbabwe

Kenya

Mr. Riungu M'Ragwa, Ministry of Agriculture and Livestock Development, Katumani, Machakos, Kenya

Senegal

Md. A.T. N'Doye, CNRA, Institute Senegalais de la Recherche Agronomique, Bambey, Senegal
Mr. A. Fofana, CNRA, Institute Senegalais de la Recherche Agronomique, Bambey, Senegal

Niger

Dr. John Clark, Purdue/NCRP, Niamey, Niger
Mr. Botorou Ouendeba, INRAN/PARA, B.P. 429, Niamey, Niger
Dr. Anand Kumar, Millet Breeder
Dr. Shadrak Okiror, Millet Breeder

United States

Dr. Lynn Gourley, Department of Agronomy, Mississippi State University, Mississippi State, MS
Professor D.J. Andrews, Department of Agronomy, University of Nebraska, Lincoln, NE
Dr. Jerry Eastin, Department of Agronomy, University of Nebraska, Lincoln, NE
Dr. Jerry Maranville, Department of Agronomy, University of Nebraska, Lincoln, NE
Dr. John Axtell, Department of Agronomy, Purdue University, West Lafayette, IN
Dr. Allen Kirleis, Department of Food Science, Purdue University, West Lafayette, IN
Dr. Fred Miller, Department of Soil and Crop Sciences, Texas A&M University, College Station, TX

Dr. Darrell Rosenow, Texas A&M Agric. Experiment Station, Lubbock, TX
Dr. Lloyd Rooney Department of Soil and Crop Sciences, Texas A&M University, College Station, TX

Dr. Richard Vanderlip, Department of Agronomy, Kansas State University, Manhattan, KS
Dr. Larry Claflin, Department of Plant Pathology, Kansas State University, Manhattan, KS
Dr. P. Bramel-Cox, Kansas State University, Manhattan, KS
Dr. C. Klopfenstein, Grain Science and Industry, Kansas State University, Manhattan, KS
Dr. G. Hanning, Tissue Culture for Crops Project, Colorado State University, Fort Collins, CO

Project Objectives

To develop widely adapted, photoperiod insensitive, early-maturing pearl millet populations, lines, germplasms, and hybrids with a) improved drought tolerance, seed size and density, seedling establishment characteristics, lodging resistance, and grain yield, b) insect, disease, bird and striga resistance; and c) acceptable food quality characteristics.

To select and evaluate materials developed in this program under a wide range of environments in the developing countries and to put superior lines and cultivars into farmers' hands.

Introduction

Breeding to preserve and enhance grain yield potential and quality characteristics, and the stability and sustainability of pearl millet production as an integral part of farming systems in both LDC's and semi-arid regions of the United States is by necessity a continuing program. It requires the collaborative support of several disciplines including agronomy, physiology, pathology, entomology, grain science and utilization, and socioeconomics. The introduction, conservation, and utilization of new sources of genetic diversity is basic to a program's success in generating stress-resistant high-yielding germplasm to alleviate production constraints.

A wide range of constraints to improved quantity, quality, and sustainability of food production need to be addressed in the countries with which this project is involved. Among the constraints usually cited are several that could be positively influenced by breeding efforts. In all of the countries listed there are interactions between genotype or cultivar and the following: seed size, seedling vigor, seedling length, and stand establishment; seasonal duration, amounts, and patterns of precipitation in relation to drought tolerance; photoperiod sensitivity and maturity; reaction to insects, diseases, birds, and striga; production and cultural practices, and poor soil fertility. Several constraints and problems are associated with the use of the crop, ranging from stalk characteristics needed for forage or construction to the apparent food quality of the grain in regard to nutritional value, ease of processing, and consumer acceptability. The production constraints common to these countries are found in varying degrees to be constraints in nearly all millet producing areas of the world.

Several production constraints are found in the United States and some are similar to those in the dry tropics, i.e., stand establishment, tolerance to drought and pests, seed size, and grain quality. Adaptability to mechanical harvest as influenced by lodging resistance, uniformity of maturity and several plant and agronomic characteristics are more limiting to production in the United States than in the LDC's, but mechanized farming is found in several areas in the LDC's and may become more common in the future.

Objectives as Related to Millet Constraints

The constraints given above are presently being addressed with varying levels of effort. Selection within new accessions and pearl millet materials segregating for stand establishment characteristics, earlier maturity, drought tolerance, lodging resist- ance, and grain yield is performed in Kansas. Superior materials are evaluated and reselected for adaptation, resistance to diseases, insects, birds, and *Striga* in several SADCC countries, Senegal, Niger, and India.

Breeding efforts related to stand establishment include selection for increased seed size and density, mesocotyl and coleoptile lengths, speed of germination and emergence, improved seedling vigor, and ability to penetrate crusted soils. Lodging resistance as affected by several stalk characteristics is being incorporated into elite materials. Evaluation and reselection for downy mildew resistance within F_2 to F_4 families, inbred lines and populations will be done by ICRISAT collaborators. Evaluation of grain yield potential and agronomic characteristics of new materials is performed in several states in regional performance trials and in LDC's. Grain quality evaluations are being determined visually and by laboratory methods in Kansas, Texas, and Patancheru, India. Evaluation and selection for heat and drought stress is performed when environmental conditions offer the opportunity.

Host Country Collaboration and Work Sites

Drs. Gupta and House are evaluating a number of materials and selecting within F_2 to F_5 progenies at Bulawayo, Zimbabwe. Superior selections are being planted in their nurseries in neighboring SADCC countries and have been made available to breeders in those countries. Dr. Gupta and Mr. M'Ragwa, Kenya, visited the KSU nurseries in 1985, selected an array of materials to be sent to them for inclusion in their 1986 programs and additional materials of the type they requested were sent in 1987, 1988 and 1989.

ICRISAT breeders, with Dr. John Witcombe as leader, and pathologists in Dr. King's program are evaluating and selecting within KSU-101 materials at Patancheru, Hissar, and several other sites in India. These are F_3 to F_5 lines and population materials that have been selected for desirable characteristics such as early maturity and large seed size in Kansas and are then reselected for adaptation and resistance to downy mildew at Patancheru. Advanced inbred lines selected for characteristics affecting stand establishment are placed in Dr. Soman's nursery to screen for ability to emerge through crusted soil. Progenies of crosses between ICRISAT and INTSORMIL lines developed at Patancheru are sent to ICRISAT stations in Africa and to KSU 101 for evaluation, reselection, and crossing to elite KSU 101 lines.

Seven populations, and 145 F_4 and F_5 lines, are being increased and screened for acid soil tolerance by MSU-104 in Mississippi for future screening on aluminum/acid soils in Columbia. Successful results are anticipated and additional materials are slated for screening in future years.

In cooperation with the Senegal Agricultural Research II Project (managed by Michigan State University), several populations and varieties will be performance tested in the Senegal River Valley in northern Senegal. Some of these materials will undergo selection for downy mildew resistance at the Bambey station.

Research Procedures

Each year 20 to 170 millet lines, F_1 hybrids, varieties, and germplasms are imported into this country under APHIS permit, grown under quarantine conditions and crossed to elite inbred lines and F_1 hybrid combinations of elite lines. These accessions and their segregating progenies are evaluated and either incorporated into appropriate populations or undergo inbreeding and development as elite lines. More than 400 groups of F_2 families from the best F_1's of crosses between new introductions and Kansas lines, and from crosses within Kansas materials are grown each year. Superior selections are advanced by pedigree and backcross breeding methods. Following initial screening and selection, many of the superior S_3, F_4, and advanced generation A lines are crossed to elite A and R tester lines to determine general and specific combining ability in hybrid combination and to evaluate their potential as germplasm for LDC use.

Breeding for improved stand establishment characteristics involves selection for long seedling mesocotyl and coleoptile structures, rapid germination and seedling elongation, and the capability to emerge through thick overburdens of soil and crusting soils. Screening and selection is carried out in the laboratory, greenhouse, and under field conditions. Data is being collected to determine if correlations exist between seedling stand establishment characteristics and seed characteristics such as crude protein and lipid levels and varying proportions of vitreous and floury endosperms.

All F_3 to F_5 lines are grown on soils with a relatively high clay content and following a reduced fallow period that limits the amount of stored subsoil moisture. Under these conditions, drought stress is usually apparent during flowering and post-flowering stages of plant development. In addition to the 1,800 to 2,500 entries grown in these nurseries each year, the Colorado State University Tissue Culture for Crops Project (TCCP) has sent 2,069 lines (70% of these lines were derived from KSU 101 materials) from their program for evaluation and reselection. The TCCP lines will be evaluated at the rate of 400 to 800 each year as field space permits. A large proportion of these lines have been cultured in stress-inducing media (PEG, NaCl, and $AlCl_3$).

Two populations are in recurrent selection programs using the S_1 progeny performance method. Five populations, grown in isolated fields, are advanced by random-mating and phenotypic mass-selection for desirable agronomic characteristics, screening for increased seed size, and gravity table separation for increased seed density. Included in this group are two tall non-bristled populations, one tall bristled population, and two D_2 dwarf populations.

Materials possessing desired characteristics are sent to collaborators in nurseries containing up to several hundred items. These materials include populations, synthetic varieties, F_2 to F_5 lines, and advanced elite lines. Parental F_2 and F_3 families that have produced desirable advanced inbreds are sent to collaborators for further selection under LDC conditions. Usually, these families are derived from crosses between Kansas lines and either landrace or improved lines originating from the LDC to which they are being sent. Superior materials selected from these lines and progenies of crosses made by LDC collaborators are returned back to Kansas for additional cycles of crossing and selection.

Measures of Success

Success of a breeding program is shown by the successful production and use of the products of the program by the ultimate consumer and the incorporation of the products as germplasm into the breeding programs of other breeders.

Anticipated Reports and Articles

Reports and papers will be written detailing the variation found in seedling mesocotyl and coleoptile lengths, the effects of differences in length of these structures on stand establishment, and the effects of temperature and seed size on development of these structures. Several populations and germplasm lines will be released. Registration statements will be published.

General Comments

Three of the millet breeders with whom we were involved have returned to graduate school. These people are Mde. N'doye, CNRA, Senegal, Boutorou Ouendeba, INRAN, Niger, and Louis Mazhani, ARD, Botswana. At this time, Mde. N'doye's work with KS101 materials is being continued by Mr. Fofana.

Materials from the Kansas breeding program in previous years have been sent to many of the workers and institutions listed in the work plan for evaluation. Several of those materials have been incorporated into their breeding programs and are being used in crosses with LDC materials. Among the first Kansas materials sent to ICRISAT (Patancheru) in 1980 were two A-B male-sterile and fertility maintainer lines, 79-2068 and 79-2221. These lines had characteristics of early maturity, large seed size, D_2 dwarf height, and good combining ability in hybrid combinations: characteristics that complemented the materials within the ICRISAT program. A significant portion of the ICRISAT male-sterile breeding project now consists of selections derived from crosses of ICRISAT and INTSORMIL lines. At last report, all Indian millet breeders involved in the All India Coordinated Millet Improvement Program were using the two A-B pairs, and commercial seed companies in India are now using the 2221 line as a female parent in large-scale hybrid seed production.

Nearly all of the germplasm materials received by KSU 101 from ICRISAT in the early 1980's required extensive crossing, backcrossing, and selection with Kansas lines to obtain materials adapted to the mid- latitudes. With each cycle of exchange of improved materials between ICRISAT and INTSORMIL grain yield and agronomic potentials have increased. The most recent set of advanced inbred lines (derived from crosses of ICRISAT and INTSORMIL lines) received from ICRISAT were crossed to KSU-101 elite lines and the hybrid combinations were tested in 1988. The 40 hybrids in this set had the best agronomic appearance of any materials tested to date. Bird depredation prevented harvesting for grain yield, but estimates indicated yields would have averaged nearly 5,000 kg/ha with several of the hybrids approaching or reaching yields of 6,000 kg/ha. It is anticipated that a large number of excellent derivations will be selected from progenies of these crosses thus reducing the time when pearl millet will be grown as a grain crop in the United States.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: Pearl Millet Germplasm Enhancement for Semi-Aird Regions

Project Leader: William Stegmeier **Project Number:** KSU-101

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=KSU101	--	----------				
Staff Salaries & Benefits	14.85	15.64	16.43	17.03	17.82	81.77
Post Doctorates	5.70	6.00	6.31	6.54	6.84	31.39
Graduate Students	6.00	6.00	6.00	7.00	7.00	32.00
Other Salaries	7.43	7.82	8.22	8.51	8.91	40.89
Supplies	6.45	6.79	7.14	7.40	7.74	35.52
Equipment	2.33	2.45	2.57	2.67	2.79	12.81
Travel	8.40	8.85	9.30	9.63	10.08	46.26
Other Direct Costs	5.78	6.08	6.39	6.62	6.93	31.80
Overhead	18.30	19.28	20.25	20.98	21.96	100.77
	75.24	78.91	82.61	86.38	90.07	413.21

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=KS101	--	----------				
University Staff	0.00	0.00	0.00	0.00	0.00	0.00
Post Doctorates	23.31	24.47	25.70	26.98	28.33	128.80
Other Salaries	6.30	6.62	6.95	7.29	7.66	34.81
Fringe Benefits	7.70	8.08	8.49	8.91	9.36	42.55
Supplies	3.66	3.85	4.04	4.24	4.45	20.24
Equipment	0.00	0.00	0.00	0.00	0.00	0.00
Travel	5.25	5.51	5.79	6.08	6.38	29.01
Other Direct Costs	0.00	0.00	0.00	0.00	0.00	0.00
Overhead	16.78	17.62	18.50	19.42	20.39	92.71
	63.00	66.15	69.46	72.93	76.58	348.11

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=KS101	--	----------				
University Staff	0.00	0.00	0.00	0.00	0.00	0.00
Post Doctorates	22.20	22.20	22.20	22.20	22.20	111.00
Other Salaries	6.00	6.00	6.00	6.00	6.00	30.00
Fringe Benefits	7.33	7.33	7.33	7.33	7.33	36.67
Supplies	3.49	3.49	3.49	3.49	3.49	17.45
Equipment	0.00	0.00	0.00	0.00	0.00	0.00
Travel	5.00	5.00	5.00	5.00	5.00	25.00
Other Direct Costs	0.00	0.00	0.00	0.00	0.00	0.00
Overhead	15.98	15.98	15.98	15.98	15.98	79.90
	60.00	60.00	60.00	60.00	60.00	300.00

Breeding Sorghum for Tolerance to Infertile Acid Soils

Project MSU-104
Lynn M. Gourley
Mississippi State University

Collaborating Institutions

Host Country:

Colombia

Dr. Manuel Torregroza, Director of Annual Crops, ICA, Bogota, Colombia. (Host Country Coordinator).
Dr. Dorance Munoz, Director Genetics and Plant Breeding, FEDEARROZ, Bogota, Colombia.
Mr. Cesar Ruiz, Sorghum Breeder, ICA, La Libertad, Apartado Aereo 2011, Villavicencio, Colombia.
Mr. Luis de Angulo, El Alcaravan Foundation, Occidental de Colombia, Inc., Bogota, Colombia.
Dr. Fabio Polania, Technical Director, FENALCE, Bogota, Colombia.

Brazil

Dr. Gilson Pitta, Soil Scientist, CNPMS/EMBRAPA, Caixa Postal 151 35.700 Sete Lagoas, M. G., Brazil.
Dr. Gabriel Alves Maciel, Breeder, EUP-PI, Serra Talhada, Brazil.
Mr. Paulo M. Ribas, Breeder AGROCERES -Capinopolis, Brazil.

Venezuela

Mr. Hector Mena, Director of Cereal Research, CENIAP-FONAIAP, Maracay (Aragua), Venezuela.
Mr. Osman Gutierrez, Breeder, on study leave at Mississippi State University.
Dr. Mauricio Riccelli M., Central University of Venezuela, Valencia, Venezuela.

Peru

Dr. Dale Bandy, North Carolina State University, Mission/INIIPA and TROPSOILS, Lima, Peru.
Mr. Pedro Carrasco, Leader of INIIPA's Selva Program, INIIPA-Yurimaguas, Peru.
Dr. Antonio Pinchinat, Research Specialist, IICA-Lima, Peru.

Zambia

Dr. Bhola Nath Verma, Sorghum Breeder, SIDA, Mt. Makulu Research Sta., P/B 7, Chilanga, Zambia.
Mr. David Hopkinson, North-West Province Area Development Project, P.O. Box 110296, Solwezi, Zambia.

Zimbabwe

Dr. Lee House, SADCC/INCRISAT Sorghum/Millet Research Program, Bulawayo, Zimbabwe.
Dr. Tunde Obilana, SADCC/ICRISAT, Sorghum/Millet Research Program, Bulawayo, Zimbabwe.
Dr. Walter de Milliano, SADCC/ICRISAT, Sorghum/Millet Research Program, Bulawayo, Zimbabwe.
Dr. Emmanuel Monyo, SADCC/ICRISAT, Sorghum/Millet Research Program, Bulawayo, Zimbabwe.
Mr. Ronald Muza, Zimbabwean Millet Breeder, on study leave at Mississippi State University.

Tanzania

Mr. Hamis Saadan, Tanzanian Sorghum Breeder, on study leave at Mississippi State University.

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Malawi

Mr. Edmund Chintu, Malawian Sorghum Breeder

United States:

Dr. Guillermo Munoz, Mississippi State University, CIAT, Apartado Aereo 6713, Cali, Colombia.
Dr. Henry Pitre, Entomologist, Mississippi State University, Mississippi State, MS.
Dr. Jerry Maranville, Plant Nutritionist, University of Nebraska, Lincoln, NE
Professor David Andrews, Sorghum and Pearl Millet Breeder, University of Nebraska, Lincoln, NE.
Dr. John Axtell, Sorghum Breeder, Department of Agronomy, Purdue University, West Lafayette, IN
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Dr. Darrell Rosenow, Texas A&M Agricultural Experiment Station, Lubbock, TX
Dr. Gary Peterson, Texas A&M Agricultural Experiment Station, Lubbock, TX.
Dr. Fred Miller, Sorghum Breeder, Texas A&M University, College Station, TX.
Dr. Pedro Sanchez, Soil Scientist, TROPSOILS Coordinator, North Carolina State University, Raleigh,NC.

Project Objectives

Screen and evaluate sorghum and pearl millet, in the laboratory and field, for sources of tolerance to low soil phosphorus (P) content and availability, and aluminum (Al) and manganese (Mn) toxicities.

Enhancement of elite U.S. and LDC sorghum germplasm with sources of tolerance to Al and Mn toxicities.

Train selected U.S. and LDC personnel.

Introduction

One of the major constraints to sorghum production in the Western Hemisphere and Central Africa is acid soils. Acid soils in Mississippi and the Southeastern U.S. pose similar production problems, but nothing in magnitude compared with tropical acid soils. This research will benefit both the LDC's and the U.S. in several ways. Al-tolerant germplasm will help increase sorghum production in acid soils in both areas with less inputs, but the 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 Latin America and Central Africa should be vast for these food and feed grain deficient countries.

Several labor intensive methods are used in Central Africa to avoid or ameliorate the toxic effects of Al or Mn for sorghum production on acid soils. These methods substitute for purchased inputs of lime and fertilizer. Subsistence farmers in Zambia, Tanzania, Zaire, Angola and possible other countries use ashes from trees and bushes, organic residue from buried grass, or elevated ridges made from topsoil in transient agriculture systems instead of using purchased inputs. Aluminum and Mn-tolerant germplasm would produce higher grain yields with better yield stability, even with this level of technology or with higher technology. Less purchased inputs would be required than with Al-susceptible germplasm.

The unique Mississippi environment of hot humid weather and large areas of johnsongrass which acts as a reservoir for most sorghum diseases and insects makes sorghum production problems in this state comparable to those in many LDC's. Every breeding project must maintain insect and disease resistance as a breeding goal or after accomplishing the primary breeding objective the material can be rendered worthless by a destructive plant pathogen or insect.

Objectives Related to Constraints

Acid soil tolerance, conveys a qualitative assessment of plant adaption to acid soil conditions including low fertilizer and lime inputs. The soil constraints must be characterized and crop response to these production-limiting factors evaluated. Less than optimum conditions for plant growth are implied in this type research. Low-input systems are considered to be transitional technology in both agronomic and economic terms. They provide low-cost alternatives for shifting cultivation in highly acid soils.

The long-range global thrusts of this germplasm conservation and enhancement project are to develop food and feed grain A, B and R-lines which will produce hybrids tolerant to Al and Mn toxicities and be efficient in extracting P from soils using low-input techniques. High yielding hybrids with these abiotic stress tolerant characteristics will be of benefit to U.S. farmers in acid

soil areas in the Southeastern U.S. Hybrid Seed Companies are more interested in the results of these long-range objectives than those that produce varieties.

The enhancement of elite sorghum lines with Al-tolerant gene(s) has been ongoing for a number of years. As new sources tolerant to high levels of Al saturation are found they too are being incorporated into tropically adapted lines. New Al-tolerant B-lines are being sterilized and used as tester females with different tolerant R-lines in combining ability studies. Although Al tolerance appears to be a simple dominant condition in some lines, hybrids with a tolerance to higher levels of Al saturation suggests that the sources are different and are producing additive or epistatic effects. The genetics of Al tolerance needs to be examined in more detail.

Host Country Collaboration and Work Sites

The main collaborative site focus of this research is Colombia with additional collaborative sites in the Southern and Western Africa ecogeographical zones. Crossing and selection research will be accomplished at Mississippi State University, CIAT-Palmira, Colombia (winter nursery), and CIAT-Quilichao, Colombia (Al toxicity field screening). Seed of selected lines and hybrids will be evaluated in observation and yield trials in Mississippi; Colombia (Quilichao, Arauca, Villavicencio and Nataima); Niger (Kolo, Bengou, Konni, and Tarna); and SADCC/ICRISAT (Bulawayo, Zimbabwe) and at sites throughout the Southern Africa region to be determined by Drs. Tunde Obilana and Walter de Milliano.

Forage sorghums (brown midrib, low lignin, grain sorghum A and B-lines, silage R-lines, and sudangrass lines) are being evaluated by Dr. Emmanuel Monyo at Bulawayo, Zimbabwe. None of this material is acid soil tolerant. Responding to the need for tropical forages, brown midrib sudangrass derivatives of crosses with IS 7173C are being screened for Al tolerance at Quilichao, Colombia.

Sorghum and pearl millet lines and populations developed and/or evaluated by this project are sent to any National Program or public research agency conducting research on acid soils.

Research Procedures

Detailed annual workplans are developed in Colombia by ICA and INTSORMIL investigators with representation and input from all other collaborating organizations in Colombia. A similar procedure is followed in the development of annual workplans for Niger. Workplans for SADCC countries have been less formal and on a scientist-to-scientist basis.

The following general research procedures for germplasm enhancement and evaluation trials will be used during the next five years.

Various field and laboratory evaluation techniques to determine sorghum and pearl millet tolerance to Al and Mn toxicity and P uptake efficiency will be utilized. The field screening technique for tolerance to Al toxicity (65% Al-saturation) which was developed by this project will be used to evaluate advanced breeding lines, yield trials of varieties, experimental Al-tolerant hybrids, and new lines from other INTSORMIL and ICRISAT projects.

Phosphorus extraction efficiency trials will be conducted in the laboratory at MSU to evaluate the genetic variability for this trait. Phosphate adsorbed to alumina is mixed throughout a container of sand and the sorghum plant's efficiency to utilize only this source of P is measured.

A total of 941 new Al-tolerant R-lines will be evaluated at three locations in Colombia (Quilichao, Villavicencio, and Arauca). The 244 photoperiod insensitive R-lines in this group will also be evaluated in Brazil and several locations in SADCC.

A total of 442 new Al-tolerant A-B pairs will be evaluated for combining ability in Mississippi and Colombia. Initially these A-lines will be tested using two white seeded Al-susceptible R-lines. Observation hybrid trials will determine height interaction, Al tolerance, tannin content, maturity and agronomic type.

Additional combining ability trials of the best Al-tolerant A-lines and R-lines will be conducted in the field in Mississippi, Colombia, and Niger and in nutrient solution culture in laboratory trials.

Screening Al-tolerant and other elite sorghum germplasm for Mn tolerance will continue at Mississippi and will include a student (Clark) thesis at the University of Nebraska.

Additional inheritance studies of Al-tolerance will be conducted using diverse Al-tolerance sorghum sources. Trials to determine the number of genes involved in Al-tolerance will be conducted. Inheritance of Mn toxicity tolerance and P uptake efficiency will be studied using conventional genetic techniques.

High quality, low lignin (brown midrib) forage sorghums are being developed for dairy cows. Sudangrass with brown midrib and Al-tolerance genes are being evaluated.

Measures of Success

One measure of success in any breeding program is the release of germplasm, populations, or breeding lines which produce superior hybrids. Several Al-tolerant and brown midrib A and B-line pairs have been approved for release. Other A and B-line pairs, R-lines, and populations which are tolerant to Al-toxicity are being prepared for release.

The real measure of research success will be when large areas of acid soil in Latin America and Central Africa are planted with Al-tolerant cultivars developed collaboratively with National Programs and which require significantly less soil amendment inputs than commercial hybrids and varieties currently available to farmers.

Anticipated Reports and Articles

A number of journal articles, proceedings of workshops and other publications developed from research conducted under this project will be published in the next five years. The Spanish version of "Sorghum for Acid Soils" has been published and is being distributed by CIAT.

General Comments

The demand for grain sorghum as feed for poultry and other livestock is high in the Andean Pact Countries and Brazil. Due to the economies of these countries, they cannot continue to import their requirements of feed grains but will by necessity have to use underutilized land resources (acid soils) to produce their own. INTSORMIL can help in this effort which will improve the nutritional level of millions of people by providing larger quantities of meat at affordable prices.

Progress (last two years)

The initial collaborative site of the acid soil research conducted by this project was Colombia. This effort has been formalized by a MOU between ICA, INTSORMIL, and CIAT. The results of breeding sorghum for tolerance to Al-toxicity have attracted outside funding and allowed an effective 2:1 leveraging of INTSORMIL funds to support research in Colombia which is consistent with the mission of INTSORMIL. El Alcaravan Foundation, a consortium of petroleum companies of Colombia, has supplied equipment for ICA and funds to support sorghum and millet germplasm enhancement efforts in the territory of Arauca.

Acid soil research in a second collaborative site, Niger, has been initiated. The sandy acid soils in Niger are physically and chemically quite different from those in Latin America and Southern Africa. The primary crop production constraint in Niger is drought, however, initial soil tests indicated high levels of Mn at two of the four test sites and no Al toxicity problem at any test site.

Training is an important component of this project. In the last two years three Ph.D. and two M.S. students have conducted some aspect of acid soil research for their degrees. Six graduate students are currently under training with the project. Dr. Guillermo Munoz (Ph.D. - MSU, May 88), a resident of Colombia, was appointed INTSORMIL PI for MS-111 (Colombia) in July 1988. He coordinates research and training activities with collaborating organizations in Colombia and with INTSORMIL projects in the U.S. Mr. Cesar Ruiz (M.S. - MSU, Dec. 87) returned to Villavicencio, Colombia to continue his breeding activities at ICA's main acid soil research station at La Libertad.

Hybrids made from Al-tolerant A-lines and R-lines developed in this project are being evaluated in Mississippi and at several locations in Colombia and Niger. Combining ability trials for Al-tolerance, yield and other agronomic traits are being conducted on about 442 new A-lines and 244 new photoperiod insensitive R-lines. These new lines have the best sources of Al-tolerance identified in Colombia. Two Al-tolerant random-mating sorghum populations, B-line and R-line, have been characterized and are ready for release. Three temperate and five tropical photoperiod sensitive R-lines have been identified and will be released in the near future.

Manganese toxicity frequently occurs with Al-toxicity in tropical acid soils. Many soils in the Southeastern U.S. have high levels of Mn and could account for more reduction in sorghum yields than Al. Evaluation of Al-tolerant and other elite sorghum genotypes for tolerance to Mn toxicity has shown that there is genetic variability for this trait. Using nutrient solution culture at 3600 uM Mn appears to be an effective screening technique.

Success stories

Three sets of Al-tolerant sorghum germplasm are being prepared for release. Two unselected Al-tolerant random-mating populations, MP1B (B-line) and MP2R (R-line), were characterized for agronomic variability. These populations have had five cycles on acid soil in Colombia and two cycles of random-mating in Mississippi. Three temperate and five tropical photoperiod sensitive Al-tolerant R-lines have been identified for release. Combining ability tests are being conducted using these temperate R-lines with elite U.S. and experimental Al-tolerant male steriles. The tropically adapted R-lines have high grain yield for direct use potential on Al-toxic tropical soils.

Two INTSORMIL supported graduates from this project have returned to Colombia to continue acid soils research and to strengthen ICA and INTSORMIL collaboration. Dr. Guillermo Munoz (Ph.D., May 88) was appointed INTSORMIL PI for the Colombian collaborative site in July 1988. Dr. Munoz coordinates research and training activities with all collaborating organizations in Colombia and with INTSORMIL projects in the U.S. Mr. Cesar Ruiz (M.S., Dec. 87) is ICA's sorghum breeder at the main acid soil research station at La Libertad. Both of these graduates strengthen the Colombian National Sorghum Improvement Program.

Benefits to U.S. and L.D.C. Agriculture

The primary benefit to U.S. and L.D.C. agriculture from this germplasm enhancement project is sorghum releases with proven acid soil stress tolerance. High yielding Al-tolerant varieties can be utilized by farmers in the humid tropics to increase sorghum grain production for food and feed. The Al-tolerant lines released to public and commercial sorghum breeders can be used in their improvement programs as germplasm or directly as parents for Al-tolerant hybrids in their tropical operations where Al-toxicity is a major sorghum production constraint. In the U.S., Mn toxicity could account for more reduction in sorghum yields in the acid soils of the Southeastern U.S. than Al-toxicity.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: Breeding Sorghum for Tolerance to Infertile Acid Soils

Project Leader: Lynn Gourley **Project Number:** MSU-104

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=MSU104	--	----------				
Staff Salaries & Benefits	16.83	17.62	18.41	19.21	20.20	92.27
Post Doctorates	6.46	6.76	7.07	7.37	7.75	35.41
Graduate Students	6.00	7.00	7.00	7.00	8.00	35.00
Other Salaries	8.42	8.81	9.21	9.60	10.10	46.14
Supplies	7.31	7.65	8.00	8.34	8.77	40.07
Equipment	2.64	2.76	2.88	3.01	3.16	14.45
Travel	9.52	9.97	10.42	10.85	11.42	52.19
Other Direct Costs	6.55	6.85	7.16	7.47	7.85	35.88
Overhead	20.74	21.72	22.69	23.67	24.89	113.71
	84.47	89.14	92.84	96.53	102.14	465.12

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=MS104	--	----------				
University Staff	22.05	23.15	24.31	25.53	26.80	121.84
Staff Benefits	3.75	3.94	4.13	4.34	4.56	20.71
Other Salaries	5.25	5.51	5.79	6.08	6.38	29.01
Fringe Benefits	1.23	1.29	1.35	1.42	1.49	6.79
Supplies	5.25	5.51	5.79	6.08	6.38	29.01
Travel	11.03	11.58	12.16	12.76	13.40	60.92
Other Direct Costs	14.70	15.44	16.21	17.02	17.87	81.23
Overhead	26.00	27.30	28.66	30.10	31.60	143.66
	89.25	93.71	98.40	103.32	108.48	493.16

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=MS104	--	----------				
University Staff	21.00	21.00	21.00	21.00	21.00	105.00
Staff Benefits	3.57	3.57	3.57	3.57	3.57	17.85
Other Salaries	5.00	5.00	5.00	5.00	5.00	25.00
Fringe Benefits	1.17	1.17	1.17	1.17	1.17	5.85
Supplies	5.00	5.00	5.00	5.00	5.00	25.00
Travel	10.50	10.50	10.50	10.50	10.50	52.50
Other Direct Costs	14.00	14.00	14.00	14.00	14.00	70.00
Overhead	24.76	24.76	24.76	24.76	24.76	123.80
	85.00	85.00	85.00	85.00	85.00	425.00

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Breeding Sorghum for Increased Nutrional Value

PRF-103
John D. Axtell
Purdue University

Collaborating Institutions

Host Country

Dr. John Clark, Purdue/Niger Cereals Project, Niamey, Niger
Dr. Idrissa Soumana, INRAN, Director General, Niamey, Niger
Mr. Moussa Adamou, INRAN Sorghum Breeder, Niger
Dr. Abdellatif M. Nour, Sorghum Breeder, ARC/Gezira Research Station, Sudan
Dr. Osman Ibrahim, ARC/Gezira Research Station, Wad Medani, Sudan
Dr. Hilu Omar, Sorghum Pathologist, ARC, Sudan
Dr. Abdelgabar, Babikher, *Striga* Specialist, ARC, Sudan
Dr. R. Jambunathan, Head of Biochemistry Department, ICRISAT, India
Dr. Dallas Oswalt, Chief Training Officer, ICRISAT, India
Dr. D.S. Murty, Plant Breeder, ICRISAT, India
Dr. Lee House, SADCC, Bulawayo, Zimbabwe
Mr. Joseph Mus'ionga, Bulawayo, Zimbabwe
Dr. Emmanuel Monyo, SADCC Sorghum Breeder, Zimbabwe
Dr. Sam Mukuru, Sorghum Breeder, ICRISAT, Kenya
Dr. Vartan Guiragossian, Sorghum Breeder, ICRISAT, Kenya
Dr. Guillermo Munoz, International Center for Tropical Agriculture (CIAT), Colombia

U.S.

Dr. Larry Butler, Dept. of Biochemistry, Purdue University
Dr. Allen Kirleis, Dept. of Food Science, Purdue University
Dr. John Rogler, Dept. of Animal Science, Purdue University
Dr. Gebisa Ejeta, Dept. of Agronomy, Purdue University
Dr. John Sanders, Dept. of Agricultural Economics, Purdue University
Dr. Herm Warren, Dept. of Botany & Plant Pathology, Purdue University
Drs. Fred Miller, Darrell Rosenow, Lloyd Rooney, R. Frederiksen, George TeetesTexas A&M University
Dr. William Stegmeier, Kansas State University
Dr. Lynn Gourley, Mississippi State University
Dr. Charles Berry, Cargill/PAG
Dr. Kay Porter, Pioneer Seed Company
Mr. David Andrews, and Dr. Jerry Eastin, University of Nebraska
Dr. George G. Graham, Johns Hopkins University

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.

Introduction

Nutritional value of sorghum has long been known to be different from other cereals. This includes the tannin problem, the protein quality problem, the protein digestibility problem, and the local processing methods involved in elevation these problems in the diets of sorghum consuming people. We have made significant progress in cooperation with Dr. Larry Butler on the tannin problem, and Sam Mukuru has now proven in studies conducted in our laboratory that high tannin sorghums traditionally grown at high elevations in Eastern Africa are very satisfactory sources of digestible nutrients if the grain is processed adequately by traditional means. Protein quality improvement will be a major breeding objective during the next five years. We have identified good sources of modified quality protein sorghums which are comparable to yield potential and grain quality which are not available in quality protein maize as developed by CIMMYT. The basic high lysine gene, P-721 opaque has been combined with sources of vitreous endosperm to give the QPS (Quality Protein Sorghum). The high yield potential has been demonstrated by Gebisa Ejeta and the modified vitreous endosperm characteristics have been documented in 1988 in Lafayette, IN. A major unresolved problem is the environmental stability of these modified endosperm sorghums. Trials will be conducted at several locations during 1989 to confirm the stability of the vitreous endosperm trait in these QPS lines across temperate and tropical environments. It is interesting to note that the digestibility of P-721 high lysine sorghum is about 10% greater than that of most normal sorghum varieties which should be an additional benefit if it can be confirmed in the QPS lines. The digestibility problem can also be approached at this time by a better understanding of traditional processing technologies. We believe the identification of a low fraction III (cross-linked kafirin fraction) sorghum variety in the World Collection has the potential to provide a genetic and breeding solution to the digestibility problem in sorghum which would be a significant achievement in utilization of sorghum as a food grain and also as a feed grain.

Objectives Related to Constraints.

The major priority for the next five years will be the development of a vitreous endosperm high lysine sorghum variety using germplasm developed from crosses with P-721 opaque. This will be a combined effort with Allen Kirleis, Gebisa Ejeta, and Larry Butler. The modified endosperm high lysine sorghum parental materials will be tested in Niger, Sudan, and West Lafayette to verify environmental stability of the vitreous endosperm and the lysine content. An extensive second cycle breeding program will be initiated to further improve the protein quality, vitreous endosperm, and protein digestibility of the new lines. Another major focus for the next five years will be to continue to ascertain the nutritional value of thin fermented porridges as used in Eastern 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 lactobacillous. Many improved sorghum varieties lack this characteristic and this factor may be responsible for low adoption rate of improved varieties. Joe Mushonga's research on developing rapid assays for diastatic power and studying inheritance of diastatic activity in sorghum cultivars will be continued. Second, Dr. Sam Mukuru has completed his study at Purdue on the digestibility of thin fermented sorghum porridges in Uganda and has found that there is no effect of the tannins on digestibility after the traditional wood ash and fermentation treatments. Another focus of activity will be to pursue the development of cold tolerant sorghum lines with markedly improved seedling vigor for higher elevations in Eastern Africa and temperate zones. The sources of cold tolerance from Northern China continue to be excellent for early spring seedling vigor. Finally, we have identified a sorghum line in the World Collection which has a significantly a reduced cross-linked kafirin fraction and shows very good digestibility results in rat feeding trials, whether cooked or uncooked. Since we believe this cross-linked kafirin is responsible for many of the digestibility problems in sorghum we are giving this activity a very high priority. Studies include inheritance of the low fraction III trait and incorporation with this genetic characteristic into improved broadly adapted sorghum germplasm.

Host Country Collaboration and Work Sites

Purdue University, W. Lafayette, IN; Niamey, Niger; Wad Medani and Khartoum, Sudan. LDC linkages already established at other locations (i.e. Hyderabad and Zimbabwe) will be continued, but we anticipate concentrating and expanding the program primarily in West and East Africa. Sam Mukuru and Vartan Guiragossian, both with ICRISAT in Kenya, will cooperate in screening cold tolerant sorghum for high elevations in East Africa.

Research Procedures

Much of the breeding activities will be conducted in Niger, Sudan, and also with the ICRISAT Southern Africa and East Africa regional centers. Gebisa will continue his collaboration with the Sudan and Niger on Striga tolerance and drought tolerance. Axtell will focus on cold tolerance screening in Kenya and the Highlands of East Africa. Considerable time and effort will be

spend working with Sudanese and Nigerien scientists on grain quality using pedigree breeding as well as population and hybrid development. A major effort will be made to develop A&B lines with good grain quality, striga tolerance, drought tolerance which are adapted to Sudan and Niger. Breeding for good grain quality and high digestibility in elite sorghum cultivars which also have African adaptability, good yield and other needed agronomic traits will be continued. 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. Screening and trials will be conducted at 3 locations in Niger as well as in Sudan. Training M.S. and Ph.D. LDC students will continue as in the past.

Research Accomplishments

Germplasm Development

Development of sorghum germplasm for LDC utilization. It impossible to know exactly how widely germplasm is utilized, but a few examples will be mentioned.

A Purdue variety released locally as ICA-Nataima is the most widely grown sorghum variety in Colombia. ICA-Nataima is also grown extensively in Peru and Bolivia, but data on the area grown is not available.

Purdue/Texas A&M germplasm selected from BC1 and BC2 cycles of the Texas/USDA sorghum conversion program are widely used by ICRISAT and also by the all India sorghum breeding programs.The segregating materials were selected at Purdue and distributed through the Purdue International Sorghum Trials. Two lines (P-954063 and P-954062) are the most widely used as parents but many others are used extensively. These materials form part of the basis for much of the ICRISAT SEPON nursery which is successfully being used in many LDCs.

Sorghum random mating populations developed at Purdue form the base together with Nebraska populations for many of ICRISAT's sorghum populations.

New A & B lines with good food grain quality have been released and at least one has excellent potential in East Africa according to Dr. Brhane (P-954066). Progeny from crosses between P-954066 and TX 623 have been sterilized and provide good potential for food grain quality A & B lines for East Africa.

Three Purdue lines have been released and are widely used in Pakistan.

Three Purdue lines and one Texas line have recently been released in Kenya. No data is available yet on how widely used.

An excellent source of cold tolerance and seedling vigor has been identified from Chinese sorghum lines. Sorghum has been widely grown in Northern China for 2000 years and good seedling vigor under cool conditions is available in many local Chinese varieties.

An excellent Purdue drought tolerant line (P-898012) has been identified by Gebisa in Sudan and confirmed by Dr. Rosenow.P-898012 is currently being used extensively at several stations for development of drought tolerant sorghum varieties.

Several high lysine sorghum varieties derived from crosses between P-721 opaque and elite sorghum varieties have been developed. Significant progress in yield and kernel modification have been made, but none are good enough yet for release.

Several food grain sorghum populations have been developed and released to LDC cooperators.

This list provides some examples of Purdue sorghum germplasm contributions but represents only a partial list of germplasm utilized in LDCs.

Research Findings Relevant or Available for Immediate Use:

Traditional food processing technologies in East Africa improve nutritive value of high tannin sorghums. High tannin sorghum [*Sorghum bicolor* (L.) Moench] is grown in many regions where birds and fungi causing grain mold are major production constraints. The objective of this study was to evaluate the effectiveness of two traditional sorghum processing methods in improving the digestibility of high tannin grain. Kabale, a Uganda variety of high tannin sorghum, was treated with wood-ash according to a Uganda village method. This removed over 97% of the tannin. *In vitro* pepsin digestibility of treated Kabale was as high as that of the low tannin control grain. Rats fed with wood-ash treated, high tannin BR64 grain showed significantly higher weight gains than those fed with untreated BR64. A non-alcoholic beverage, Obushara, and an alcoholic beverage, Omuramba, made from high tannin, ash-treated grain also had *in vitro* digestibility values equal to those found with low tannin sorghum. Mumbala, or local magadi, is a mineral soil found in abundance in Kilimanjaro, Tanzania. The potential for its use to detoxify sorghum tannins was tested. A water extract from magadi (pH 9.7) increased the *in vitro* pepsin digestibility of a high tannin sorghum variety IS 1291 by 15%, similar to that of a tannin-free variety P721N. No significant change was

observed by treating the tannin-free variety. This implies a potential for use of magadi to improve the nutritive value of high tannin sorghums.

Kernel characteristics and protein fraction changes during seed development of high-lysine and normal sorghums. Changes in seed characteristics and the proportions and electrophoretic mobilities of Landry-Moureaux (L-M) endosperm protein fractions of high-lysine opaque and normal sorghums were followed during kernel development. Seed weight and volume increased steadily through 45 days after half-bloom for normal but plateaued a week earlier for opaque. Percentage embryo of whole seed increased similarly for both lines from an average 2.1 to 8.1% during development. Normal endosperm protein declined 0.7% during seed maturation while that of opaque increased 1.2%. L-M fraction I (albumins and globulins) differed little among lines. Fraction II plus III (total kafirin) accumulation in opaque plateaued two weeks before normal, whereas fraction IV plus V (total glutelin) increased more rapidly in opaque than normal endosperms. Sodium dodecyl sulfate-polyacrylamide gel electrophoresis of endosperm protein fractions showed few or no differences in banding patterns. It is concluded that the opaque gene (O) manifests itself in a pleiotropic manner with respect to endosperm proteins through quantitative rather than qualitative shifts in major fractions. The enhanced lysine content of opaque results primarily from an increase in relatively lysine-rich glutelins and decrease in lysine-deficient kafirins.

In vitro digestibility and amino acid composition of pearl millet (*Pennisetum typhoides*) and other cereals. The purpose of this study was to compare *in vitro* digestibility, protein distribution patterns, and amino acid composition of pearl millet with other major cereals. Digestibility values for the pearl millet varieties were higher than that of sorghum and comparable to that of maize. In contrast to sorghum, digestibility of pearl millet and maize did not decrease significantly upon cooking. Protein distribution patterns of uncooked pearl millet and shifts in the different fractions as a result of cooking also resembled that of maize and not sorghum. The amino acid profile of pearl millet is more favorable than that of normal sorghum and normal maize and is comparable to the small grains, wheat, barley, and rice. On the basis of these finding, it appears that pearl millet is a nutritious and well-digested source of calories and proteins for humans.

Combining ability of high lysine sorghum lines derived from P-721 opaque. The P-721 opaque (P-721Q) endosperm of sorghum [*Sorghum bicolor* (L.) Moench] has better protein quality (lysine/protein ratio) than normal sorghum endosperms. However, sorghum with opaque endosperm has not been readily accepted for wide cultivation due to its lower yield potential and some other problems associated with its soft endosperm. The objective of this study was to determine whether hybrids between high yielding opaque lines resulted in heterotic response for grain yield and kernel weight without loss in protein quality. Each of 10 high lysine lines derived from P-721Q was mated with the same three cytoplasmic male-sterile lines, also derived from P-721Q by backcrossing to sterile cytoplasm. The F1 hybrids derived from these matings were field-evaluated for grain yield, 100-kernel weight, protein concentration, and lysine concentration in protein on a fine-silty, mixed, mesic Typic Haplaquoll. Significant differences among general combining ability effects were observed for all characters except grain yield, whereas significant differences among specific combining ability effects were observed for only grain yield. Correlation between grain yield and protein in the 30 hybrids was negative and significant ($r = -0.63$); correlation between grain yield and lysine concentration in protein was also negative but not significant. The best male parent, R-3 (P-850314), also produced hybrids with the highest lysine concentration. Among the female parents. A-3 (P-851063) gave hybrids with the highest protein quality. The best single-cross hybrid, A-3 x R-3, for agronomic and protein quality, had 35% more lysine than the normal cultivar P-721N and yielded as much as the NK-180 check. Thus, this hybrid has the potential of substituting for other expensive protein and lysine sources in the semiarid tropics.

Protein and lysine levels in developing kernels of normal and high-lysine sorghum. Farmers in Ethiopia consume high-lysine sorghums strictly at immature stages of grain development. The protein and lysine levels in the endosperm and germ fractions of developing kernels of eight high-lysine and normal sorghum varieties at 21, 31, and 61 days after flowering were evaluated to determine changes in protein quality and content at these stages. At 31 days after flowering (the late dough stage), high-lysine sorghums had higher endosperm protein and higher endosperm lysine contents than normal sorghums. The highest endosperm lysine content of all genotypes was also observed at the late dough stage. These findings suggest a nutritional basis for the tradition of farmers in Ethiopia to consume high-lysine varieties exclusively at the milk dough and late dough stages of grain development.

Dry-matter accumulation and carbohydrate composition in developing normal- and high-lysine sorghum grain. Eight sorghum [*Sorghum bicolor* (L.) Moench] varieties (four high lysine and four normal) were evaluated 21, 31, and 61 days after flowering (DAF) for changes in total dry-matter accumulation and carbohydrate composition. The chemically induced high-lysine mutant P-721 opaque was not significantly different from P-721 normal in whole-kernel weight, endosperm

weight, germ weight, germ percent, and moisture percent as well as in carbohydrate composition. High-lysine natural mutants from Ethiopia (IS 11758, IS 11167, YM-3) showed lower kernel weight, lower endosperm weight, higher percent germ, and higher percent moisture than normal sorghum varieties at all stages of grain development. More significantly, distinct differences were found in the overall carbohydrate profile and the rate of starch synthesis, as well as the level of total sugars at the various stages of grain development in the Ethiopian high-lysine and Ethiopian normal varieties. Between 21 and 31 DAF, starch synthesis was delayed and a concomitant accumulation of sugars occurred in the high-lysine sorghums. The level of sugars was the highest at the late-dough stage (31 DAF), providing a nutritional basis for the Ethiopian tradition of consuming the high-lysine varieties at the late-dough stage.

Progress (last two years)

A detailed report on research progress can be obtained from the recent INTSORMIL Annual Reports. The purpose of this page is to provide a summary capsule of some principle areas of research success which have important implications in LDCs and the US.

High Tannin Sorghums - It has been known for many years that people in East Africa consume and thrive on high tannin grain sorghums in spite of the fact that the research data shows substantial antinutritional effects of the tannins. We now understand that local village processing of these high tannin sorghums in LDCs eliminates the antinutritional effects of tannins. The work by Dr. S.Z. Mukuru of ICRISAT during his sabbatical leave at Purdue in John Axtell's laboratory showed that alkali processing with wood ash is a very effective way to detoxify the tannins. This is a widely used procedure which solves a potentially serious nutritional problem in Eastern Africa. The implications for U.S. agriculture are that we could expand the area of cultivation into the Southeast which is a feed grain deficite area by the utilization of alkali processing procedures based on Mukuru's work and developed by Larry Butler. Sorghums are not as widely grown in the Southeast as they should be because grain molds and weathering destroy the low tannin sorghums and the poultry industry has to date refused to use the high tannin sorghums. There is an excellent opportunity to exploite the research for the benefit of U.S. agriculture.

Protein Quality and Digestibility Studies - Kirleis, Ejeta, and Axtell have made significant progress on the improvement of sorghum nutritional value using modern techniques in molecular biology as well as traditional genetic and breeding techniques. We know it is now possible to improve the protein quality of sorghum grain up to the level found in wheat grain. Protein digestibility can now be improved by processing technology and there is hope that a breeding solution to the digestibility problem in sorghum may be in the near future. This research offers significant promise to make sorghum a higher value feed grain in the U.S. and in the export market.

Cold Tolerance - Sorghum is a tropical crop which lacks seedling vigor under cool temperate conditions in the spring. This limits utilization of the sorghum crop in temperate zones where it is grown in competition with maize which has much better seedling vigor under cool spring conditions. Many of these areas are drought prone and sorghum would be the cereal grain of choice if seedling vigor could be improved. We have identified sources of cool tolerance in sorghum which are better than any previously available. These sorghums come from Northern China, where sorghum was introducted by the Budhists two thousand years ago from India. The Chinese have selected these sorghums for cool temperate conditions and have dramatically improved their ability to grow competitively in temperate conditions. These sources of sorghum germplasm are being introgressed into U.S. sorghum cultivars and the results should be to move the range of sorghum North into the Southern cornbelt where drought tolerance on lighter soils is a problem for corn production.

Molecular Basis of Drought Resistance in Sorghum - The mechanisms of drought resistance in sorghum have been widely studied. We have incorporated techniques from molecular genetics to improve our understanding of how sorghum plants can tolerate drought conditions. We are using transposon tagging in sorghum to identify major genes for drought resistance in sorghum. We are using mutagenesis as a mechanism to derive isogenetic drought susceptible and resistant lines for studies by physiologists, biochemists, and molecular biologists. We are developing and RFLP map for sorghum and millet to use for studies of drought resistance, cold tolerance and striga resistance. The RFLP map in sorghum to date containes approximately 45 markers and appears to be colinear with the maize chromosome map. The procedure in sorghum is greatly facilitated by the evident homology between maize and sorghum since the maize unique sequence probes hybridize very well with sorghum genes. Recent Progress and Success

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: Breeding Sorghum for Increased Nutrional Value

Project Leader: John Axtell **Project Number:** PRF-103

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=PRF103 -- ----------						
Staff Salaries & Benefits	19.80	20.79	21.78	22.57	23.76	108.70
Post Doctorates	7.60	7.98	8.36	8.66	9.12	41.72
Graduate Students	8.00	8.00	8.00	9.00	9.00	42.00
Other Salaries	9.90	10.40	10.89	11.29	11.88	54.36
Supplies	8.60	9.03	9.46	9.80	10.32	47.21
Equipment	3.10	3.26	3.41	3.53	3.72	17.02
Travel	11.20	11.76	12.32	12.77	13.44	61.49
Other Direct Costs	7.70	8.09	8.47	8.78	9.24	42.28
Overhead	24.40	25.62	26.84	27.82	29.28	133.96
	100.30	104.93	109.53	114.22	119.76	548.74

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=PRF103 -- ----------						
University Staff	6.27	6.58	6.91	7.26	7.62	34.65
Staff Benefits	1.70	1.78	1.87	1.97	2.07	9.39
Post Doctorates	22.49	23.62	24.80	26.04	27.34	124.28
Other Salaries	15.06	15.82	16.61	17.44	18.31	83.23
Fringe Benefits	5.98	6.28	6.59	6.92	7.27	33.04
Supplies	3.80	3.99	4.19	4.40	4.62	21.00
Travel	7.35	7.72	8.10	8.51	8.93	40.61
Other Direct Costs	8.00	8.40	8.82	9.26	9.72	44.19
Overhead	34.35	36.07	37.87	39.77	41.75	189.82
	105.00	110.25	115.76	121.55	127.63	580.19

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=PRF103 -- ----------						
University Staff	5.97	5.97	5.97	5.97	5.97	29.86
Staff Benefits	1.62	1.62	1.62	1.62	1.62	8.09
Post Doctorates	21.42	21.42	21.42	21.42	21.42	107.10
Other Salaries	14.35	14.35	14.35	14.35	14.35	71.73
Fringe Benefits	5.69	5.69	5.69	5.69	5.69	28.47
Supplies	3.62	3.62	3.62	3.62	3.62	18.10
Travel	7.00	7.00	7.00	7.00	7.00	35.00
Other Direct Costs	7.62	7.62	7.62	7.62	7.62	38.08
Overhead	32.72	32.72	32.72	32.72	32.72	163.58
	100.00	100.00	100.00	100.00	100.00	500.00

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Development and Enhancement of Sorghum Germplasm with Sustained Tolerance to Drought, Striga, and Grain Mold.

Project Number PRF-107
Dr. Gebisa Ejeta
Purdue University

Collaborating Institutions

Host Country

Mr. Issoufou Kapran, INRAN Sorghum Breeder, Niger
Dr. John Clark, Purdue/Niger Cereals Project, Niamey, Niger
Mr. Soumana Idrissa, INRAN, Director General, Niamey, Niger
Dr. Abdellatif M. Nour, Sorghum Breeder, ARC/Gezira Research Station, Sudan
Dr. Osman Ibrahim, Sorghum Breeder, ARC/Gezira Research Station, Wad Medani, Sudan
Dr. Hilu Omer, Sorghum Pathologist, ARC, Sudan
Dr. Abdelgabar, Babikher, Striga Specialist, ARC, Sudan
Dr. Sit Badi, Food Research Centre, Sudan
Dr. R. Jambunathan, Head of Biochemistry Department, ICRISAT, India
Dr. Dallas Oswalt, Chief Training Officer, ICRISAT, India
Dr. Lee House, SADCC, Bulawayo, Zimbabwe
Mr. Joseph Mushonga, Harare, Zimbabwe
Dr. Tunde Obilana, SADCC Sorghum Breeder, Zimbabwe
Dr. Emmanuel Monyo, SADCC Sorghum Breeder, Zimbabwe
Dr. Vartan Guiragossian, Sorghum Breeder, ICRISAT, East Africa, Kenya
Dr. Sam Mukuru, Sorghum Breeder, ICRISAT, East Africa, Kenya

U.S.

Dr. Larry Butler, Dept. of Biochemistry, Purdue University
Dr. Allen Kirleis, Dept. of Food Science, Purdue University
Dr. John Rogler, Dept. of Animal Science, Purdue University
Dr. John D. Axtell, Dept. of Agronomy, Purdue University
Dr. John Sanders, Dept. of Agricultural Economics, Purdue Univ.
Dr. Herm Warren, Dept. of Botany & Plant Pathology, Purdue Univ.
Dr. Fred Miller, Texas A&M University
Dr. Darrel Rosenow, Texas A&M University
Dr. Lloyd Rooney, Texas A&M University
Dr. Richard Frederiksen, Texas A&M University
Dr. George Teetes, Texas A&M University
Dr. William Stegmeier, Kansas State University
Dr. Lynn Gourley, Mississippi State University
Mr. David Andrews, University of Nebraska
Dr. Jerry Eastin, University of Nebraska

Program Objective

To strengthen sorghum research capabilities of collaborating scientists in Less Developed Countries, thereby accelerating the rate at which the production and utilization of sorghum is enhanced.

Research Objective

To develop and enhance sorghum germplasm with increased levels of resistance to drought, *Striga*, and grain mold infection.

To characterize traits associated with resistance to drought, *Striga*, and grain mold in sorghum.

To study the inheritance of traits associated with resistance to drought, *Striga*, and grain mold in sorghum lines.

To elucidate mechanisms of resistance to drought, *Striga*, and grain mold in sorghum.

To develop and evaluate alternative breeding and selection strategies for efficient manipulation of these traits.

Introduction

The overall constraints and objectives addressed by PRF-107 continue to be in the areas of drought, grain mold, and striga resistance. These are major constraints of sorghum production in many developing countries that need continued interdisciplinary efforts to accumulate useful research information.

Drought stress is perhaps the most important constraint to sorghum production in both Niger and Sudan, two African countries where Project PRF-107 has the most involvement. Sorghum germplasm accessions with good levels of drought tolerance have not been widely used in research programs in Niger and Sudan. Practical methodologies for screening sorghum germplasm for drought tolerance have been lacking. Breeding efforts to incorporate drought tolerance with higher than average yield potential are limited by a lack of rapid field screening procedure as well as lack of knowledge of sources of sorghum germplasm possessing useful traits.

Sorghum grain mold (weathering) is a major constraint limiting the spread of improved high yielding sorghum varieties in many parts of Africa. Grain molds are also of significant importance in the USA. Only a few resistant sources have been identified and the physiochemical mechanisms contributing to the resistance have been unknown.

Striga hermonthica, a parasitic weed, is a major production constraint of sorghum in both Sudan and Niger, as it is in many countries in tropical Africa. Various control measures including the use of resistant varieties, improved cultural practices, and use of high level of nitrogen fertilization have been suggested. Few resistant sorghum varieties have been identified. However, the inheritance and mechanism of *Striga* resistance in sorghum are not known. The efficiency of integrating various control measures in alleviating *Striga* infestation has also not been sufficiently investigated.

Objectives Related to Constraints

We have on-going research, via graduate students thesis projects, in all the three production constraints identified (i.e. *Striga*, drought, and grain mold resistance). Specific host country collaborative projects to be undertaken are described in sections that follow.

Host Country Collaboration and Work Sites

PRF-107 project activities are focused primarily in two African countries, namely Niger and Sudan. In both countries, there is a growing interest in both the development and evaluation of F_1 sorghum hybrids. We have developed new elite pollinator lines for evaluation in hybrid combination in both Niger and Sudan.

In Niger the major collaboration is with Mr. Issoufou Kapran who returned last year from graduate training at Purdue. He is stationed at the Tarna Research Station outside Maradi, where he is in charge of the sorghum breeding program. We have developed joint programs in germplasm development for hybrids, identify superior drought tolerant sorghum lines and hybrids, and evaluation of sorghum hybrids synthesized from *Striga* resistant parents. In addition, we have formulated projects to address *Striga* control using an integrated approach (resistant variety, fertilization, and legume intercropping) and to investigate problems associated with stability of resistance to *Striga* in some sorghum lines. For this we collaborate also with Charif Ari, INRAN agronomist. We made a collection of *Striga* "strains" in the summer of 1988 from different regions in Niger. Accordingly, we designed experiments to purify strains and cross inoculate strains to different varieties at different infection levels and evaluate inoculum by cultivar interaction. An array of advance generation progenies from our *Striga* and drought programs will be also evaluated in several countries in Africa.

Major collaboration in Sudan is with Drs. Osman Ibrahim and A.T. Babikher. Collaboration with Dr. Babikher is primarily in the area of *Striga* research, whereas with Dr. Ibrahim joint projects include the development and evaluation of parental lines and hybrids, development of germplasm with increased level of drought resistance through intercrossing of local and exotic adapted germplasm, and identification of genotypes with broad/stable resistance to *Striga*.

Collaborative work in Sudan is primarily at Wad Medani for *Striga* and Gadembalia and Wad Medani for drought evaluation.

Research Procedures

The development and enhancement of sorghum germplasm with increased levels of resistance to drought, *Striga*, and grain mold will be done using a large pool of sorghum germplasm available in the program. New variants are generated primarily via conventional crossing

and intercrossing among parental lines selected on the basis of inherent trait expression. Field and laboratory screening techniques are employed. Field screening for drought is accomplished through a Collaborative Research Support Program (CRSP), with cooperators in Sudan and Niger in Africa and also at the Texas A&M Experiment Station, Lubbock, West Texas, using their rain-out shelter facilities. Field screening for resistance to *Striga* is carried out in Africa (Niger and Sudan). Facilities at the Agronomy Farm, Purdue University are used for field screening against grain mold infection. Laboratory screening procedures are also carried out at Purdue University as described below.

Grain mold and weathering resistant sorghum lines identified in the screening program are routinely characterized on the basis of plant color (tan, red, purple), grain pericarp color (white, yellow, brown, etc.) and total tannin levels (low, high). Each group is assayed for levels of procyanidins and other low molecular weight phenols using procedures developed by Dr. L. Butler to check if resistant sorghum lines have higher than normal concentration of a particular group of phenolic compounds.

Sorghum lines developed in the *Striga* resistant breeding program will be characterized for presence or absence in the roots, shoots, and seeds of various phenolic compounds, namely flavan-4-ols, proanthocyanidins, and total phenols. The use of tissue culture to generate variants with varying capacity in their production of phenolic compounds and quinones is also under investigation in collaboration with Dr. L. Butler.

Intercrosses of known drought resistant and susceptible lines, segregating and advanced progenies, as well as isogenic lines will be generated for cooperative research effort on drought resistance mechanisms in sorghum. Characterization of such variants will include primarily the composition of organic solutes in leaf tissues. Shoot apical tissues will be evaluated for glyinebetaine (betaine), amino acids (proline), sugar, sugar alcohol and organic acid composition as a function of tissue water relations. In addition, sorghum germplasm will also be evaluated for leaf and root morphology as well as physiological traits (turgor pressure, photosynthetic and transpirational capacity etc.) associated with water use efficiency.

Genetic studies will be conducted with appropriate germplasm generated using parental lines with contrasting features for as many of the traits (listed above) as time and resources allow.

In cooperation with an interdisciplinary team of research scientist (McKnight Foundation Grant) at Purdue University studies on morphological, physiological, and biochemical mechanisms associated with drought resistance will be undertaken as partially described above. The contribution of this project to this team effort will be in generating appropriate germplasm, determine inheritance, and establish drought stress reactions to correlate with other complementary data from the team. A similar approach will be used on the mechanisms of resistance to *Striga* and grain mold in cooperation primarily with Dr. L. Butler.

Alternative breeding methods including recurrent selection schemes are evaluated to efficiently select for the above mentioned traits. There is a high positive correlation between maturity, height and grain yield in sorghum. By use of a restricted selection index we plan to select for increased grain yield in a random mating population of sorghum while holding maturity and plant height of the population constant.

Overall, I anticipate the integration of new molecular biology techniques into the ongoing breeding program. The immediate interest is in the area of restricted fragment linked polymorphism (RLFP) analysis as markers of genes and gene products that correlate with resistance to *Striga*, drought and grain mold infection. The potential to trace specific chromosomal segments through RFLP analysis as "cites" for gene or gene products of interest is a technology that needs to be exploited.

Measures of Success

I believe the measure of success in collaborative breeding and genetics project such as PRF-107 will have to be made as follows:

The identification and use of germplasm developed in the program by collaborating host country programs as well as the US seed industry.

The strengthening and maturation of the collaborating breeding programs as full-fledged and functional research entities.

The generation of new research information as evidenced by journal publication and reports.

The training of graduate students.

Recent Progress of Work

We have made modest progress in many of our research fronts in sorghum breeding and genetics.

Through earlier work in Sudan and via the Ph.D. thesis research of Dale Hess in Niger, we identified a highly *Striga* resistant sorghum line, SRN-39. We have established that SRN-39 is significantly more resistant to

Striga hermonthica than any sorghum cultivar reported to date and that this resistance is simply inherited possibly controlled by one or two major genes. We have found that SRN-39 is also resistant to *Striga asiatica*. Hence the genetic resistance of SRN-39 is stable across both species and strains of *Striga*.

We have generated advanced breeding lines from crosses of SRN-39 and other *Striga* tolerant lines. These progenies combine excellent agronomic and evident food quality parameters and are expected to possess cumulative factors for *Striga* resistance from both parents. We are now in the process of developing laboratory assays for successful screening of genotypes for resistance to *Striga*.

We studied the effects of integrated cultural practices including varietal resistance, urea application and mode of tillage on *Striga* infestation in Niger. Varietal resistance was found to be the most effective treatment independent of other inputs. Early season application of urea delayed *Striga* emergence, reduced infestation, and increased grain yield. Tillage improved water infiltration in a dry year but resulted in increased *Striga* infestation in a year with above average rainfall.

We have identified two sorghum lines P-898012 and P-954035 that have superior levels of drought tolerance. Testing under controlled environments, we have found that these sorghum lines possess both pre-flowering and post-flowering drought tolerance. Such genotypes are very rare in sorghum germplasm. We also observed that these two sorghum lines contained a much higher level of osmoregulatory compounds compared to other sorghum and corn genotypes and that this trait was heritable. We are currently using these genotypes as the basis for a University-wide interdisciplinary research to elucidate possible mechanisms of drought resistance.

Pre-harvest grain molding is a major constraint limiting the spread of improved sorghum varieties and hybrids in the USA and other parts of the world. As production of sorghum hybrids expands toward the humid Southeast and the Northern parts of the United States, the need for sorghum germplasm with genetic resistance to Pre-harvest molds has become important. Only few resistant genotypes have been identified and the physiochemical mechanisms contributing to the resistance are unknown. However, we have now established in characterization of grain mold resistant traits that a low molecular weight flavanoids generically known as Flavan-4-ols show the strongest correlation with resistance. This will be very useful in breeding effort to develop sorghum germplasm with increased levels of grain mold resistance.

Our collaborative efforts with colleagues in Africa have also made significant progress in developing sorghum germplasm with potential utility both in the U.S. and Africa. Several breeding lines derived from crosses of elite U.S. parental lines with drought resistant germplasm from Sudan have showed excellent potential as new male parents for hybrids in cooperative trials conducted in Sudan, Niger, Indiana and Texas. Ten of these lines have been selected for release in 1989.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: Development and Enhancement of Sorghum Germplasm with Sustained Tolerance to Drought, Striga and Grain Mold

Project Leader: Gebisa Ejeta **Project Number:** PRF-107

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=PRF107	--	----------				
Staff Salaries & Benefits	22.77	23.96	25.15	26.14	27.52	125.54
Post Doctorates	8.74	9.20	9.65	10.03	10.56	48.18
Graduate Students	9.00	9.00	10.00	10.00	11.00	49.00
Other Salaries	11.39	11.98	12.57	13.07	13.76	62.77
Supplies	9.89	10.41	10.92	11.35	11.95	54.52
Equipment	3.57	3.75	3.94	4.09	4.31	19.66
Travel	12.88	13.55	14.22	14.78	15.57	71.00
Other Direct Costs	8.86	9.32	9.78	10.16	10.70	48.82
Overhead	28.06	29.52	30.99	32.21	33.92	154.70
	115.16	120.69	127.22	131.83	139.29	634.19

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=PRF107	--	----------				
University Staff	48.04	50.44	52.96	55.61	58.39	265.43
Staff Benefits	13.02	13.67	14.35	15.07	15.82	71.93
Grad Students	8.85	9.29	9.75	10.24	10.75	48.88
Fringe Benefits	0.13	0.14	0.14	0.15	0.16	0.71
Supplies	1.60	1.68	1.76	1.85	1.94	8.82
Travel	4.20	4.41	4.63	4.86	5.11	23.21
Other Direct Costs	5.78	6.06	6.37	6.69	7.02	31.91
Overhead	39.15	41.11	43.16	45.32	47.59	216.33
	120.75	126.79	133.13	139.78	146.77	667.22

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=PRF107	--	----------				
University Staff	45.75	45.75	45.75	45.75	45.75	228.75
Staff Benefits	12.40	12.40	12.40	12.40	12.40	61.99
Grad Students	8.42	8.42	8.42	8.42	8.42	42.12
Fringe Benefits	0.12	0.12	0.12	0.12	0.12	0.62
Supplies	1.52	1.52	1.52	1.52	1.52	7.61
Travel	4.00	4.00	4.00	4.00	4.00	20.00
Other Direct Costs	5.50	5.50	5.50	5.50	5.50	27.50
Overhead	37.29	37.29	37.29	37.29	37.29	186.43
	115.00	115.00	115.00	115.00	115.00	575.00

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The Enhancement of Sorghum Germplasm For Stability, Productivity and Utilization

Project TAM-121
Fred R. Miller
Texas A&M University

Collaborating Institutions

Host Countries

G. Vega, Institute Nacional de Investigaciones Agricolas, Celaya, Mexico
Miguel Hernandez, Institute Nacional de Investigaciones Agricolas, Celaya, Mexico
L. Herra Romero, Institute Nacional de Investigaciones Agricolas, Celaya, Mexico
M. Alvarez, Institute Agronomia Nacional, Caacupe, Paraguay
Wilhem Giesbrecht, Institute Agronomia Nacional, Caacupe, Paraguay
F. Gomez and D. Meckenstock, Secretaria de Recursos Naturales, Escuela Agricola Panamericana, Honduras
Lee House, T. Oblina, ICRISAT Sorghum/Millet Improvement Program, Bulawayo, Zimbabwe
Sansan Da, C. Pattenayak, Institute de Recherches Agronomiques,Bobo Dioulasso, Burkina Faso
M. Traore, L. Traore, Institute Economie Rurale, Bamako, Mali
J. Clark, Mousa Adamou, Purdue/Niger Cereals Research Project, Niamey, Niger
Abdel Latif, M. Nour, Agricultural Research Corporation, Wad Medani, Sudan
N. Ochanda, Ministry of Agriculture, Alupe Agricultural Research Station, Busia, Kenya
M. Chisi, Bhola Nath, Ministry of Agriculture, Mount Makulu Research Station, Chilanga, Zambia
R. Kenga, Ministry of Agriculture, Cameroon
M. Galiba, Global 2000, Accra, Ghana

U.S.

D.T. Rosenow, Texas A&M Agricultural Experiment Station, Lubbock, TX
L.W. Rooney, Department of Soil & Crop Sciences, Texas A&M University, College Station, TX
G. Teetes, Department of Entomology, Texas A&M University, College Station, TX
R.A. Frederiksen, Department of Plant Pathology, Texas A&M University, College Station, TX
R. Toler, Department of Plant Pathology, Texas A&M University, College Station, TX
L. Clark, Texas A&M University, Vernon, TX
R. Newton, Texas A&M University, College Station, TX
W. Jordan, Department of Soil and Crop Sciences, Texas A&M University, College Station, TX
John Axtell, Department of Agronomy, Purdue University, West Lafayette, IN
G. Ejeta, Department of Agronomy, Purdue University, West Lafayette, IN
Larry Butler, Department of Biochemistry, Purdue University, West Lafayette, IN
Allen Kirleis, Department of Food Science, Purdue University, West Lafayette, IN
Dr. Jerry Eastin, Department of Agronomy, University of Nebraska, Lincoln, NE
Professor David Andrews, Department of Agronomy, University of Nebraska, Lincoln, NE
Dr. Lynn Gourley, Department of Agronomy, Mississippi State University, Mississippi State, MS

Project Objectives

Develop through enhancement procedures appropriate 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.

Determine the heterotic germplasm pools (subspecies) within sorghum and characterize the constraints to yield improvement among West African cultivars (guineese types) and evaluate the germplasm availability suitable for enhancement.

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Determine the relationship between yield and photosynthetic ability.

Assessment and utilization of physiological measures of drought resistance to enhance sorghum for local and international utilization.

Distribute improved lines, hybrids and early generation populations possessing superior productivity to collaborating LDC's where sustainable agriculture is necessary.

Develop specific germplasm pools and resources for use in impacting a sustainable agriculture in Latin America, South America, and Africa.

Introduction

A sustainable agriculture is dependent upon an acceptable yield of sorghum in those areas of the world which are constrained by risks associated with unstable productivity and cultivars which are incapable of offering solutions to those constraints. The overall objective of this project is to reduce risks through the creation of enhanced germplasm pools, lines and hybrids (properly evaluated) with stable potentially high yield, good food quality and a high level of resistance to significant diseases, pests, and stress factors while maintaining acceptance and nutritional quality. Sorghum is generally grown under less favorable environmental conditions in areas of the world where human nutrition levels are at marginal levels of acceptability. The constraints to productivity which are addressed through this project are genetic limitations to yield, disease resistance, drought, inadequately developed germplasm resources, unimproved food quality and unavailability of improved seeds.

Because sorghum is a native species to much of Africa where natual resources must be conserved, it is evident that its hardy growth habits will have limited impact upon the environment as we enhance the available germplasms.

Sorghum production is expanding in Latin America because of the recognition that sorghum is a viable food, feed, and energy resource. Mexico has limited areas of high yield sorghums, but much of the country is marginal for production of current materials where drought, both high and low temperatures and diseases are constraints. Similarly, major food limitations occur with maize production and sorghum is a viable supplement to insuring a food supply in Mexico and throughout Latin America. Problems with drought, diseases, adaptation, high and low temperatures and limitations of food quality among existing materials necessitate involvement of INTSORMIL. Perhaps most important to the distribution of a broad base of sorghum technology is the role that Mexico can play as a collaborator. Through Mexico's adaptation and assimilation of sorghum technology, such technology is made more easily available to the rest of Latin America. Materials utilized in Mexico are therefore evaluated for stepwise enhancement and transfer to Guatemala, El Salvador, etc. and are reinforced in Honduras. Our involvement with Honduras (Prime Site) and collaboration in other Latin American countries increases the success of our program of germplasm conservation, improvement and utilization.

South America offers a new horizon for sorghum production. Brazil, Argentina, and a few areas have developed production potentials, but with constraints of grain quality, diseases, insects, grain weathering and yield consistency. Paraguay sorghum production is increasing and has major potential. Availability of improved seedstocks with adequate disease resistance and acceptable food quality are major limitations to reasonable expansion. Downy mildew, anthracnose, and other diseases limit production throughout South America and through collaboration sources of resistance in higher yielding materials can be introduced. Enhanced germplasm pools which are evaluated cooperatively in this area are moved to other regions and programs.

In Tanzania, Kenya, Ghana, Sudan, Niger, and Mali, the overall situation is different: because photoperiod sensitivity is required in some cases, but food quality is paramount. Materials possessing drought resistance, food quality, and disease resistance from Texas have shown good adaptation. Using the means of local collaborators and other programs, some impact on food quality, yield, and disease resistance can be made in Tanzania, Kenya, Ghana and Mali.

In Uganda, sorghum is the second most important cereal and is used for food, beer, and livestock fodder. The major constraints are yield with stability of production and adapted cultivars possessing resistance to diseases and insects while maintaining excellent food quality factors, as well as meeting the needs of both larger plantings and small farms. Lines and hybrids have potential, but both must fit the rainfall/photoperiod constraints. In Cameroon, the same situation exists. Hybrid production represents good potential. But there has been a decline in yield and hybrids are seen as a way to produce greater returns. Grain quality sufficient for human consumption and nutrition must be the constraint addressed within any hybrid program. In Zambia, sorghum production and breeding research have improved with the program of Dr. Bhola Nath. The constraints which need attention are yield, stability of production, tolerance to acid soils, food quality, and brewing quality. It is apparent that sorghum materials developed, enhanced, and exchanged with these programs and the others (Niger, Mali, Sudan,

Ethiopia, Burkina Faso) through TAM121 will have an impact.

Enhancing sorghums for productivity has received considerable attention in the U.S., but not until recently has food quality received recognition as a constraint. Stability of yield is important to all major constraints and to all sorghum productions whether in the U.S. or in LDC's. In order that progress can be made to improve sorghums potential for yield multiple diverse sites must be used in selections and screenings. This project in cooperation with other INTSORMIL activities will evaluate germplasm for yield, disease resistances and food quality across a wide range of environments. Enhancment of sorghum for stability, grain quality and productivity is multi-faceted. Genotypes must be developed which need further evaluation and selection under sustainable agriculture systems. By augmenting this research with LDC collaboration in Mexico, Honduras, Niger, Mali, Cameroon, Uganda, Tanzania, Kenya, Zambia, Ghana, Paraguay, and other countries, new superior materials will be identified to reduce risk to productivity. All of these programs are focal points and gauge the role of sorghum in broad regional activities. This international testing and evaluation system supports the breeding and selection criteria used in Texas.

Research Procedures

Elite germplasm possessing known adaptation type (TA-tropical adaptation; TE-temperate adaptation) will be crossed with locally adapted germplasm and selected for broader ranges of adaptation and stability. Emphasis will be placed on materials possessing higher levels of yield potential and disease resistance from TAM-122, TAM-124 and TAM-121.

- Crosses and F_1 generation in Texas
- Evaluation and selection will be done in Mexico, Honduras, Guatemala, El Salvador, Tanzania/Kenya, Zambia, Niger, Mali, Zimbabwe, South America (Brazil, Paraguay and Argentina), and People's Republic of China.
- Re-evaluation will be across Texas sites.

Introductions from LDC's, known sources of drought tolerance and elite germplasm materials, will be used to develop elite populations for selection of drought tolerance. Both field and laboratory screening procedures will be used to evaluate newly derived materials. As these materials are evaluated and determined to possess drought tolerance, they will be further evaluated for yield and food quality, as well as disease and agronomic stress resistance. Elite drought tolerant, non-senscent cultivars will be crossed to the best food quality sorghums to combine the traits.

- Crosses and initial selections are made in Texas
- Evaluations of drought tolerance are then made in multiple sites in Nueva Leon, Mexico; Tanzania, Mali, Niger, Sudan, Paraguay, Argentina and at several locations in Texas.
- Elite drought tolerant materials are assembled and re-evaluated for disease resistance in Texas disease nurseries.
- Progeny will then evaluated for food quality in trials in Honduras and Texas in 1989/94 and will be evaluated in Mali after preliminary evaluation in Meso-America.

Breeding materials (inbred lines and varieties) will be generated from crosses among various high yield potential materials, various disease resistance sources, agronomic elite lines, and food quality sources. Materials which will be screened and initially selected in large field disease adaptation nurseries will be advanced to international testing. Advanced generation materials are then incorporated into several standard, replicated trials for further critical and extensive comparative evaluations in selected locations in Texas, outside Texas and with collaborators. Materials possessing food quality or the potential are evaluated by TAM-126.

- Initial development - Texas
- Initial evaluation - Texas, Mexico (multiple locations), Paraguay, Honduras
- Secondary evaluation made in breeding programs of collaborators - Mexico, Honduras, Guatemala, Paraguay, Tanzania, Sudan, Kenya, Ethiopia, Burkina Faso, Niger, Zimbabwe, Uganda, and Cameroon.

Best known sources of multi-desirable traits (yield, adaptation, disease resistance, food quality, etc.) which are combined to produce F_1 hybrids either within specific types or among types will be evaluated in trials to compare adaptation, stability, and performance under diverse environmental situations.

- Accumulated data across sites for eliteness for specific traits in Texas from multi-collaborator associations.

- Produce hybrids, prepare trials and distribute

- Evaluation of elite materials for constraints Mexico (multi-locations), Honduras, Guatemala, Paraguay, Argentina, Brazil, Sudan, Tanzania, Kenya, Ethiopia, Zambia, Burkina Faso, Zimbabwe, Uganda, and Cameroon.

Germplasm from each of the taxonomic groups of sorghum will be combined by direct line X line crosses to establish test materials to determine heterotic pools within the species. Findings will allow the maximum heterosis in hybrids and in development. Stability of yield at higher yield levels will be addressed by studying crosses of West African guineese sorghums with other taxonomic groups. Both parental materials and F_1 hybrids will be evaluated for plant, panicle and kernel traits to determine components relating to stability.

- Sources of information and background - West Africa, (Mali, Niger, Kenya, and Tanzania, Sudan)

- Crosses and seed increases -- Texas, Puerto Rico and Honduras.

- F_1 hybrid trials and F_2 segregations -- Texas and Mali.

Using random mating populations resources, elite line crosses, F_1 hybrids, etc. this project will develop and distribute food quality materials for evaluation in selected food systems. In Mexico, using F_1 hybrids evaluate performance, acceptance, and yield of sorghums solely or in mixture with maize for tortilla quality and related foods. In Tanzania, Mali, Uganda, Cameroon, Zimbabwe, and Zambia, variable populations will be used for ugi or porridge like foods. There are two uniform trials which are intended for standardization; International Food Sorghum Trial (IFSAT) and International Food Sorghum Variety Trial (IFSVT).

- Generate and select food quality materials - Texas.

- Evaluate using NaOH and other techniques developed by students in Texas, Mexico, Honduras, Africa - work done in Texas.

- Evaluate tortilla quality and mixtures of sorghum/maize - University of Sonora, Mexico, and Honduras

- Evaluate t/ugali quality and other foods - Zimbabwe, Uganda

- Evaluate ugi quality (porridge foods) - Tanzania/Kenya

- Assemble data on performance and redevelop superior food quality populations - Texas

- Assess the headbug response to NaOH selections for food quality - Mali, Niger, Zimbabwe

Advanced generation selections from the development and sterilization of TA food quality materials which possess high yield potential will be crossed to drought tolerant lines high yield males and good food quality males for evaluation in Sudan and Honduras.

- Development, identification and sterilization - Texas

- Evaluation of performance as lines - Sudan and ICRISAT, Paraguay, Mexico, Honduras, and Zambia

- Production of hybrids on superior A-lines - Sudan, ICRISAT, Honduras, Paraguay, Mexico, Zambia, Zimbabwe, and Texas.

Materials identified from current and previous trials and evaluations in LDC's impacting constraints to productiv-ity will be crossed together and with elite local materials to develop early generation populations of superior germplasm. These F_2 and F_3 materials will be introduced into collaborative programs when desirable to provide further strength to the program base.

- Evaluation and selection for constraints

- Mexico - Food quality in white grain types; INTFAP and University of Sonora

- Mexico - Drought tolerance, disease resistance; yield, INTFAP and University of Nuevo Leon

- Honduras - Food quality, disease resistance,yield, drought tolerance; INTSORMIL and Res. Nat.

- Guatemala - Disease resistance, yield, drought tolerance, lodging resistance, and food quality; ICTA

- Paraguay - Disease resistance, yield, grain quality, weathering resistance; INA
- Tanzania/Kenya - Food quality, yield, maturity, drought tolerance; TARO and INTSORMIL
- Niger - Food quality, drought tolerance and yield; USAID
- Mali - Food quality, drought resistance, headbug resistance, and yield; ICRISAT
- Zambia - Food quality, yield and hybrid vigor; Ministry
- Miscellaneous - Ethiopia, Burkina Faso, and Zimbabwe

Advanced generation materials will be used to produce F_1 hybrids for use in standard, replicated yield trials which will allow collaborators to gather data on elite materials for potential release and distribution within country(s). These trials will be prepared, distributed and coordinated from this project. Assistance will be provided for data analysis and for increase of initial parental stocks identified as useful from the trials.

Stand establishment and early seedling drought resistance are major constraints to productivity in West Africa and much of the Sahel. U.S. breeding materials and hybrids are much inferior to locally adapted West African cultivars. Both seed and seedling characteristics will be measured to determine what contributes to superior establishment; i.e. water uptake, lower water content/ germination ratio, root development rates, depth of seedling vs. establishment, etc.

- Basic information and germplasm - Kenya, Mali and Texas (India)
- Laboratory, greenhouse and preliminary field studies - Texas
- Field evaluations - Mali, Kenya and Texas

Continue graduate training program of international and U.S. students. Solicit more students which are interested in quality graduate training on sorghum productivity in relationship to breeding and genetics. Attract quality students identified through SADCC and ICRISAT networks. Develop theses and research problems which lend themselves to solving international constraints and local constraints to productivity through TAM121, 122, 124 and 126.

Because the project has made a major impact upon the yield and general productivity of both non-food and food sorghums around the world and because there are now trained former students in many national (collaborating) programs, this program will initiate a project to develop and distribute high yielding, food quality sorghum germplasm pools. These will consist of selected-elite F_2 populations that will allow selection in the local environment for specifically adapted genotypes. These F_2 populations will have at least one or perhaps both parents segregating for white grain, vitreous normal endosperm, round grains, tan plant color, free threshing glumes, and low levels of polyphenols ((NaOH)screened). The background that the populations will be made with will be those parents which have proven productive in the local environment based upon IFSAT and ITAT trials. The materials will be distributed to collaborating LDC programs with breeders who can select the materials. Joint selections (INTSORMIL and Collaborator) will be made wherever possible. This program will be aimed at the Year 10 collaborators in Honduras, Paraguay, Mali, Burkina Faso, Kenya, Ethiopia, Niger, Zambia, Zimbabwe, and Mexico.

Measures Success

The success of this project will be determined in several ways divided into short-term and longer-term scenarios.

Short-term success can be measured by the amount (numbers) of germplasm samples of production genotypes distributed to collaborating primary and secondary programs; the performance of immediately introduced hybrids or varieties which compete well in comparison trials within the country or ecogeographic zone; number and description of secondary constraints to production identified (it is assumed the primary constraints are known); number of graduate students identified and enlisted into advanced training programs; number and quality of workshops and training sessions participated in within the scope of the program, scientific publications, etc.

Long-term success or a meaningful impact upon productivity will be measured by changes in food production or changes in types of sorghum grain grown. To measure this indirectly would involve extensive economic data collection. A reasonable measure of long term success is the extent of germplasm utilization in National programs, the release of improved cultivars, publication of scientific papers based upon the interactions within the collaborative research framework, and probably the most significant long term measure of success is the training of staff. Graduate or higher degree training which will increase long-term scientific capability of National

programs in Sorghum and Millet research is the best measure of success of the program.

Anticipated Reports and Articles

Reports of progress and articles covering preliminary research results will be published in Sorghum Newsletter (anticipate approximately five). During the year we anticipate that at least one random mating population of sorghum will be released from the program. In addition, we anticipate the release of two or more new female lines for use in hybrids. This release will be complimented with an anticipated release of several improved male (R-lines) inbreds.

We expect the completion of two to four graduate students who have collaborated on this project.

Productivity is a measure of crop success often expressed in kg/ha. etc. Crop yield or productivity is a major limiting characteristic in most areas where sorghum is grown. Sorghums with stability of higher potential productivity over a wide array of environmental and hazard related conditions would reduce significantly the risks of production. In this CRSP a broad base of interdiscipline research backstops principles of growth and development, insect and disease control, quality and nutrition, as well as agronomy. The general over-all purpose or goal of this project is to create and deploy germplasm populations, inbred lines and hybrids which possess stable potentially high yield, good grain quality, and a high level of resistance to significant diseases, pests and stress factors while maintaining acceptance and nutritional quality. Although this is an ambitious goal, it is a summation project designed to deliver an end-product to collaborating National programs at various levels or stages of completion - whether that be deployment of germplasm stocks to be used in crossing programs in the National program; elite F_2 or early generation populations for selection; inbred lines for direct consumption in farmer production schemes; or F_1 hybrids for use in more sophisticated systems of production. This project, through its domestic and collaborative components was designed to address the risks of crop yield, its stability, protection, and utilization.

Sorghum has the unique position of being a species with a wide germplasm base. Through the USDA/ARS Sorghum Conversion Program which supports this project there is a constant input of new resources in raw germplasm. As new germplasm resouces are identified any place in the world which have potential they go into the program and are quickly extracted for enhancement. These elite germplasm resources have direct and immediate impact on sustainable agriculture situations. Enhanced sorghum/millet inputs are essential by improving the stability, quality and productivity of existing systems of production in those areas where sorghum /millet are major commodities.

General Comments

This project has as its objectives to develop higher yielding, stable and agronomically desirable sorghums with high levels of disease, insect and agronomic stress resistance which possess high grain quality. By development of germplasm pools, inbred varieties and hybrids the constraints of unstable productivity are reduced.

In the short-term this project has released, distributed or otherwise made available in several forms elite, enhanced germplasm to collaborators in Mexico, Honduras, El Salvador, Paraguay, Colombia, Guatemala, and other Central and South American countries as well as Sudan, Mali, Burkina Faso, Cameroon, Niger, Nigeria, Zimbabwe, Ethiopia, and other countries in Africa. The nature of the materials provided for collaborative interaction has been germplasm which possess excellent food quality, elite foliar disease resistance, substantial drought resistance and increased yield capability. These have been contained in replicated yield or agronomic trials provided to collaborators i.e. International Tropical Adaptation Trial, International Food Sorghum Adaptation Trial, International Food Sorghum Variety Trial and early generation breeding materials for further refinement and selection within the host country. Specific examples of success have been the naming of variety and hybrid releases to farmers in Mexico, Honduras, El Salvador, Paraguay, Colombia, and Guatemala of materials developed in part in this project.

Perhaps the longer term success of the project will be measured in the achievements of the 39 graduate students who have been trained in the project. These scientists will impact the economic, social and political problems of each country in which they work. African scientists trained in the project now provide leadership in sorghum/millet research programs in Ethiopia, Kenya, Tanzania, Cameroon, Zambia, Niger, Mali, Sudan, Burkina Faso, Ghana (in Africa) and Mexico, Honduras, Venezuela, Argentina, Paraguay, and Brazil (in the Americas).

This project is an interdiscipline research scheme which uses elite germplasm, newly identified disease/insect resistances, food quality traits etc., to enhance germplasm for deployment against constraints. Materials from this system have shown good resistance to head-bugs in Mali, high yield of quality grain in Zambia and Southern Africa; demonstrated wide ranges of adaptation from the Americas to Central and Southern Africa; provided yield and drought resistance in Sudan etc.; and is widely distributed in Mexico and the Meso-American countries for food quality and high stable yields. Sor-

ghums from this project have formed the base of materials used in Mexico and Honduras for tortilla research. Germplasm has been identified and distributed which produces excellent tortillas. The project has used the expertise of international collaborators to identify gene-systems impacting food quality in sorghum. Such traits as tan plant color, straw or light colored glumes, vitreous seeds, round seeds, clean threshing seeds, and the genetics of color of the grain have lead to a clear working relationship between collaborating scientists.

This project has developed sorghums with significantly improved non-sensence, deep rooting capability, larger panicles with increased grain numbers of an acceptable size, and increase non-structural carbohydrates. These traits which impact the physiology of the growth, development, and productivity of sorghum have been placed in germplasm pools which have been and continue to be distributed to collaborators. These materials are used in the on-going research program to affect American sorghum production also. The development and release of elite food quality sorghums to American producers is an example of understanding a system used in African sorghum production and deploying it in the American production system.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: Enhancement of Sorghum Germplasm for Stability, Productivity and Utilization

Project Leader: Fred R. Miller **Project Number:** TAM-121

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=TAM121	--	----------				
Staff Salaries & Benefits	15.84	16.63	17.42	18.22	19.21	87.32
Post Doctorates	6.08	6.38	6.69	6.99	7.37	33.51
Graduate Students	6.00	6.00	7.00	7.00	7.00	33.00
Other Salaries	7.92	8.32	8.71	9.11	9.60	43.66
Supplies	6.88	7.22	7.57	7.91	8.34	37.92
Equipment	2.48	2.60	2.73	2.85	3.01	13.67
Travel	8.96	9.41	9.86	10.30	10.86	49.39
Other Direct Costs	6.16	6.47	6.78	7.08	7.47	33.96
Overhead	19.52	20.50	21.47	22.45	23.67	107.61
	79.84	83.53	88.23	91.91	96.53	440.04

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=TAM121	--	----------				
Post Doctorates	15.10	15.85	16.64	17.48	18.35	83.41
Other Salaries	12.60	13.23	13.89	14.59	15.32	69.62
Fringe Benefits	5.81	6.11	6.41	6.73	7.07	32.13
Supplies	19.66	20.64	21.67	22.76	23.90	108.63
Travel	4.67	4.91	5.15	5.41	5.68	25.82
Other Direct Costs	1.58	1.65	1.7[illegible]	1.82	1.91	8.70
Overhead	24.58	25.81	27.10	28.46	29.88	135.83
	84.00	88.20	92.[illegible]	97.24	102.10	464.15

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=TAM121	--	----------				
Post Doctorates	14.38	14.38	14.38	14.38	14.38	71.89
Other Salaries	12.00	12.00	12.00	12.00	12.00	60.00
Fringe Benefits	5.54	5.54	5.54	5.54	5.54	27.69
Supplies	18.72	18.72	18.72	18.72	18.72	93.62
Travel	4.45	4.45	4.45	4.45	4.45	22.25
Other Direct Costs	1.50	1.50	1.50	1.50	1.50	7.50
Overhead	23.41	23.41	23.41	23.41	23.41	117.06
	80.00	80.00	80.00	80.00	80.00	400.00

Kenya

Ben Kanyenji and Newton Ochanda, Ministry of Agriculture, Kenya
Vartan Guiragossian and Sam Mukuru, ICRISAT, Nairobi, Kenya

Zimbabwe

L.R. House and A. Tunde Obilana, ICRISAT, Bulawayo, Zimbabwe

U.S.

L.E. Clark and G.C. Peterson, Texas A&M Agricultural Experiment Station, Lubbock, TX
R.A. Frederiksen, F.R. Miller, LW. Rooney, R.D. Waniska, Texas A&M University, College Station, TX
R.D. Waniska, Texas A&M University, College Station, TX
G.N. Odvody, Texas A&M University, Corpus Christi, TX
J.D. Eastin and D.J. Andrews, University of Nebraska, Lincoln, NE
G. Ejeta, J.D. Axtell and A.J. Kirleis, Purdue University, West Lafayette, IN
L. Gourley, Mississippi State University, Mississippi State, MS

Project Objectives

Enhance the germplasm of LDC's by developing and distributing early generation breeding germplasm involving genetically improved disease and drought resistance and other desirable traits specifically for use and selection in host countries with emphasis on Honduras, Sudan, Mali, and Niger.

Develop high yielding cultivars for LDC and US with genetically enhanced 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, high yielding, agronomically desirable types with superior combinations of pre and post-flowering drought tolerance for use in the U.S. and host countries.

Identify, in basic sorghum germplasm lines, new sources of drought tolerance and resistance to diseases of importance in the U.S. and in LDC's.

Collect new sorghum germplasm, including wild types, and evaluate for traits needed in developing countries. Introgress these traits into improved lines.

Introduction

Disease 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, so much progress is possible in developing improved varieties with improved levels of drought tolerance. Texas has a semi-arid environment plus high temperatures and is ideal for large scale field screening and breeding for improved drought tolerance. It has been proven that lines with identified high levels of specific types of drought tolerance in Texas, such as pre- or post-flowering drought tolerance, exhibit a similar drought response in such countries as Sudan, Mali, Niger, and India, indicating that drought resistance as identified and screened for in West Texas has direct LDC application. 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 ideal for screening and breeding sorghums with high levels of resistance to most internationally important diseases. This project is the primary breeding program which supports the major Texas Pathology Project, TAM-124, and maintains seed, packages, and assists in distribution of most of the various uniform and cooperative disease trials.

Among presently used germplasm there is a need for new sources and enhanced levels of certain traits in developing countries. Among these are drought tolerance, disease resistance, and insect resistance. It is proposed to collect new diverse germplasm, even in the wild species, and evaluate these in collaboration with scientists in developing countries and the USA.

Major host countries of collaboration with TAM-122 are Sudan, Honduras, Mali, and Niger. The major constraint in much of Sudan is drought, and drought related production problems. Moisture stress related

Germplasm Enhancement for Resistance to Pathogens and Drought and Increased Genetic Diversity

Project TAM-122
Darrell T. Rosenow
Texas A&M University

Collaborating Institutions

Host Country

Honduras

Francisco Gomez, sorghum breeder and Head of National Sorghum Program, Secretaria Recursos Naturales (SRN), Choluteca, Honduras
Dan Meckenstock, INTSORMIL/Honduras, sorghum breeding, Tegucigalpa, Honduras
Lindolfo Fernandez, agronomist/pathologist, SRN, Comayagua, Honduras
Alejandro Palma, breeder/agronomist, Escuela Agricola Panamericana, Tegucigalpa, Honduras

Sudan

Osman Ibrahim, sorghum breeder, Agricultural Research Corporation, Wad Medani, Sudan
El Hilu Omer, pathologist, Agricultural Research Corporation, Wad Medani, Sudan

Mali

Moussa Traore, physiology, Institute of Economie Rurale (IER), Bamako, Mali
Oumar Niangado, Head, plant breeding, SRCVO, IER, Cinzana, Mali
Noel Beninati, sorghum breeder, ICRISAT/Mali, Bamako, Mali
Mamourou Diourte, pathology, SRCVO, IER, Bamako, Mali

Niger

Moussa Adamou, sorghum breeder, INRAN, Maradi, Niger
John Clark, Purdue/INRAN Sorghum/Millet Research, Niamey, Niger

Colombia

Manuel Terragrosa, Annual Crops Division, ICA, Bogata, Colombia

Botswana

Louis Mazhani, Ministry of Agriculture, Gaborone, Botswana
Douglas Carter, INTSORMIL/KSU/Botswana, Gaborone, Botswana

El Salvador

Sonjia Morales, CENTA

Mexico

INIA, Pathology and Breeding, Tom Hash and Rene Clara, ICRISAT/CIMMYT

charcoal rot 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 very important. Drought is also important in Honduras and Central America. 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. High yielding, improved introductions often fail due to the grain quality -head bug - grain mold complex, stand establishment problems, or improper maturity. We believe that head bugs are a major constraint to the use of non-Guineense type sorghums in much of West Africa. Much of the collaborative research in West Africa is developing and providing source materials along with studying the various traits of the West African Guineense type sorghums which makes them uniquely adapted to the more humid areas of West Africa. In the northern areas of Mali and in Niger where drought stress is severe, earlier, less-photosensitive material can be used, and the non-Guinea sorghums generally perform well. In these areas, U.S. developed drought tolerant materials may have direct application. Diseases other than grain mold are also important, such as anthracnose and sooty stripe in portions of Mali, long smut in both Niger and Mali.

Objectives Related to Constraints

The five project objectives relate directly to either the drought or the disease constraints to sorghum production discussed for Honduras, Sudan, Mali, and Niger. They include: (a) screening and identification of new sources of disease and drought resistance; (b) development of improved sorghums with genetically enhanced levels of drought and/or disease resistance with selection and evaluation in both the USA and LDC's; and (c) enhance the germplasm in LDC's with the development and distribution to LDC's of new germplasm sources, improved breeding lines,early generation breeding germplasm, and standard trials for use and selection under LDC conditions.

Research Procedures

Introductions from Sudan, Mali, Niger, Nigeria, Honduras, El Salvador, Burkina Faso, Botswana and Senegal, including locals and improved breeding lines with desirable drought or disease resistance, or specific desirable grain or plant traits, will be crossed in Texas to appropriate elite U.S. lines and elite breeding materials. Seed of the F_2 and/or early generation bulks such as F_2's will be sent to LDC's, particularly Honduras, Sudan, Mali, Niger, and Botswana for selection of appropriate traits and adaptation. Technical assistance will be provided, as time and travel permit, in the selection and evaluation and use of such breeding material in the host country.

Breeding material will be generated from crosses among various disease resistant sources, agronomically elite lines, and new sources of resistance. Initial screening will be done in large disease screening nurseries utilizing natural infection in South Texas supplemented by artificial inoculation in the field and laboratory screening. Selected advanced materials will be sent to LDC's for evaluation and also will be incorporated into various standard replicated trials for extensive evaluation at several locations in Texas, U.S., and host countries.

Crosses among newly identified sources of drought tolerance (i.e. pre and post-flowering drought tolerance) and elite, high yielding lines will be made to develop improved drought tolerance. Progeny will be selected initially under field conditions for pre-and post-flowering drought tolerance yield, and adaptation at several locations in West Texas in the Lubbock area and at Chillicothe which vary in their degree and time of moisture and heat stress. Selected advanced materials will be sent to LDC's for evaluation and use as well as evaluated at additional locations in Texas under a rainout shelter.

Converted and partially converted lines from the Sorghum Conversion Program, exotic lines, new introductions, and breeding materials will be screened and evaluated initially in Texas for sources of resistance to internationally important diseases in a cooperative program with pathologists.

Sorghum germplasm will be collected in areas where specific production constraints are severe. Collaboration for collecting and evaluating will be sought from the local scientists and from other scientists who are most knowledgeable of those hazards. Any germplasm deemed to have merit for a specific trait no matter what are its other characteristics, will be evaluated for the transferability of that trait into desirable cultivated sorghum.

Host Country Collaboration and Work Sites

Sudan, Mali, and Niger will be major sites for collaborative research on drought tolerance. Nurseries containing entries identified in the U.S. or LDC's as drought tolerant will be evaluated in Sudan, Niger, Mali, and in both pre-and post-flowering drought screening nurseries in Texas, in order to identify the best sources and establish relationships among locations. Introductions from

Sudan, Niger and Mali will be screened for drought in Texas, crossed to appropriated U.S. breeding lines, and F_2 or advanced generation bulks returned to these countries for host country breeders to select and use.

In Sudan, many U.S. developed sorghums are very well adapted. Tx623 is the female parent of Hageen Dura 1, the first hybrid released in Sudan, while the male parent, Karper 1597, was selected from germplasm that originated at Lubbock, Texas. Although it performs very well, HD1 is susceptible to post-flowering drought stress and charcoal rot. Selections from crosses involving BTx623 and B35 have been made to combine the yield potential and adaptation of BTx623 with the stay-green or post-flowering drought tolerance of B35. These progenies will be evaluated in nurseries and in uniform tests in the U.S. and in Sudan for drought tolerance, adaptability, and yield potential. Experimental hybrids from the most advanced new A lines will also be evaluated. Several new male lines, selected by Dr. Gebisa Ejeta from Purdue from crosses made in TAM-122 involving elite U.S. lines and drought tolerant sorghums identified in Sudan, will be released cooperatively between Purdue and Texas. Drought breeding collaboration in Sudan is primarily with Dr. Osman Ibrahim. Specific studies in Sudan are with Dr. Hilu, pathologist, to study the charcoal rot resistance of new B-lines and other stay-green lines, and hybrids. Major drought and adaptation evaluation sites in Sudan will be Wad Medani (irrigated), El Obeid (dryland), and Gadambalia (dryland).

In Niger, F_2's and F_3 bulks involving elite U.S. x Niger dune adapted varieties will be planted in Niger for selection and use. Collaborators in Niger are Mousssa Adamou and the Purdue INRAN sorghum breeder, John Clark. Major sites will be Kolo and Maradi.

In Mali, research will concentrate on studying the physiological traits and mechanisms which contribute to drought and charcoal rot resistance. In the Guinea sorghums, this study will be done in Texas and on site in Mali at Cinzana. Other research will attempt to determine the effect of head, glume, and grain traits of Guinea sorghums on head bug and grain mold tolerance and on screening for head bug resistance. Collaborators include Dr. Moussa Traore (physiology/drought), Dr. Oumar Niangado (breeding and drought), Mamourou Diourte (pathology), and Dr. Noel Beninati (breeding). F_2's involving high yield x Mali adapted locals or improved lines will be sent and planted in Mali for selection. Collaborative disease research will include grain mold, anthracnose, and sooty stripe evaluation. Major sites in Mali will be Cinzana, Sotuba, and Sikasso.

In Honduras emphasis will be on drought tolerance, downy mildew, grain mold, foliar diseases, and improved yield. The maicillos crillos breeding will be on site at Choluteca, Zamarano, and Comayagua, using U.S. lines as sources of resistance. Non-photoperiod sensitive germplasm will be generated in Honduras and Texas, with exchange of breeding material, lines, and hybrids and evaluation and screening at Choluteca, Zamarano, Comayagua, and Olancho. Comayagua will be the prime downy mildew site in Honduras with screening for resistance to the new pathotype of downy mildew. Maicillo breeding material developed in Honduras as well as standard disease trials will be evaluated in El Salvador nd Guatemala. Partially converted maicillos criollos and F_2's and F_3's involving MC's will be evaluated for drought tolerance in Texas. Collaborators in Honduras include Dr. Meckenstock (breeding), Dr. Francisco Gomez (SRN sorghum breeder), and Lindolfo Fernandez (downy mildew screening).

Measures of Success

Measures of success in LDC's will be determined by the strengthening of the host country national sorghum program in terms of support, personnel, effective research, the number of host country scientists receiving both short and long term training and their placement in the national programs, and the release of new varieties or hybrids and their subsequent use in the LDC's. Releases and their use in the U.S. are important measures of success. Also important will be the degree of use of germplasm generated by TAM-122 in the host country national research program. New findings such as new diseases, races of pathogens, and adoption of new screening and selection techniques are also important. Another important measure of success is the use made in the U.S. (for USA use) of germplasm, introductions, techniques, and ideas from LDC's or from contact and interaction with LDC scientists. Publications and papers generated from the collaborative research are also important measures of success.

Anticipated Reports and Articles

Summarizing research results in U.S. and host country annual reports, and presentations at host country or U.S. meetings.

Papers at regional or national meetings such as CLAIS, PCCMCA, SICNA, and international workshops.

Papers in refereed journals on (1) breeding for drought tolerance, (2) sources of downy mildew resistance in converted exotic sorghums, and (3) sources of head smut resistance in converted exotic sorghums.

Registration of new drought tolerant and disease resistant releases in Crop Science.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: Breeding Sorghum for Drought Resistance and Increased Genetic Diversity

Project Leader: Darrell Rosenow **Project Number:** TAM-122

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=TAM122 -- ----------						
Staff Salaries & Benefits	19.80	20.79	21.78	22.57	23.76	108.70
Post Doctorates	7.60	7.98	8.36	8.66	9.12	41.72
Graduate Students	8.00	8.00	8.00	9.00	9.00	42.00
Other Salaries	9.90	10.40	10.89	11.29	11.88	54.36
Supplies	8.60	9.03	9.46	9.80	10.32	47.21
Equipment	3.10	3.26	3.41	3.53	3.72	17.02
Travel	11.20	11.76	12.32	12.77	13.44	61.49
Other Direct Costs	7.70	8.09	8.47	8.78	9.24	42.28
Overhead	24.40	25.62	26.84	27.82	29.28	133.96
	100.30	104.93	109.53	114.22	119.76	548.74

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=TAM122 -- ----------						
Grad Students	1.68	1.76	1.85	1.94	2.04	9.28
Other Salaries	29.61	31.09	32.65	34.28	35.99	163.61
Fringe Benefits	5.59	5.87	6.17	6.48	6.80	30.91
Supplies	14.23	14.94	15.69	16.47	17.29	78.62
Equipment	4.20	4.41	4.63	4.86	5.11	23.21
Travel	16.17	16.98	17.83	18.72	19.65	89.35
Other Direct Costs	4.88	5.12	5.38	5.64	5.93	26.94
Overhead	28.64	30.07	31.58	33.16	34.81	158.26
	105.00	110.25	115.76	121.55	127.63	580.19

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=TAM122 -- ----------						
Grad Students	1.60	1.60	1.60	1.60	1.60	8.00
Other Salaries	28.20	28.20	28.20	28.20	28.20	141.00
Fringe Benefits	5.33	5.33	5.33	5.33	5.33	26.64
Supplies	13.55	13.55	13.55	13.55	13.55	67.75
Equipment	4.00	4.00	4.00	4.00	4.00	20.00
Travel	15.40	15.40	15.40	15.40	15.40	77.00
Other Direct Costs	4.64	4.64	4.64	4.64	4.64	23.22
Overhead	27.28	27.28	27.28	27.28	27.28	136.39
	100.00	100.00	100.00	100.00	100.00	500.00

Germplasm Enhancement for Increasing Resistance to Insects and Improving Efficient Nutrient Use in Sustainable Production Systems

Project TAM-123
Gary C. Peterson
Texas A&M University

Collaborating Institutions

Host Country:

Honduras

Dr. Francisco Gomez, Recursos Naturales, Tegucigalpa, Honduras
Ing. Lindolfo Fernandez, Recursos Naturales, Tegucigalpa, Honduras
Dr. Dan Meckenstock, Escuela Agricola Panamericana, Tegucigalpa, Honduras

Mali

Mr. Zoumana Kouyate, Department of Agricultural Research, Bamako, Mali
Dr. Oumar Niangado, Department of Agricultural Research, Bamako, Mali
Mr. Mamadou Doumbia, Department of Agricultural Research, Bamako, Mali
Dr. Moussa Traore, Department of Agricultural Research, Bamako, Mali

Botswana

Mr. C.S. Manthe, Department of Agricultural Research, Gaborone, Botswana

ICRISAT/CIMMYT

Dr. C.T. Hash, Mexico

United States:

Drs. G.C. Peterson, A.B. Onken, Texas A&M Agricultural Experiment Station, Lubbock, TX
Drs. D.T. Rosenow, C.W. Wendt, T.L. Archer, Texas A&M Agricultural Experiment Station, Lubbock, TX
Dr. G.L. Teetes, Texas A&M University, College Station, TX
Dr. D.T. Rosenow, Texas A&M Agricultural Experiment Station, Lubbock, TX
Dr. R.A. Frederiksen, Texas A&M University, College Station, TX
Dr. F.R. Miller, Texas A&M University, College Station, TX
Dr. L.W. Rooney , Texas A&M University, College Station, TX
Dr. B.R. Wiseman, USDA-ARS, Tipton, GA
Dr. A. Sotomayor, USDA-ARS, Puerto Rico
Dr. R.R. Duncan, University of Georgia, Experiment, GA

Project Objectives

Obtain and evaluate exotic sorghum germplasm for resistance to selected LDC sorghum pests.

Determine the resistance trait(s) and the inheritance of insect resistance.

Develop and release high yielding ecologically fit germplasm resistant to selected insects, and additional specific stress factors, which are responsive to sustainable LDC and U.S. production systems.

Identify and define potential sources of more efficient plant nutrient extraction and/or utilization in sorghum and study responsible mechanisms.

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Refine methodology of determining efficient nutrient use.

Determine the effect(s) of efficient nutrient use on efficient water use in sorghum.

Develop agronomically superior sorghum germplasm with increased efficiency in nutrient and water utilization capability.

Introduction

Development of sustainable grain sorghum production systems with a higher, more stable yield potential will be facilitated by partial or complete alleviation of several biotic and abiotic stress factors. The most efficient mechanism for developing genotypes with increased environmental fitness is a broad-based, multi-disciplinary research program which attempts to improve crop production with minimum disruption to the ambient ecosystem. Change in production agriculture systems causes the dynamic equilibrium of the ecosystem to shift with additional biotic and/or abiotic stress factors, and resistance, becoming important. Thus, as new cultivars change the indigenous insect population a viable ongoing crop protection component is needed to insure that progress in alleviating one stress is not nullified by increased susceptibility to other stress factors. Improvement in knowledge and understanding of resistance to insects is particularly important as production systems, and insect complexes, change due to higher yielding cultivars in a dynamic evolving production ecosystem. Development of cultivars resistant to insects will readily interface with other required inputs in an integrated production and stress control strategy to facilitate an ecologically sound production ecosystem with large potential benefits in subsistence and mechanized agriculture. Ecological fitness may be increased by incorporating host plant resistance to insects with additional stress tolerance or traits of economic importance in a single genotype. Development of plant resistance to insects methodology, sources, and production cultivars is therefore an integral component of crop improvement systems.

Lack of supplemental fertilizer in LDC agriculture is a major constraint to increased sustainable production. This is particularly devastating since LDC soils are more deficient in plant nutrients than soils in DC's. Development of methodology, sources, and cultivars which produce economically viable yields on little or no supplemental fertilizer will substantially enhance efficiency and stablity of crop production systems, particularly in LDC's.

Sorghum is a major food grain in the Sahelian zone of Africa, and the soils on which the crop is grown are low in available nutrients as well as available water. Using sorghums identified by the INTSORMIL (TAM-123) program as different in nutrient use efficiency, joint INTSORMIL/TROPSOILS research has shown a definite relationship between nutrient use efficiency and water use efficiency. In addition, responsiveness to fertilizer applications has been shown to be closely related to water use efficiency. It is clear that for research to have the best chance for success in increasing yield and establishing a system of sustainable crop production in Sahelian Africa, nutrient deficiencies and water deficits will have to be addressed simultaneously.

In West Africa, millet is most often planted on sandy soils in preference to sorghum. It had been previously assumed that this was done because millet was more drought tolerant. However, observations indicate the possibility of soil chemical effects, among which is low soil fertility. If this is the case appropriate correction should allow increased flexibility in West African farming systems. To effectively plan future research in West Africa we need precise information as to different responses of these two crops.

Host Country Collaboration and Work Sites

Honduras. Sorghum midge is a biotic constraint in some sorghum production areas of Central America. Development of resistant germplasm by national programs is restricted by a lack of knowledge concerning methodology required for identification, development, and testing of resistance sources, elite germplasm, and hybrids. Recursos Naturales scientists are evaluating germplasm developed by TAM-123 in Olancho state, Honduras. Previous research indicates that TAM-123 developed germplasm exhibits excellent yield potential in the local production ecosystem and is suitable for use in that region. Midge line and hybrid trials will continue to be grown in replicated trials in primary and secondary production seasons. The midge resistant material will be compared against locally grown germplasm for adaptation and yield potential. Additional germplasm will be provided to cooperators in Guatemala for evaluation and testing in that production ecosystem.

Botswana. The sugarcane aphid is a pest of sorghum is Botswana and has been identified in Central America and Florida. Germplasm provided by TAM-123 indicated a differential response to infestation by sugarcane aphid in preliminary trials. Based upon the preliminary trials, TAM-123 developed numerous segregating populations for studies in elucidating the mechanism(s) of resistance. TAM-123 also provided converted exotic sorghum genotypes and elite germplasm with resistance to other biotic or abiotic stress factors for evaluation and/or utilization.

Mali. Division of Agronomic Research scientists are involved in collaborative research to elucidate the mechanism(s) in sorghum of efficient nutrient use. TX123 is developing screening techniques to assist in the identification of additional lines with efficient nutrient use in LDC environments.

Division of Agronomic Research scientist and Texas A&M University graduate student Abdoul Sow is conducting research, at Lubbock, to elucidate the mechanism(s) in sorghum responsible for nutrient use and water use efficiencies particularly as they relate to phosphorus. His study includes both Malian and improved sorghum types. This research is being conducted in cooperation with TROPSOILS.

Spatial variability is limiting agronomic research with sorghum on certain soils in Mali. One theory is that toxic effects due to exchangeable aluminum are responsible. INTSORMIL will collaborate with TROPSOILS in furnishing aluminum tolerant material to be compared to local types for response to this problem.

A collection of Sahelian zone sorghums will assembled and utilized in collaborative screening trials at the Cinzana station. Evaluations will be made for performance under 1) low levels of available water and fertility, 2) responsiveness to inputs of fertility and water and 3) tolerance for soil chemical factors causing problems of stand establishment and crop growth. Improved sorghums and converted Sahelian sorghums of known responses will be used for comparisons in these trials. In addition to measurements of general adaptability and grain yield, water use, nutrient uptake and physiological measurements such as transpiration, leaf water potential and morphological characteristics will be made, as funds permit, in order to investigate mechanisms responsible for observed differences.

Research Procedures

Domestic Technical Support

Nursery sites at diverse locations in Texas, Georgia, and Puerto Rico will be utilized to support and backstop all proposed research. This will permit only the best material and research techniques to be utilized in LDC locations.

Research environments for host plant resistance to insects will be in field nurseries at Lubbock, Halfway, Corpus Christi, Beeville, and College Station, Texas, and Experiment, Georgia. The diverse locations provide an excellent range of environments for imposing severe biotic and abiotic stress to facilitate identification of resistance sources, and identification and development of ecologically fit genotypes.

Research sites for efficient nutrient use will be in field nurseries at Beeville, Lubbock, and Halfway, Texas, and laboratory facilities at Lubbock, Texas. Field plots, greenhouses, rainout shelters, and laboratories at Lubbock will be utilized for determining the interaction effects of genotypes, efficient nutrient use, and efficient water use in sorghum.

A winter nursery research site at Isabela, Puerto Rico, provides the opportunity to evaluate germplasm in a tropical environment for adaptation, biotic stresses (primarily diseases) not present in Texas, to advance elite material an additional generation per year, and to obtain needed seed quantities of exotic lines. Materials and expertise at each location provides logistical support for LDC research and is a necessary component of a viable, ongoing collaborative research program.

Domestic nursery locations involve a broad based, multi-disciplinary research team that includes INTSORMIL projects TAM-121, TAM-122, TAM-124, TAM-125, TAM-126, and TAM-128. Nursery locations, particularly in South Texas, provide LDC graduate students and visiting scientists the opportunity to observe multidisciplinary research and gain expertise in diverse research disciplines and methodologies. The total program culminates in the development of agronomically elite, ecologically fit insect resistant cultivars suitable for most areas of sorghum production.

The diverse environments in Texas provide the opportunity to develop sorghums with resistance to insects and other stress constraints, particularily diseases and drought, which are present in many sorghum production environments. Appropriate studies and activities will be undertaken to facilitate development of germplasm with resistance to multiple stress constraints suitable for numerous production environments. Primary emphasis will be on host plant resistance to insects and associated traits. Increased emphasis will be placed on combining resistance to insects with drought tolerance (pre-and post-flowering) and disease resistance (primarily downy mildew, rust, anthracnose, and head smut).

TAM-123 will evaluate introductions and resistant germplasm lines developed by cooperators as they become available. Lines identified with excellent midge resistance and acceptable agronomic traits will be crossed with TAM-123 material to develop more broad-based segregating breeding populations suitable for use in wider ecological zones. Utilization of exotic germplasm broadens the genetic diversity of the program and provides the opportunity to combine midge resistance and other favorable traits.

Field studies will be conducted at Lubbock in which sorghum lines identified as being different in nutrient use

efficiency and drought tolerance will be utilized. Treatments will consist of graded levels of nitrogen and available water in factorial combination. Appropriate soil and plant measurements (water extraction, transpiration, and photosynthesis) will be made to further elucidate the relationship between nutrient and water use efficiencies. These studies will be cooperative with TROPSOILS. Results from these studies will be utilized to design collaborative research with Sahelian sorghums in Mali.

Graded nitrogen studies with five rates will be conducted with sorghum genotypes identified as differing in nitrogen use efficiency and responsiveness to nitrogen. The objective will be to determine if differences exist in their response curves to applied fertilizer with the view of selecting sorghums most responsive to low levels of input.

Sorghum genotypes have been identified that differ in their ability to produce grain under low levels of water and fertility and that differ in response to low levels of input. To partially elucidate the genetic control of and relationship between NUE and WUE crosses will be made between specific genotypes to produce segregating populations for selection under varying levels of available water and fertility. The objective will be to study inheritance of these characteristics and to determine if they can be combined into a single genotype with superior grain production under low nutrient/water levels and responsiveness to applied nutrients/water.

Honduras

The economic threshold of midge susceptible sorghums, which constitute nearly all sorghum production, is one midge per panicle. TAM-123 will continue to develop agronomically improved midge resistant germplasm with a higher economic threshold and excellent yield potential in certain production environments.

Improved grain quality has received considerable emphasis by the INTSORMIL Honduras program and the national program due to its importance in relation to the end uses of sorghum. The combination of midge resistance and improved grain quality traits will create a more stable and environmentally fit genotype with superior grain quality. As additional improvements are made in LDC sorghums and improved germplasm with less photosensitivity becomes available, the combination of midge resistance and food quality will help stabilize production.

TAM-123 has developed and sent to Honduras a photoperiod sensitive random-mating population (TP28) which combines midge resistance and food quality from indigenous maicillos criolles. TAM-123 has developed a photoperiod insensitive population combining midge resistance and food quality (TP27). Initial evaluation resulted in the elimination of the midge susceptible germplasm from both populations. The photoperiod insensitive population is being random-mated using half-sib selection. Progeny from each cycle are evaluated for midge resistance, adaptation, grain quality, etc. The superior progeny are then used in the pedigree breeding program and recombined in the population. Simultaneous improvement in several traits will create a broad-based, widely adapted population suitable for use in most sorghum production environments.

Hybrids developed in TAM-123 will continue to be evaluated at various locations in Honduras in comparison with local hybrids. Midge resistant lines and hybrids will be evaluated in the primary and secondary growing seasons to study the suitability of midge resistant germplasm. Recursos Naturales personnel will continue to provide all local research expertise with TAM-123 producing and supplying needed genetic material. On-site visits will occur as needed to evaluate germplasm, research progress, and plan furthur cooperative research.

Research on midge resistance will be expanded to include locations in Guatemala. Germplasm and research expertise similar to that for Honduras will be provided to the Guatemalans for testing in their sorghum production environments.

Botswana

Research will continue in a program to determine mechanisms and inheritance of resistance to sugarcane aphid. Research towards identifying additional sources of resistance in converted exotic sorghum lines and other elite germplasm provided by TAM-123.

The greenbug has been identified in Botswana. TAM-123 has provided seed of sorghum differentials to the known biotypes (C&E) of greenbug which attack grain sorghum in the United States. Studies will be initiated to identify the greenbug biotype present in Botswana. If a different biotype(s) from the U.S. is present, appropriate additional research will be conducted to identify mechanisms, sources, and inheritance of resistance.

Mali

Converted West African sorghums will be evaluated in field studies under a factorial combination of nitrogen and water sufficient and deficient conditions. Initially a local Malian sorghum, CSM63, and improved Malian sorghum Malian, 84-7, and a Nigerian sorghum, El Mota, will be used. As additional genotypes become available they will be incorporated into the program. The objective will be to determine differences in nutrient and water use efficiencies and to evaluate screening techniques for use

in West Africa. Comparisons will be made with improved sorghums of known responses. This will also be a joint effort between INTSORMIL and TROPSOILS.

Rainout shelter research will be conducted in mini-lysimeters to establish the plant and soil components contributing to nitrogen use efficiency and response to nitrogen in sorghum. When these components are established it will be possible to develop an effective screening technique to be used in breeding programs for selecting and developing sorghums more use efficient and responsive with respect to nitrogen.

Measures of Success

Success and effectiveness of the project may be measured by scientist visits, information exchange, germplasm exchange, germplasm release, improvement in host country research capability (institution building, scientist training, and technical expertise), improvement in host country sorghum production, and additional understanding of the expression of sorghum traits.

It is anticipated that germplasm will be released from TAM-123 during the next 5 year period for resistance to sorghum midge or greenbug. Several of the released lines will contain resistance to multiple stress factors. New germplasm releases possess unique genetic combinations not presently available with wide adaptation to many sorghum production environments.

Anticipated Reports and Articles

Research results will be published as they become available.

Crop Science registration articles for germplasm releases will be submitted for publication following release approval.

New Research Thrusts

If additional INTSORMIL funds become available TAM-123 will undertake additional research in host plant resistance to insects and efficient nutrient use. Potential additional research thrusts in host plant resistance include the headbug complex in West Africa (currently receiving increased emphasis in collaborative INTSORMIL-IER activities), sorghum midge in Africa (particularily as the production ecosystem is changed with improved cultivars), and fall armyworm in Central America (collaborative INTSORMIL-SRN research has identified genotypes with tolerance or nonpreference). Potential additional research thrusts in nutrient efficiency include expanded collaborative resiearch in West Africa to sites representing other ecological zones in which sorghum is grown (e.g. Sudanian zone), intensified studies into physiological mechanisms responsible for genotype x fertility x water interactions in sorghum and increased training of West African students.

Progress (last two years)

Two hundred eighty-one (281) introductions (from ICRISAT and Australia) were evaluated for resistance to sorghum midge (Contarinia sorghicola). Data from two years of trials identified 8 lines with potentially useful levels of resistance and acceptable agronomic traits. These lines are being utilized in a crossing program to transfer the resistance genes, and other useful traits, to U.S. type germplasm.

Fifty-seven (57) newly converted genotypes were evaluated for resistance to sorghum midge. Data from several locations resulted in the identification of lines which possess some resistance at low midge population density. All were susceptible at high midge population density and not useable in the breeding program.

Evaluation of sorghum midge resistant germplasm lines continued domestically and internationally. Test results identified a number of lines with excellent resistance, sustaining approximately 40% less damage than a resistant check and being nearly as resistant as the most resistant check under high midge density. The lines appeared to be widely adapted and potentially useful at numerous locations, including Olancho state, Honduras.

Results of hybrid tests planted domestically and internationally identified new agronomically improved midge resistant pollinators which produce excellent yielding widely adapted hybrids. In some trials where midge were controlled, midge resistant hybrids produced the highest yields. Results indicate the existence of an ecological production niche in which midge resistant hybrids perform very well. These results have been confirmed in Honduras, where midge resistant hybrids will produce over 4,000 kg/ha.

Results from midge line and hybrid trials identified 22 new germplasm lines with excellent resistance to sorghum midge and good agronomic traits. The lines have been proposed for release and seed will be distributed in the Fall, 1989.

Germplasm lines (10) resistant to biotype E greenbug (Schizaphis graminum) and which produce widely adapted, high yielding hybrids were identified and seed increased. The lines have been proposed for release and seed will be distributed in the Fall, 1989.

Program support grants were utilized to develop computer expertise and software necessary to manage the breeding program utilizing a desktop PC, laser printer,

and PC-SAS. The computer programs enable TAM-123 to process all breeding records, seed inventories, pedigree revision, fieldbooks, etc., by computer. The programs are flexible, easy to use, and can be executed anywhere on the appropriate hardware.

Research was initiated to study the relationship between yield and evapotranspiration (ET) and yield and yield/ET (WUE_{ET}) for grain sorghum genotypes differing in nutrient use efficiency on nutrient deficient soils. A significant positive linear relationship between grain produced and ET, and a highly significant positive linear correlation between grain yield and WUE_{ET} was identified. Factors that affect sorghum grain yield will also affect ET and WUE_{ET}. Results indicated that with respect to WUE_{ET}, increasing yield due to N application or breeding line resulted in increased WUE_{ET}. With respect to N application, the greatest increases in WUE_{ET} occurred with those breeding lines most responsive to N application. If WUE_{ET} is to be increased through fertilizer application, sorghums most responsive to fertilizer must be selected.

The interaction between fertilizer and water level on sorghum were was studied using three water levels in combination with three N (nitrogen) levels. There was a positive relationship between ET and crop yield across water levels, but yield and ET were independent of each other across fertilizer rates. The data indicated a strong interaction between water levels, fertilizer rate, and crop yield response. As yields increased at each water level due to fertilizer, WUE_{ET} increased. These relationships were more complex as yields increased due to more available water within a fertilizer rate.

Research was conducted to determine the effects of amounts of available water and soil fertility level on water use efficiency (WUE) of sorghums differing in nutrient use efficiency. Water use efficiency was influenced by water level, nitrogen fertility, total nitrogen in the plant tissue, and sorghum genotype. In order to increase water use efficiency through soil fertility, efficient responsive cultivars must be identified and used. Strong interactions exist between level of available water, cultivar, and soil fertility in efficient use of available water, measured in terms of both ET and T.

Research using West African sorghum and millet studied the influence of nitrogen and phosphorus applied separately and together on water use efficiency and uptake and translocation of nitrogen and phosphorus. Significant increases in dry matter production occurred for both species due to increased fertility and available water. At the low water level, application of nitrogen or phosphorus alone did not result in increased dry matter production over the check. When nitrogen and phosphorus were applied together, both species produced significant increases in dry matter over the check. Increased available water resulted in significantly greater sorghum production when phosphorus was applied alone and in combination with nitrogen. Each application of fertilizer produced increased millet yields at the high water level; with the nitrogen + phosphorus treatment producing the greatest amount of dry matter in the experiment. Millet response to a combination of available water and fertility was greater than for sorghum. Water use efficiencies were affected by species, water level, and fertility level. Both species had consistently higher WUE's at low available water than at high available water. Water use efficiencies were generally higher for sorghum than for millet except where millet was fertilized with both nitrogen and phosphorus. A portion of the sorghum genotype x fertility level x water level research was conducted cooperatively with TROPSOILS and utilized Program Support Grants.

Benefits to U.S. and LDC Agriculture

Germplasm lines resistant to sorghum midge (22) or biotype E greenbug (10) will be of benefit wherever the insect causes damage. The midge resistant pollinators (A1 cytoplasm) have resistance equal to or better than previous midge resistant releases, and significantly higher yield potential than previous releases. The lines will be of benefit to breeding programs throughout the world. Elite lines resistant to biotype E greenbug with excellent yield potential as a hybrid parent will be of significant benefit principally in the Western Hemisphere. There are presently few available lines with these traits.

The results of the NUE and WUE studies resported here have strong implications for developing countries, particularly those producing sorghum in the Sahelian ecological zone. They clearly show that correction of soil fertility problems coupled with proper genotypes will play a mayor role in increasing yields and improving the utilization of water available from limited rainfall. These results also have major implications with respect to other agronomic research including plant breeding (conditions under which selections are made) and cultural practices to increase available water from rainfall (tied ridges, etc.). Data from these studies will also contribute much needed information to emerging domestic crop production research. From the beginning this research has been directed toward increasing production with minimun inputs. Due to this fact, the data generated from this research will provide a basis for development of low input sustainable agricultural (LISA) production systems which are now receiving increased emphasis for use in U.S. agriculture.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: Germplasm Enhancement for Increasing Resistance to Insects and Improving Efficient Nutrient Use in Sustainable Production Systems

Project Leader: Art Onken/Gary Peterson **Project Number:** TAM-123

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=TAM123 -- ----------						
Staff Salaries & Benefits	16.83	17.62	18.41	19.21	20.20	92.27
Post Doctorates	6.46	6.76	7.07	7.37	7.75	35.41
Graduate Students	6.00	7.00	7.00	7.00	8.00	35.00
Other Salaries	8.42	8.81	9.21	9.60	10.10	46.14
Supplies	7.31	7.65	8.00	8.34	8.77	40.07
Equipment	2.64	2.76	2.88	3.01	3.16	14.45
Travel	9.52	9.97	10.42	10.86	11.42	52.19
Other Direct Costs	6.55	6.85	7.16	7.47	7.85	35.88
Overhead	20.74	21.72	22.69	23.67	24.89	113.71
	84.47	89.14	92.84	96.53	102.14	465.12

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=TAM123 -- ----------						
Post Doctorates	14.86	15.60	16.38	17.20	18.06	82.09
Other Salaries	15.33	16.09	16.90	17.74	18.63	84.69
Fringe Benefits	6.16	6.47	6.79	7.13	7.49	34.05
Supplies	4.20	4.41	4.63	4.86	5.11	23.21
Travel	7.35	7.72	8.10	8.51	8.93	40.61
Overhead	20.36	21.37	22.44	23.56	24.74	112.48
	68.25	71.66	75.25	79.01	82.96	377.12

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=TAM123 -- ----------						
Post Doctorates	14.15	14.15	14.15	14.15	14.15	70.74
Other Salaries	14.60	14.60	14.60	14.60	14.60	72.99
Fringe Benefits	5.87	5.87	5.87	5.87	5.87	29.35
Supplies	4.00	4.00	4.00	4.00	4.00	20.00
Travel	7.00	7.00	7.00	7.00	7.00	35.00
Overhead	19.39	19.39	19.39	19.39	19.39	96.93
	65.00	65.00	65.00	65.00	65.00	325.00

Breeding Sorghum for Stability of Performance Using Tropical Germplasm

Project UNL-115
David J. Andrews
University of Nebraska

Collaborating Institutions

Host Countries:

S. M. del Campo-Valle, cereal breeder, Aguascalientes, Mexico
Tom Hash, cereal breeder, ICRISAT/CIMMYT, El Batan, Mexico
L. M. Mazhani, cereal breeder and UNL-GRS, Sebele ARS, Gaborone, Botswana
L. R. House and T. Obilana, sorghum breeders, ICRISAT, Bulawayo, Zimbabwe
Osman Ibrahim, sorghum breeder, ARS, Wad Medani, Sudan
Omar Niangado, cereal breeder, Bamako, Mali
C. Trouche, sorghum breeder, CNRA, Bambey, Senegal
D. S. Murty, ICRISAT, Kano, Nigeria
S. M. Mukuru, sorghum breeder, ICRISAT, Hyderabad, India

U. S.

D. J. Andrews, plant breeder, Department of Agronomy, University of Nebraska, Lincoln, NE
J. D. Eastin, physiologist, Department of Agronomy, University of Nebraska, Lincoln, NE
J. W. Maranville, physiologist, Department of Agronomy, University of Nebraska, Lincoln, NE
M. D. Clegg, physiologist, Department of Agronomy, University of Nebraska, Lincoln, NE
J. D. Axtell, plant breeder, Department of Agronomy, University of Nebraska, Lincoln, NE
Paula Bramel-Cox, Kansas State University, Manhattan, KS
M. D. Witt, Kansas State University, Garden City, KS
R. R. Duncan, Sorghum Breeder, University of Georgia, Griffin, GA
G. Odvody, Texas A&M University, Corpus Christi, TX

Research Objectives

Develop by crossing exotic and U.S. stocks, pedigree material and random-mating sorghum populations possessing attributes of high yield, desirable agronomic and physiological traits, and evident acceptable grain quality.

Evaluate stress (temperature, moisture, and mineral deficiencies) tolerance in sorghum germplasm; determine the most efficient breeding methodology for developing new materials with resistance or tolerance to these stresses.

Identify useful lines, hybrids, bulks, and populations as cultivars or components of cultivars for use in LDC's or in the U.S.A.

Provide training both formally in Nebraska and informally as a result of joint in-country field operations.

Introduction

Improving sorghum production in the LDC's for food or feed requires that higher yielding, more efficient plant types be identified and utilized in the national programs overseas. The need is urgent if standards of living are to be increased, or even maintained, in face of population increases. Although constraints to sorghum production in both developed and developing nations are agronomic, physiologic, nutritional, pathological, entomological, and even sociological, plant breeding is the avenue through which more production restraints can be addressed, either individually or collectively, than through any other single category of research.

Objectives Related to constraints

Conventional (pedigree, backcross, hybrid) breeding techniques traditionally have been employed with sorghum, and the methods are well established. The success of these plant breeding methods, aided by im-

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proved culture of the crop, is reflected in the 10-fold increase in grain sorghum production in the U.S. from 1919-23 to 1964-68. The transfer of this technology to the LDC's is basic to establishing breeding programs overseas.

Improving sorghum cultivars for developing countries will benefit Nebraska and the U.S.A. Sorghum originated in Africa, but relatively little (with a few exceptions) of the total native variability has been used in the U.S. breeding programs largely because of the low yielding background of exotic varieties. Within the last decade, however, some of the basic variability has been used in the LDC's to develop a new range of higher yielding lines and varieties that variously have been released in China and several African and Latin American countries. This represents a new pool of variability particularly for yield, white, low tannin quality grain and tan plant color which can contribute to U.S. agriculture through plant breeding. At the same time, the LDC's will have the benefit of crosses with elite U.S. germplasm and our technical advice in their national programs.

Objectives

Utilization of existing project material both at LDC locations and in Nebraska/Kansas.

To cooperate in conducting collaborative breeding nurseries in Mali, Senegal, Sudan, and possibly Kenya, and further develop Botswana collaboration on sorghum.

Use existing project material and other U.S. stocks in crosses with newly introduced material, chosen because of performance in multilocation international tests in India and Africa, also using Botswana and high altitude stocks from El Batan, Mexico. Feed this new variability to cooperative locations and evaluate it in Nebraska in collaboration with other UN-L projects.

Host Country Collaboration

With agreement from the host-country breeder, appropriate segregating material produced at UN-L is sent for selection in the host-country in support of his breeding objectives. Breeding procedures are discussed in situ. Example is with L. M. Mazhani at Sebele, Botswana, with the objective of producing seed parents from crosses with Segeolane type. In 1988, testcrossing commenced on 62 lines retained after 3 years of selection. Further related material was sent for testing in 1988/89. In another project, short-season, cool-tolerant lines were farm tested near Francistown, the best retained and multiplied for larger tests in 1988/89. Similar collaboration will commence in 1989 in Senegal (work plans have been developed with USAID/DAKAR and Michigan and Arizona State Universities), and possibly in shorter season higher altitude localities in Kenya.

Nurseries of breeding material will continue to be sent out as in 1989, when they were sent in response to requests from Senegal, Mali, Sudan, Nigeria, and Zimbabwe (ICRISAT).

The winter nursery is now conducted in Mexico where agroclimatic conditions are excellent for breeding operations and rapid production of high quality seed. Nursery will be used for collaboration with INIA and ICRISAT/CIMMYT.

Where possible and where local advisors are available, thesis work for UN-L Ph.D.'s will be done in the student's country on a topic of importance at that location, as with L. M. Mazhani.

Research Procedures

Introduce and cross elite germplasm from LDC's with elite U.S. material, grow F_1's and distribute F_2-F_4's to LDC's for inbreeding and selection. Results from Botswana indicate F_3 lines are the best stage to send. After evaluation remnant seed of selected lines is used at UN-L to make backcrosses or testcrosses. This is a continuing process which utilizes the best emerging lines in new crosses appropriate to the county program needs.

Cross elite germplasm from LDC's to existing random-mating populations, random mate, and distribute the new populations for breeding purposes.

Test early generations from pedigree breeding in multi-site locations, particularly in LDC's.

Test advanced lines derived from crosses made in 4 a) above for performance in drought and nutrient stress conditions in Nebraska (in collaboration with NE 114 and 116E) and in Kansas (with KSU) with grant assistance from USDA/OICD and both the Nebraska and Kansas Grain Sorghum Boards.

Measures of success

Establishment of collaborative field research at LDC locations. (Botswana, Mexico, and Senegal ongoing, Mali, Nigeria, Sudan, and Zimbabwe planned.)

Performance of new material, at various levels of testing against standard checks, both in LDC locations, and in the U.S. Selections most advanced in Botswana.

Release of varieties or germplasm stocks with parentage traceable to project activities. Releases of

seed parents and germplasms have commenced and will continue in Years 12 through 16.

Publication of results and participation in workshops. (2 book chapters and 2 workshop papers in press, participation planned in two 1989 workshops)

Number of LDC scientists obtaining degrees, upgrading expertise of LDC technical staff through involvement with cooperative field activites. (currently one M.S. and one Ph.D. student)

Annual report, conference papers, and joint release of 6 parental lines (4 jointly) and 36 germplasms in Year 10. Further releases planned for Years 12-16.

General comments

Crosses made with exotic food quality introductions made in the new phase of the project begun in 1984 have produced outstanding material which resulted in germplasm releases in early 1989. These will be further exploited in Years 12-16 in Nebraska (for performance and seed parent production), in Kansas (drought testing), and in Georgia (disease resistance and tolerance to acid soils). Selected lines will be tested in Senegal, Mali, Nigeria, Sudan, and Zimbabwe, and Botswana where one student/national breeder will work on project material.

The project has leveraged funds from USAID/Dakar for breeding work in Senegal and from USDA/OICD and the Nebraska and Kansas Grain Sorghum Boards for stress research in the U.S.A.

Progress (last two years)

In the last two years, material has been supplied for selection in Senegal and the Sudan. Three years (generations) of selection have been conducted in Botswana under conditions of strong drought stress. Sixty-two lines have been developed which are being evaluated both as varieties and parental lines for hybrids (which are an objective in the national program). Very early maturing lines have also been found to have promise when planting is unavoidably delayed, a not unfrequent occurrance in Botswana. Nurseries of breeding lines were also sent to Niger, Mali, Nigeria, and Zimbabwe.

In the U.S.A., three seed parents (N122, N123, and N124 A&B) and 36 germplasm bulks of good grain quality derived from crosses with tropical germplasm have been released from NE 115 for use by public and private breeders. The project was one of three projects which attracted 3 year funding totalling $132,000.00 from USAID/USDA and the Nebraska and Kansas sorghum check-off boards to conduct breeding for stressful dryland conditions.

Benefits to U.S. and LDC Agriculture

The major centers of diversity for sorghum are in Africa and though it is an important crop in the U.S., the germplasm base available to breeders in the U.S. in narrow relative to the total variability existing in the species. Evaluating and making crosses with sorghum germplasm in Africa is thus very valuable to U.S. breeding programs. The "food quality" grain type which is exclusively utilized in NE 115 is in general of superior value as feed. Breeding lines and germplasm bulks directly useful to public and private breeders in the U.S. have been and will continue to be released from NE 115 in early generations.

Sorghum was domesticated in African and millions of people in semi-arid Africa rely on this crop as their major cereal source. Much of the estimated 11 M.t of grain produced annually in Africa comes from traditional sorghum cultivated in the same manner as it has been for centuries. Over the last 5 years, production has increased, but ominously this has come entirely from a 27% increase in cultivated area, while per hectare yields have declined 8% (1987, FAO Production Yearbook). There are instances in Africa (Botswana, Uganda, Tanzania, Zimbabwe, Nigeria, Zambia, Sudan) where improved varieties and hybrids have been adopted to some extent, but this has been strongly connected with available markets and willingness to investment in production. There is a clear and urgent need to generate a combination of new more productive food varieties, and production agronomy technologies at the level which can be adopted by the peasant farmer. A socio-economic input is needed so that technology development is relevant to the peasant farmers needs. Additional problems with sorghum are with nutritional quality and grain qualities to meet consumer expectations. Apart from the known pests and diseases which are serious enough, sorghum is the prime host for the root parasite Striga, whose incidence and build-up is closely associated with the use of susceptible varieties and declining production conditions.

Increased production will only come when the above problems are jointly addressed. New varieties and better agronomic practices are both needed for improved production. The best breeding approach, which is used in this project in Botswana, Senegal, and commencing in Sudan, is, after joint discussion with the national breeders, to supply segregating material and parental lines in support of the national program for selection in-country to obtain the necessary local adaptation, including elimination of striga susceptible material. Annual field visits are made to work with the breeder in the country nursery, and to build further on the emerging lines, with new crosses, either from the NE 115 base program, other INTSORMIL sorghum programs or ICRISAT, with which close liason is maintained.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: Breeding Sorghum for Stability of Performance Using Tropical Germplasm

Project Leader: David Andrews **Project Number:** UNL-115

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=UNL115 -- ----------						
Staff Salaries & Benefits	7.92	8.32	8.71	9.11	9.50	43.56
Post Doctorates	3.04	3.19	3.34	3.50	3.65	16.72
Graduate Students	3.00	3.00	3.00	3.00	4.00	16.00
Other Salaries	3.96	4.16	4.36	4.55	4.75	21.78
Supplies	3.44	3.61	3.78	3.96	4.13	18.92
Equipment	1.24	1.30	1.36	1.43	1.49	6.82
Travel	4.48	4.70	4.93	5.15	5.38	24.64
Other Direct Costs	3.08	3.23	3.39	3.54	3.70	16.94
Overhead	9.76	10.25	10.74	11.22	11.71	53.68
	39.92	41.76	43.61	45.46	48.31	219.06

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=NE115 -- ----------						
University Staff	17.33	18.19	19.10	20.06	21.06	95.73
Staff Benefits	3.47	3.64	3.82	4.01	4.21	19.15
Post Doctorates	5.25	5.51	5.79	6.08	6.38	29.01
Other Salaries	1.05	1.10	1.16	1.22	1.28	5.80
Fringe Benefits	1.26	1.32	1.39	1.46	1.53	6.96
Supplies	1.26	1.32	1.39	1.46	1.53	6.96
Equipment	0.42	0.44	0.46	0.49	0.51	2.32
Travel	0.63	0.66	0.69	0.73	0.77	3.48
Overhead	11.34	11.91	12.50	13.13	13.78	62.66
	42.00	44.10	46.30	48.62	51.05	232.08

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=NE115 -- ----------						
University Staff	16.50	16.50	16.50	16.50	16.50	82.50
Staff Benefits	3.30	3.30	3.30	3.30	3.30	16.50
Post Doctorates	5.00	5.00	5.00	5.00	5.00	25.00
Other Salaries	1.00	1.00	1.00	1.00	1.00	5.00
Fringe Benefits	1.20	1.20	1.20	1.20	1.20	6.00
Supplies	1.20	1.20	1.20	1.20	1.20	6.00
Equipment	0.40	0.40	0.40	0.40	0.40	2.00
Travel	0.60	0.60	0.60	0.60	0.60	3.00
Overhead	10.80	10.80	10.80	10.80	10.80	54.00
	40.00	40.00	40.00	40.00	40.00	200.00

-12-

Breeding Pearl Millet for Stability of Performance Using Tropical and USA Germplasm

Project UNL-118
David J. Andrews
University of Nebraska

Collaborating Institutions

Host Country

L. M. Mazhani, Agricultural Research Station, Sebele, Botswana
L. M. Gourley, Mississippi State University, Colombia Coordinator, Mississippi State, MS
D. Meckenstock, Escuela Agricola Panamericana, Tegucigalpa, Honduras
J. R. Witcombe, millet breeders, ICRISAT, Patancheru P.O., Andhra Pradesh, India
O. Niangado/K. Traore, Department of Agricultural Research, Bamako, Mali
S. M. del Campo-Valle/Tom Hash (ICRISAT/CIMMYT), Mexico
A. T. N'doye/Amadou Fofana, Institute Senegalais de las Recherche Agronomique, Bambey, Senegal
El Hag Abuelgasim, El Obeid Research Station, El Obeid, Sudan
F. P. Muuka, Ministry of Agriculture, Lusaka, Zambia
S. C. Gupta, SADCC/ICRISAT Sorghum Millet Program, Bulawayo, Zimbabwe

U. S.

M. D. Clegg, Department of Agronomy, University of Nebraska, Lincoln, NE
J. W. Maranville, Department of Agronomy, University of Nebraska, Lincoln, NE
J. D. Eastin, Department of Agronomy, University of Nebraska
W. M. Stegmeier, Ft. Hays Experiment Station, Kansas State University, Hays, KS
J. D. Axtell, Department of Agronomy, Purdue University, West Lafayette, IN
A. Kirleis, Department of Food Science, Purdue University, West Lafayette, IN
W. W. Hanna, USDA-ARS, Tifton, GA
L. W. Rooney, Soil & Crop Sciences, Texas A&M University, College Station, TX
D. T. Rosenow, Texas A&M Agricultural Experiment Station, Lubbock, TX
L. M. Gourley, Department of Agronomy, Mississippi State University, Mississippi State, MS

Research Objectives

Identify high yielding pearl millet stocks with tolerance to moisture deficits and high and low temperatures, for use as parents in crosses with host country varieties, and in the U.S.

Visit annually and collaborate in cooperative breeding operations with NE 118 material in Senegal, Botswana, Mali, Sudan, Zambia, and potentially Kenya.

Introduce well adapted LDC millet varieties and breeding material to combine with those in D1 above, and to exploit the resulting variability in LDC locations and in Nebraska.

Establish breeding populations for recurrent selection.

Train LDC post-graduates in breeding processes.

Introduction

Pearl millet is the major millet of Africa and the Indian subcontinent, where about 25 million ha are grown. It is the principal dryland cereal in the lower rainfall, hot, drought-prone sandy areas of these continents, because it can give more reliable yields under these conditions than other cereals such as sorghum or maize. However, in the last 10-20 years in these pearl millet zones, because of rainfall instability, possible climatic changes, and increasing pressure on the land, demand for food has greatly increased. While the problem has been recognized, there has not been an adequate response in efforts to stabilize and improve food production. Against this background, research into the genetic

improvement of pearl millet should be accorded a high priority.

Objectives Related to Constraints

Apart from a proportion of the Indian crop, most pearl millet hectarage is planted with traditional varieties (or morphologically similar reselections) with little change from traditional cultivation practices. Traditional varieties are generally well (though often narrowly) adapted with adequate resistance to biotic constraints, and give a stable, but low production of acceptable grain. Considering the environment they grow in, traditional varieties give a good biomass production, but their efficiency in converting this to grain is poor. It is, therefore, necessary to breed more grain efficient (i.e., higher yielding varieties) which can respond to realistic cultural improvements. U.S. breeding stocks were the original source of high yielding materials first used in the form of hybrids in India, and the first higher yielding varieties have also been recently produced there. These steps have not been taken in Africa, and much still needs to be done on the Indian subcontinent, where it has been demonstrated that the type of material developed in the Midwest (Kansas) has applicability.

Pearl millet is a potential as an alternative grain crop of high feed value for the U.S.A., in the hotter, drier parts of the Great Plains, where sorghum production becomes doubtful, and possibly in double cropping. The KSU program has made considerable progress in this direction, but more improvement is still needed, especially in stem strength, and seed setting ability which will largely depend on the exploitation of new material, particularly from ICRISAT millet breeding locations.

Objectives

Introduce new material from LDC's (commenced in 1983/84) to cross with U.S. stocks.

Select among existing program stocks for appropriate parents.

Visit LDC locations (Bambey, Senegal; Cinzana and Sotuba, Mali; western Zambia; Sebele, Botswana; El Obeid, Sudan; and possibly Kenya) to assist in cooperative breeding and testing activites. Visit other locations and participate in workshops to transfer millet breeding technology.

Cross exotic material and U.S. stocks to produce varability for pedigree selection and constructing breeding populations in chosen LDC locations and in Nebraska.

Evaluate breeding material selected in Nebraska nurseries jointly with KSU and other INTSORMIL projects.

Provide post-graduate training in millet breeding at Nebraska.

Host Country Collaboration and Sites of Research

Collaboration ranges from on-site discussion and review of breeding strategies (Botswana, Mali, Sudan, Zimbabwe) to the conduct of tests on material sent from UN-L (Mali, Senegal,and Sudan). Crosses have been made for collaborative breeding projects in Zambia and Malawi. Breeding material has and will be sent elsewhere on request. Collaboration in the Asian zone has not materialized (except exchange of germplasm and cosponsoring workshops with ICRISAT) due to funding reductions. Collaborative research on pearl millet breeding will be followed up with Kenya.

Research Procedures

Introduce exotic stocks, hand cross with U.S. stocks, make breeding populations, and select in individual crosses. Testcrosses will indicate lines for seed parent or pollen parent development. Best lines will contribute to synthetics.

Winter nurseries will be used to more quickly advance material.

Early generation products of crosses from a) above will be sent to cooperative sites for evaluation and selection which will involve grain quality considerations. Selection methods used will emphasize formation of stable (durable) varieties.

Tests on a modified mass selection scheme will continue using the Nebraska Dwarf Millet Population (NBDMP). Varieties will be produced from 3 new populations which have been formed from the process described in paragraph one.

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. An important added criteria is selection for stalk strength on which a specific study has been commenced.

Joint research will be under taken on food and feed quality in pearl millet.

Measures of success

Establishment of field research at projected cooperative locations. (Collaborative breeding ongoing Mali, Senegal, Botswana, and Sudan--nursery evaluations at other sites.)

Performance of new material, at various levels of testing against standard checks, both in LDC locations, and the USA. Number of lines retained after selection in African locations, number of repeat requests received from Latin American nurseries. Interesting yield levels now being obtained in the U.S.A.

Release of varieties or germplasm stocks with parentage traceable to project activities. (Releases of inbred lines and breeding populations projected in U.S., 1990-1995).

Participation in workshops and publication of results. (2 book chapters and 2 workshop papers in press, 3 more workshops planned)

Number of LDC scientists obtaining degrees, upgrading expertise of LDC technical staff through involvement with cooperative field activities. (Currently 1 Ph.D., 2 M.S. students, involvement with breeding personnel at collaborating sites

Chapters in two books on pearl millet are expected to be published in Year 11. Varieties and parent lines will be released in the U.S.

General comments

Material already produced for Mali, Senegal, Sudan, and Zambia will be progressively selected in respective in-country breeding programs. New crosses, as appropriate, will be fed in. Material will be moved rapidly into national trials and hence to regional trials and other relevant INTSORMIL country projects. There will be feed back of selected material into the Nebraska breeding program. In the U.S., selection will continue on new composites which have been made and the Regional Grain Pearl Millet Test will continue annually in several U.S. states. Hybrid parent lines and populations of use to U.S. agriculture will be released during the work plan period, the first lines are expected to be ready in 1991.

Progress (last two years)

In-country collaboration was continued in Botswana, Mali, Senegal, and Sudan. In each country the basis had previously been laid through visits and joint planning with national breeders for an interactive collaborative breeding program appropriate to the objectives of each national breeding program. Except for Botswana populations of crosses between leading country varieties with UNL-118 lines are being selected in country using jointly developed breeding methods. In Botswana, due to manpower shortages, selection is being conducted in a highly variable well adapted local variety which has a good potential for gain. In 1989, material is in F_2 in Senegal, F_2 and BC F_1 in Mali, F_3 in Sudan, and first cycle of selection has been completed in Botswana. F_2 seed is being produced for Zambia. The same crosses are also being selected in Nebraska to expand the basic germplasm resources in the project.

In the U.S. program in Nebraska in the last two years the principal achievements have been:

Development of many different inbred lines including lodging resistant stocks which have been used in:

- breeding new seed and pollen parents adapted to the mid-west
- testing 3 types of hybrids
- crosses designed for collaborating country breeding programs
- constructing 6 new breeding populations, including a stiff stalk population
- Ph.D. and M.S. theses and genetic studies

Grain yields in unfertilized hybrid and variety trials of up to 4,500 kg/ha, 85% of sorghum.

Initial test results showing pearl millet is equal or better than sorghum or maize in a chicken feed ration.

Advancing Nebraska dwarf pearl millet population to the 3rd cycle of selection. Two varieties (EDS and MLS) produced from this population, which also make good topcross hybrids, being multiplied for release in the USA.

A regional pearl millet grain yield test for the U.S. was initiated in 1988 and is being grown at 6 sites in 1989 in Indiana, Nebraska (2), Kansas, Mississippi, and Georgia.

Advising 3 post-graduate students in pearl millet breeding and on committees of 2 others.

Benefits to U.S. and LDC Agriculture

There is a growing body of evidence that pearl millet grain has higher protein and energy levels than corn and especially sorghum and thus is a better cereal for chickens, hogs, and steer feed rations. There are farming

opportunities for pearl millet as an early maturing feed grain in lower rainfall, hot short season areas in the mid-west (e.g. western Nebraska and Kansas), and for double cropping in longer season areas.

Progress has been made in developing plant types appropriate for combine harvesting but more lodging resistance is needed. Grain yields have been raised close to sorghum productivity but on the basis of pearl millets very high growth rate, much higher yields should be possible. Unique hybrid combinations, which are the basis for commercial seed sales of corn and sorghum in America, have hardly been researched in pearl millet. The UNL-118 INTSORMIL pearl millet breeding project has now developed the base germplasm to produce experimental varieties and hybrids for large scale tests. Germplasm will be released continuously within the next 5 years (2 source populations will be released in 1989), which will enable the public sector and private industry in the USA to produce commercial hybrids and explore markets.

Pearl millet is essential to cereal food production in farming in seasonally dry low rainfall in regions with lighter sandy soils in sub-saharan Africa, especially in countries in the West African Sahel. With the increased frequency of cropping, the need for increased yields, from a combination of more productive varieties with improved farming techniques (better agronomy), is becoming rapidly critical. Even in stress situations, higher yield potential is a component in better performance, but when production conditions are improved, varieties which can respond well to these improvements are essential. The thrust of the UNL-118 pearl millet breeding project is aimed at these situations in the countries in which collaboration has been established. High yield potential (developed in the U.S. home program) are combined with adaptation (in the best country varieties) and the resultant variability is selected for higher performance in situ. While details differ, this is in principle which has worked in the past using high yield U.S. germplasm in developing country sorghum and corn breeding programs. The benefits from even a 10% increase in yield from a new variety are substantial and large compared to the development and technology implementation (seed production) costs.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: Low Input Ecologically Defined Management Strategies for Insect Pests on Sorghum

Project Leader: Henry Pitre **Project Number:** MSU-105

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=MSU105	--	----------				
Staff Salaries & Benefits	14.85	15.64	16.43	17.03	17.82	81.77
Post Doctorates	5.70	6.00	6.31	6.54	6.84	31.39
Graduate Students	6.00	6.00	6.00	7.00	7.00	32.00
Other Salaries	7.43	7.82	8.22	8.51	8.91	40.89
Supplies	6.45	6.79	7.14	7.40	7.74	35.52
Equipment	2.33	2.45	2.57	2.67	2.79	12.81
Travel	8.40	8.85	9.30	9.63	10.08	46.26
Other Direct Costs	5.78	6.08	6.39	6.62	6.93	31.80
Overhead	18.30	19.28	20.25	20.98	21.96	100.77
	75.24	78.91	82.61	86.38	90.07	413.21

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=MS105	--	----------				
Grad Students	16.80	17.64	18.52	19.45	20.42	92.83
Other Salaries	4.20	4.41	4.63	4.86	5.11	23.21
Fringe Benefits	0.32	0.33	0.35	0.36	0.38	1.74
Supplies	3.15	3.31	3.47	3.65	3.83	17.41
Equipment	9.90	10.39	10.91	11.46	12.03	54.68
Travel	7.35	7.72	8.10	8.51	8.93	40.61
Other Direct Costs	2.10	2.21	2.32	2.43	2.55	11.60
Overhead	13.94	14.64	15.37	16.14	16.94	77.02
	57.75	60.64	63.67	66.85	70.20	319.11

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=MS105	--	----------				
Grad Students	16.00	16.00	16.00	16.00	16.00	80.00
Other Salaries	4.00	4.00	4.00	4.00	4.00	20.00
Fringe Benefits	0.30	0.30	0.30	0.30	0.30	1.50
Supplies	3.00	3.00	3.00	3.00	3.00	15.00
Equipment	9.43	9.43	9.43	9.43	9.43	47.13
Travel	7.00	7.00	7.00	7.00	7.00	35.00
Other Direct Costs	2.00	2.00	2.00	2.00	2.00	10.00
Overhead	13.28	13.28	13.28	13.28	13.28	66.38
	55.00	55.00	55.00	55.00	55.00	275.00

Sustainable Plant Protection Systems

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Biotechnological Determination of the Causal Agents of Stalk Rot Complexes of Millet and Sorghum

Project KSU-108
Larry E. Claflin and John F. Leslie
Kansas State University

Collaborating Institutions

Host Country

Dr. Lewis Mughogho, Principal Pathologist, ICRISAT, Hyderabad, India
Dr. Wiwqut Daengsubha, Chairman, Microbiology Department, Kasetsart University, Bangkok, Thailand
Dr. W.A. deMilliano, Principal Pathologist, SADCC/ICRISAT, Bulawayo, Zimbabwe
Mr. Issoufou Kolo, Plant Pathologist, INRAN, Niamey, Niger
Dr. Hilu Omer, Agricultural Research Corporation/INTSORMIL, Wad Medani, Sudan
Dr. Carlos Casela, Sorghum Pathologist, EMBRAPA/CNPMS, Sete Lagoas, Brazil
Ing. Jesus Narro, Sorghum Pathologist, Campo Agricola Experimental Bajio, Celaya, Mexico

U.S.

Dr. Paula J. Bramel-Cox, Department of Agronomy, Kansas State University, Manhattan, KS
Drs. Paul E. Nelson & T. A. Toussoun, Pennsylvania State University, Fusarium Research Center
Dr. Richard E. Fredriksen, Exas A&M University, Department of Plant Pathology, College Station, TX
Dr. Gary D. Odvody, Texas A&M Agricultural Experiment Station, Corpus Christi, TX
Dr. Charles Y. Sullivan and D.J. Andrews, University of Nebraska, Lincoln, NE
Dr. D.T. Rosenow, Texas A & M Agricultural Research Station, Lubbock, Texas

Project Objectives

To ascertain the importance of *Pseudomonas avenae* and *Xanthomonas campestris* pv. *pennamericanum* as seedborne pathogens contributing to yield losses.

To identify and characterize *Fusarium moniliforme* isolates from LDCs with respect to mating type and vegetative compatibility group.

To determine the relative importance of seedborne vs. soilborne strains of *F. moniliforme as causes of stalk rot.*

Introduction

Bacterial diseases. Bacterial streak (*Xanthomonas campestris pv. holcicola*) and bacterial stripe (*Pseudomonas andropogonis*) are implicated as seedborne diseases although the available research data are not yet conclusive. Our laboratory has developed mutants in these bacteria that are resistant to streptomycin (100 ug/ml). These mutants, which have retained their pathogenicity, have been inoculated into sorghum plants. By utilizing these mutants in combination with a semi-selective medium, we can follow the progress of the bacteria through the host plant. This technique is more sensitive than our previous serological technique which had a detection threshold of 10^4 cells/gram of plant tissue.

The mode of entry by the bacterium into the plant remains unknown. We will use scanning electron microscopy to determine if the bacteria can enter through natural openings in the plants, such as stomates or hydathodes, or if wounding of plants is required. Understanding the mode of entry is important in developing a control strategy for these diseases. If access is normally made through natural openings, then breeding for smaller access sites could reduce the ease of infection. If wounding is required then control of other pests, e.g. stalk borers, might be the most effective way to reduce these diseases.

Yellow leaf blotch of grain sorghum, pearl millet, and maize was described by Zummo as a *Pseudomonas* spp. No additional research on this disease has been conducted since its description, despite repeated outbreaks of this disease in West and East Africa. Yellow leaf blotch has increased in frequency during the past three years and the causal agent may be seedborne. Our research on plant specimens from Niger in 1988 revealed

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that insect toxins and/or a spiroplasma/mycoplasma are the likely cause of this disease, rather than the cell-walled prokaryote phytopathogenic *Pseudomonas* that was reported. Cross sections of specimens examined using electron microscopy depicted disintegration of phloem tissue. Such disintegration is consistent with damage induced by either insect toxins or wall-less spiroplasmas or mycoplasmas. No prokaryotes were observed in the vascular bundles or on other leaf tissue, and we assumed that they would remain neither viable nor intact in dried specimens. The specimens collected in Niger were dried prior to departure in the absence of the fixatives required for the preservation of these fragile plant pathogens for detection in the electron microscope.

Fungal diseases. Stalk rots may be the single most important disease affecting sorghum on a worldwide basis. This importance is underscored in the recent publication (Mughogho, 1984) of a book designed to address "Research Needs and Strategies for the Control of Sorghum Root and Stalk Rot Diseases." Stalk rot of sorghum and millet is a late season disease of maturing plants and may be caused by several different fungi (Turner, 1982). During vegetative growth, the plant is colonized by numerous pathogenic and nonpathogenic fungi. Stalk rot disease symptoms are not normally manifested during vegetative growth of the host, however, and the fungi responsible for the disease are assumed to be latent (Young & Kucharek, 1977; Kommedahl, Windels & Stucker, 1979). Following anthesis, host metabolism of carbon and nitrogen shifts dramatically as the host progresses from vegetative growth to reproductive growth, grain fill, and maturation. This portion of the life cycle is frequently accompanied by drought stress. It is during these latter portions of the life cycle that the stalk-rotting fungi appear to become aggressive and stalk rot develops.

Three fungal species are often associated with stalk rots of sorghum and millet: *Fusarium moniliforme* (=*Gibberella fujikuroi*), *Fusarium graminearum* (=*Gibberella zeae*), and *Macrophomina phaseolina*. In Kansas, these fungi cause an annual loss of 5-8% of the sorghum crop, although localized losses may exceed 50% (Lengkeek, 1979). Of these three fungi, *F. moniliforme* is the most common and is the easiest to work with under laboratory conditions. This organism grows well on defined media in shake flasks or on agar plates, is amenable to modern molecular biological techniques, completes its life cycle under laboratory conditions and generates meiotic progeny which can be used as mutagenesis targets and for the purification of novel mutant phenotypes, and can be readily recovered from host material grown in the field or the greenhouse. Recently, we have identified a variety of *F. moniliforme* that is reproductively isolated from the rest of the species and isolated preferentially from sorghum (Klittich and Leslie, 1988b). We have proposed that this group be named *Gibberella thapsina* to reflect this genetic isolation.

Fusarium moniliforme can be found in sorghum roots, stalks and seeds throughout the life of the plant, and is endemic in cultivated fields worldwide (Nelson, Toussoun & Marasas, 1983). It commonly attacks drought-stressed plants and can grow in culture on media with a water potential of -200 bars (Woods & Duniway, 1986). Although the main losses associated with this fungus result from stalk rot, F. *moniliforme* can also produce toxic and/ or carcino-genic metabolites on improperly stored grain (Marasas et al., 1984, 1986; Marasas, Nelson & Toussoun, 1984; Farber & Sanders, 1986). Nitrogen metabolism is thought to play an important role in both toxin production and growth in response to stress.

In population survey work conducted in Kansas, there was more variability between isolates from different fields than there was between isolates recovered from the same field (Leslie et al., 1988). One possible explanation for this phenomenon is that seedborne *F. moniliforme* provides the primary source for inoculum for the coming year. Thus, when a field is sown with a single cultivar, it is also sown with one, or a few strains of *Fusarium* as well. Ascertaining the relative importance of seedborne and soilborne inoculum is important in determining cultural practices to lessen the inoculum available to infect the plant. We will determine the relative importance of seedborne inoculum in establishing fungal infection of the plant and in causing stalk rot. In general, there is less variability within populations of *G. thapsina* than there is within the more common *G. fujikuroi* form of *F. moniliforme*.

Objectives Related to constraints

Bacterial diseases are often incorrectly identified due to limited, or no training, of scientists in LDCs in this subject matter. For example, symptoms of bacterial diseases 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.

Only limited information is available on sexual races, mating types and vegetative compatibility groups of *F. moniliforme* isolates from lesser-developed countries. In particular, the relative frequency of *G. thapsina* is unknown. Since this fungus appears to be particularly virulent to sorghum seedlings in preliminary tests, more information on its distribution is desperately needed. Information of this kind is of critical importance since the races present in LDCs may be different from those present in the United States, and because some races may preferentially attack some cultivars and ignore

others. Studies of nitrogen metabolism in most filamentous fungi other than *Aspergillus* and *Neurospora* are in their infancy.

The importance of seedborne (vs. soilborne) *F. moniliforme* in the cause of stalk rot has not been established. Identification of a primary inoculum source will aid in the design of cultural practices to reduce this disease.

Host Country Collaboration and Work Sites:

Due to limited resources, it is anticipated that most of the collaborative research objectives will be accomplished with the aid of the collaborating P.I.s. Plant samples for bacterial analysis will be shipped directly to Kansas. Plant samples for fungal analysis will be shipped by international collaborators to Drs. Nelson & Toussoun in Pennsylvania. They will isolate Fusaria and retain all isolates except those in the *Liseola* section, which contains *F. moniliforme*. These isolates will be forwarded to Kansas for analyses of mating type and vegetative compatibility group.

This work will be conducted by Mr. Molapo Qhobela, a Ph.D. student from Lesotho, Mr. Petros Zvoutete, a Ph.D. student from Zimbabwe, Mr. Reza Farrokhi-Nejad, a Ph.D. student from Iran, Ms. Chulee Chaisrisook, a Ph.D. student from Thailand and Dr. Nancy Duteau, a postdoctoral researcher from the United States. Mr. Qhobela and Mr. Zvoutete are sponsored by SADCC/ICRISAT and are working on the bacterial portion of this proposal. Mr. FArrokhi-Nejad, Ms. Chaisrisook, and Dr. Duteau are working on the fungal portion of the proposal.

Research Procedures

Bacterial Diseases. Determining the potential seedborne role of the bacterial pathogens of pearl millet will be accomplished by utilizing standardized bacteriological tests and with serological procedures such as the dot-immunobinding assay. It is anticipated that pearl millet seeds will be collected by INTSORMIL Principal Investigators who have collaborative projects in African countries. Our laboratory will furnish the necessary quarantine permits for the importation of this material into the United States.

Fungal Diseases. Our approach to this problem is to test sorghum stalks and seeds from different geographic locations for their endogenous *Fusarium*. We will identify these *Fusarium* according to their race, their mating type and their vegetative compatibility group or VCG (see below for details). We are particularly interested in the *Gibberella thapsina* isolates which have so far been recovered only from sorghum plants (Klittich and Leslie, 1988b). From these studies we will determine if the variability within the fungal population is geographically limited. We expect the strains recovered from this diverse sample to differ widely in their ability to cause stalk rot, and anticipate that different fungal isolates may affect different host cultivars differently. We anticipate that we may identify very aggressive strains, which could be used in breeding for resistance, and that we may identify a weakly virulent strains which could be used in a biological control program. Since we will eventually test multiple fungal isolates against multiple host cultivars, we may also detect pathological races of the fungus. Such races would be pathogenic on some cultivars but not on others. Genes for resistance to particular pathological races could then be introduced via conventional breeding methods.

F. moniliforme isolates will be characterized as to their sexual race, their mating type, and their VCG. *F. moniliforme* can be divided into four races - A, B, C, and D - (Hsieh et al., 1977; Kathariou, 1981), or varieties *moniliformis* (=A), *sacchari* (=B), *fujikuroi* (=C), and *intermedia* (=D) (Kuhlman, 1982). We have added two additional races to this list *subglutinans* (=E) and *thapsina* (=F) (Leslie, Klittich and Correll, 1988; Klittich and Leslie, 1988b). Within each of these races, individuals may be identified as either "+" or "-" mating type. Strains that belong to the same race, but which are of opposite mating type, may cross with one another to form the sexual stage and complete the life cycle. All of the fungal isolates used to deliberately infest soils in this study will be sexually fertile to enable further genetic analysis of these strains as needed. All isolates used in this study will be classified by both race and mating type.

Fungal isolates will also be placed into a vegetative compatibility group, or VCG (Correll, Klittich and Leslie, 1987). The VCG to which a particular fungal isolate belongs is determined by its genetic composition at a number of loci, termed vic loci, which are scattered throughout the organism's genome. Enough vic loci exist to specify over 4,000 different clones of *F. moniliforme* (Puhalla and Spieth, 1985; Klittich and Leslie, 1988a). We will use the specificity of the VCG type to follow our strains through the infection and demise of the plant. Using this marker, we will be able to distinguish the fungal strain we introduce into the soil from other strains that may infect the plant. We have been using this technique to characterize *F. moniliforme* isolates for several years (Leslie, Klittich and Correll, 1988; Leslie, 1988), and do not anticipate any problems with these analyses. If variability is found within a local population, as preliminary studies have indicated, then we will study variability in the mitochondrial DNA to determine if the variability we are observing is due to migration (mtDNAs should be different) or sexual recombination (mtDNAs should be similar).

Measures of Success

Preparation of journal articles and filing timely reports to host country cooperators.

Progress Report (last two years)

Bacterial Diseases. Polyacrylamide get electrophoresis of membrane proteins and restriction endonuclease analysis of genomic DNA were utilized in identifying *Xanthomonas campestris* pv. *holcicola* (*X. c.* pv. *holcicola*), the bacterial leaf streak of sorghum (*Sorghum bicolor*). fifteen strains of *X. c.* pv. *holcicola* were either obtained from established culture collections or isolated from diseased plant tissue. The cultures had a wide geographical distribution Australia, New Zealand, Mexico, Lesotho, Republic of South Africa and the United States. Both techniques were capable of distinguishing *X. c.* pv. *holcicola* from other pathovars of *Xanthomonas campestris* and other phytopathogenic bacteria examined. *X. c.* pv. *holcicola* had two unique proteins of approximately 45 and 30 kd. The genomic DNA digested with the EcoRI restriction endonuclease was also unique with a blur in the region from 4.8-5.0 kb and a pair of bands at 3.7 and 3.9 kb, respectively.

Within *X. c.* pv. *holcicola* we have determined that races exist based on tests with sorghum genotype differential hosts. The sorghum genotypes employed in our tests were BTx-623, Btx-630, B8106, QL3, Tam 428, Tx 434, 84C-7730, and 65L-21905. With one exception all of the bacterial isolates were pathogenic to BTx-623, Tam 428, 84C-7730, and 85L-21905. The genotypes BTx-630 and QL3 were resistant to all of the bacterial strains.

We have identified and subsequently published in scientific journals on two new bacterial diseases affecting pearl millet in Niger and Nigeria. These diseases are bacterial leaf streak, caused by *Xanthomonas campestris* pv. *pennamericanum*, and bacterial leaf stripe, caused by *Pseudomonas avenae.*

Fungal diseases. Work in this area has been in progress for only slightly over a year now. During this time a novel *Fusarium* spp. has been identified. This new species appears to be specific to sorghum and has so far been found in material from Kansas and Texas. We are just now beginning to screen material from outside the United States for the presence of this "sorghum-specific" phenotype. Some members of this group appear to have characteristics of two different *Fusarium* species. If this finding is confirmed, then most of the species in the *Liseola* section of the genus will require redescription. Confusion of this type over taxonomy makes disease diagnosis difficult since several different fungal species with quite different abilities can easily be lumped together in one group. Meaningful generalizations, e.g. species xxx is responsible for disease xxx, are then exceedingly difficult to make.

Success stories

We are the only laboratory in the Free World that is actively pursuing research on bacterial diseases of sorghum and millet. In the past we have been requested to identify numerous bacterial diseases, but have been forced to decline because of the difficulties associated with obtaining import permits. Our objective was to provide a bacterial identification service to cooperators in LDCs. We have developed a dot-immunobinding assay (DIA) for detecting bacterial pathogens in sorghum. The technique is relatively simple and inexpensive, thus eliminating the need for costly and/or sophisticated laboratory equipment, and does not require the transportation of plant material, thus eliminating the need for import permits. In brief, the DIA identification scheme will consist of sending 3x5 cm strips of nitrocellulose paper to the cooperator, who will apply sap from diseased plant tissue to it. The bacteria in the plant sap will be fixed to the paper and all of the microorganisms in the preparation are killed by the addition of ethyl alcohol and acetic acid. The paper is then returned to Kansas to complete the identification process, which requires approximately 24 hours after receipt. The results can be sent by mail, telex or fax, as appropriate, to the cooperator. The only equipment required by the LDC laboratories will be a few pipettes, small test tubes for making dilutions, 5 ul glass capillary pipettes and several liters of ethyl alcohol and acetic acid. The total cost of these supplies, which should be sufficient for a year's worth of assays, should not exceed $20.

Benefits to US and LDC Agriculture.

For the past six years we have screened the grain sorghum All Disease and Insect Nursery developed by Texas A and M University for accessions that are tolerant or resistant to covered kernel smut. This disease is relatively rare in the United States since effective seed treatments are available. Several of these chemicals, e.g. Captan, have been closely scrutinized recently however, because of undesirable breakdown products, and the registrations for some or all of these chemicals could be revoked in the near future. In LDCs, covered kernel smut is a serious problem. Sorghum plants in some fields in Lesotho were observed to be nearly 50% smutted. In LDCs seed treatments are either unavailable or financially not worthwhile. Thus a need for tolerant genotypes is of immediate importance to LDCs and of potential importance in the United States.

Our screening tests have shown that three genotypes, B35-6, SC414-12, and Sureno, are immune to covered kernel smut. Several lines with less than 5%

infection were also identified: 80C2241, 82DM499, BTx378, R4244, R6078, R6956, SC630-11, and Tx 2783. Incorporating these genotypes into appropriate breeding programs should prevent damage from this pathogen without the need for seed treatments.

Fusarium taxonomy as it applies to those *Fusarium* spp. commonly found on sorghum and millet is going through an important revision. Much of this revision is attributable to new techniques, e.g. sexual compatibility tests, and to new isolates being recovered from sorghum and millet in Africa by INTSORMIL cooperators. Differences observed from many African isolates are more distinct than those observed in isolates from the United States. Thus the isolates from the LDCs are being used to better define the taxonomy of this set of fungi. Even more important however is the fact that many of these isolates produce potent toxins and/or carcinogens whose characterization has just begun. Since many of these isolates are recovered from apparently healthy grain, the extent of this problem in either LDCs or the United States is not yet manifest.

Summary

Stalk rot is an important disease of sorghum worldwide. Yearly losses range from 5-8% of the crop, but localized losses frequently exceed 50%. One of the prime causes of this disease is the filamentous fungus *Fusarium moniliforme*. This organism is both seedborne and soilborne. We will conduct experiments to ascertain the relative importance of these two inoculum sources in establishing a fungal infection and in causing stalk rot. Results from these experiments will be used in outlining cultural practices for reducing the inoculum available to infect the plant.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: Biotechnological Determination of the Causal Agents of Stal
Rot Complexes of Millet and Sorghum.

Project Leader: Larry Claflin **Project Number:** KSU-108

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=KSU108 -- ----------						
Staff Salaries & Benefits	13.86	14.65	15.44	16.04	16.83	76.82
Post Doctorates	5.32	5.62	5.93	6.16	6.46	29.49
Graduate Students	5.00	6.00	6.00	6.00	6.00	29.00
Other Salaries	6.93	7.33	7.72	8.02	8.42	38.42
Supplies	6.02	6.36	6.71	6.97	7.31	33.37
Equipment	2.17	2.29	2.42	2.51	2.64	12.03
Travel	7.84	8.29	8.74	9.07	9.52	43.46
Other Direct Costs	5.39	5.70	6.01	6.24	6.55	29.89
Overhead	17.08	18.06	19.03	19.76	20.74	94.67
	69.61	74.30	78.00	80.77	84.47	387.15

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=KS108 -- ----------						
Post Doctorates	11.00	11.55	12.13	12.73	13.37	60.78
Fringe Benefits	2.86	3.00	3.15	3.31	3.48	15.80
Supplies	3.58	3.75	3.94	4.14	4.35	19.76
Travel	1.05	1.10	1.16	1.22	1.28	5.80
Overhead	7.76	8.15	8.56	8.99	9.44	42.91
	26.25	27.56	28.94	30.39	31.91	145.05

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=KS108 -- ----------						
Post Doctorates	10.48	10.48	10.48	10.48	10.48	52.38
Fringe Benefits	2.72	2.72	2.72	2.72	2.72	13.62
Supplies	3.41	3.41	3.41	3.41	3.41	17.03
Travel	1.00	1.00	1.00	1.00	1.00	5.00
Overhead	7.40	7.40	7.40	7.40	7.40	36.98
	25.00	25.00	25.00	25.00	25.00	125.00

Low Input Ecologically Defined Management Strategies for Insect Pests on Sorghum.

Project MSU-105
Henry N. Pitre
Mississippi State University

Collaborating Institutions

Host Country

Dr. Dan Meckenstock, INTSORMIL, TAM-131, Agronomist, Honduras
Dr. Keith Andrews, Entomologist, Pan American School, Honduras
Dr. Francisco Gomez, Plant Breeder, Recursos Naturales, So. Honduras

U.S.

Dr. Billy Wiseman, Entomologist (MS-105), USDA, Tifton, GA
Dr. Lynn Gourley, Agronomist, Mississippi State University
Dr. Randy Luttrell, Economic Entomologist, Mississippi State University
Ms. Willye Harrison, USDA Quarantine Officer, Stoneville, MS.

Project Objectives

1. Studies on biology, ecology, behavior and population dynamics of pest and beneficial insects.

2. Development of host plant resistance to insect pests.

3. Develop insect pest management strategies for LDC's.

Introduction

A complex of insect pests attack sorghum and corn in Honduras and in general, where these crops are grown in the Americas. These grain crops are damaged by insects from the time the seeds are planted through grain head maturity and seed storage. In many areas of North, Central and South America, one or more insect pest species is considered a principal constraint to sorghum production. In most areas more than one species causes economic damage in most years or complete loss of the crop in some years, particularly in areas of subsistence farming. In the United States monocropping sorghum production systems have experienced multiple insect pest problems resulting in economic yield reductions. These pest constraints on yield reduce crop production stability and are deterrents to sustainable agriculture in areas employing low as well as in areas employing high technology production practices. Many of these insect pests have wide geographical distribution in the Americas. The MSU-105 project is designed to investigate the insect pest problems for the purpose of developing control tactics and strategies for effective and practical management of the insect pests in Honduras and surrounding developing countries, as well as provide practical information in relation to certain pest outbreaks on sorghum in the U.S. The thrust of this entomological research is designed to develop insect management strategies that contribute to increased and stable yields in developing countries and to reduce production costs in the U.S. Emphasis is placed on bio-intensive insect pest management tactics including management of insect pests using alterations in cultural practices, crop varieties with resistance to pests, and biological control agents that are effective against specific insect pests. The insect management practices can be employed in crop production systems on traditional small subsistence farms and in large production farms in the U.S. They are sound, ecologically safe practices that will contribute to increased crop production in durable agricultural systems without detrimental effects to man and environment. Basic biological and ecological studies will provide the basis for implementation of these pest management practices to insure sustainable crop production. The research in the U.S. dealing with some cosmopolitan pests, i.e., fall armyworm, stalk borers and panicle feeders, as well as some beneficial insects, is programmed for transfer of pest management information to production systems in these developing countries. The entomological research in Honduras and the U.S. emphasizes biological investigations involving relationships between insects and plants to develop an ecological framework for understanding the structural and function of organisms in different sorghum-corn cropping

agroecosystems. This bio-intensive research will provide the information that will allow for the integration of cultural, biological and chemical control tactics in the implementation of insect pest control programs. This project has a principal objective to work with insect pest problems encountered by low income, subsistence farmers in developing countries and to investigate the principal insect pests in Mississippi for development of pest control methods which do not rely entirely on chemical insecticides. In Honduras 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.

As stated above, these control methods have emphasized host plant resistance, cultural control tactics and biological control. Complementary studies in Mississippi with insect pests like the fall armyworm, a significant pest in the Americas, common to both areas, contribute to understanding such phenomena as insecticide resistance and migratory habits of insects. Investigations of foliage feeding insect pest biology, population dynamics and reactions to insecticides, considering pest species collected in different Latin American and Caribbean Basin countries and the southern United States, have contributed to our understanding of insect migration and development of insecticide resistance in pest outbreaks in the southeastern United States. This program provides assistance to farmers in the developing countries, and also is designed to facilitate the development of strategies for managing insect pests of international importance, especially those entering the continental United States, without total dependence on insecticide control.

Foreign student training and collaborative investigations with host country scientists are important parts of the MSU-105 project. Student research programs are related to the Project objectives. Investigations in Honduras and the U.S. during 1989-1994 will include identification of sorghums with resistance to insect pests. In Honduras native landraces and improved varieties will be investigated for resistance to foliage feeding insect pests, emphasizing the fall armyworm, and mechanism of resistance will be determined. Host plant resistance investigations in the U.S. will continue to identify resistant sorghums for planting in sustainable, high technology input agricultural production systems. Studies will be conducted in Honduras to determine interactions of specific foliage, stalk, and panicle feeding insect pests with noncrop vegetation, and impact on crop yield (damage assessments) as basis for development of cultural practices (ex. weed control) that will be ecologically safe for stable crop production and sustainable agriculture. Studies in Mississippi will continue to emphasize the integration of cultural, biological and chemical control practices for management of insect pests of principal economic importance in the southeastern United States, including the fall armyworm, corn earworm and sorghum webworm.

Objectives to work on during years 11-15.

The objectives and goals of Project MS-105 for years 11-15 are expansions of research investigations conducted during the previous 2-3 years, and work will be conducted on aspects of all objectives. It is the intent of the investigations in Honduras to develop as quickly as possible practical and implementable insect pest control methods for immediate use in the host country and other areas with similar insect pest problems. An example of progress in MSU-105 is the research findings related to antibiosis resistance to fall armyworm in Honduran native, landrace sorghums. This research accomplishment by MSU-105 and TAM-131 will provide the basis for expansion of breeding studies in the sorghum improvement program in Honduras. Additionally the completion of studies that identified soil inhabiting insect pests responsible for seed destruction and the development of selective use of soil insecticide control methods for these pests in southern Honduras will allow the subsistence farmer to plant sorghum and corn at desirable times without the loss of part or all of the crop due to soil inhabiting insect pests. In working collaboratively with the Extension Department personnel in the area, this was accomplished. In the U.S. research will emphasize the significant, economic, lepidopterous pests, including fall armyworm, corn earworm and sorghum webworm, in developing integrated cultural, biological and chemical insect control methods. In developing ecologically safe insect pest management strategies without the total reliance on insecticides, crop production systems will become more stable and sustainable, without significant harmful effects on the environment.

Host Country Collaboration and Work Sites

Objectives 1 and 3

Ecological studies with the complex of lepidopterous larvae referred to as "Langosta", that are responsible annually for the destruction of seedling and early whorl stage plants, and stalk borers will be conducted on subsistence farms in the hills and on the plains in different cropping systems in southern Honduras. This work will be in collaboration with Dr. Francisco Gomez (Ministry of Natural Resources), Dr. Dan Meckenstock (TAM-131), and Dr. Keith Andrews (Pan American Agricultural School). The Extension Service (RN) in this area assisted in selection of fields for these studies. Biological investigations involving studies to establish strain relationships among fall armyworm isolates, larval feeding and development tests to determine duration of insect life stages, ecological and biological studies and efficiency

levels of beneficial insects (parasitoids and predators), and mechanisms of host plant resistance will be conducted in fields in Honduras and at the Panamerican Agricultural School using the Entomology Department facilities. Related field tests to measure host plant resistance and tests to evaluate minimum use of insecticides on the Langosta in integrated pest management programs (ex., utilizing weed control) will be conducted in fields in Central and southern Honduras, respectively. Drs. Andrews, Meckenstock and Gomez will collaborate. Studies on mechanisms of resistance in sorghum to fall armyworm will be conducted in the U.S. at Tifton, Georgia with Dr. Billy Wiseman collaborating. Dr. Lynn Gourley and Dr. Meckenstock provide sorghum cultivars for evaluation. Chemical and biological investigations for integration of control tactics will be conducted in Mississippi with Dr. Randy Luttrell cooperating.

Research procedures to be followed.

Objectives 1 and 3

Early season ecological and biological studies have been conducted and will be conducted in southern Honduras on the Langosta complex, including larvae of the fall armyworm, southern armyworm, grass looper and *Metaponpenta rogenhoferi*. These insects may cause complete crop destruction and are responsible for replanting in many years, a cost which the subsistence farmer can not afford. Thus, many fields are not replanted because of the associated cost. The relationships of non-crop vegetation with insect infestations and population dynamics will be investigated during the growing season. The possibility of using weed host control methods for control of the damaging larval populations will be tested, incorporating timely and selective insecticide spray applications for supplemental or complete control on some replicate sites on the test farms. Additionally, in these studies in southern Honduras, stalk borers damaging in crops and panicle feeding insect pests will be identified during the growing season to determine infestation levels and aspects of biological control. The influence of defoliator, stalk borer and panicle pests on crop productivity (yield loss assessments) will be determined using plant life table methods for assessing components associated with plant yield reductions. These investigations, designed to determine the extent of insect damage caused to the sorghum and corn crops, will provide the information to critically define the role of the pest insects in the economics of the production system.

Laboratory colonies will be established at the Panamerican Agricultural School for use in biological studies with insect species mentioned above, as well as panicle feeding insect pests. Comparative studies will also be made on morphology and behavior of fall armyworm populations collected on sorghum and corn (possibly other host plants) to elucidate race relationships. Recent literature reports differences in strains of the fall armyworm; this has a significant impact on insect ecological, behavioral and biological studies with associated crop vegetation in specific areas. Insecticide tests will also be conducted to determine levels of insecticide susceptibility in these lepidopterous larvae. This information is important not only to local farmers in Honduras, but also to international agriculture as it relates to insect migration and the spread of insecticide resistant populations.

In Mississippi lepidopterous larval infestations will be monitored in sorghum and corn in monoculture (representative of U.S. production) and in intercropped systems (typical of subsistence production in Honduras) to determine levels of infestations and age specificity of larvae on plants in different phenological growth stages, age specificity of larvae associated with parasitization, and influence of insecticides on the pests and levels of parasitization on whorl and panicle stages of plant development. The fall armyworm will be emphasized in both whorl and seed head stages, and the corn earworm and sorghum webworm will also be included in the seed head stages. Insecticide spray applications will be made to some plots disregarding biological control for comparisons with the selective use of insecticides in plots integrating bilogical and chemical control methods.

Objective 2

Evidence of antibiosis host plant resistance in Honduran native maicillo criollo sorghums, first observed in 1986, has stimulated an expansion of research on this insect control tactic. Host plant resistance in the form of antibiosis, antixenosis (nonpreference), and/or tolerance in these tropical sorghums will be evaluated at El Zamorano and local production fields in the area of Central Honduras. An even larger number of maicillo criollo sorghums will be evaluated in 1989-1991 than tested in previous years to determine how wide spread the antibiosis resistance is in the native sorghums. Antibiosis will be evaluated based on insect developmental rates and times, and larval and pupal weights (indicators of adverse effects of the host plant on the insects). The stability of this observed insect resistance characteristic through several generations will be examined.

Additional studies on the mechanisms of plant resistance, including antixenosis and tolerance, will be tested in choice and/or no-choice feeding and behavioral tests using adults in small cages (oviposition tests) and larvae in small arenas; tolerance (plants ability to tolerate insect damage) will be evaluated in small field plots. All experiments will be conducted in Central Honduras.

Host plant resistance studies in the U.S. will also be expanded and emphasized during the next 5 years be-

cause of the earlier research results indicating resistance to the FAW in the Honduran native sorghums (MSU-1O5 and TAM-131) and in certain other selected sorghum genotypes available for production in the U.S. and other areas of high technology (Wiseman GA, MSU-1O5). The following tests will be conducted:

Converted lines, selected for evidence of FAW leaf feeding resistance from tests with 340 lines in 1988, will be evaluated for FAW leaf feeding resistance in 6 to 10 leaf stages in replicated field tests.

Converted lines, selected for evidence of FAW panicle resistance in 1988 will be evaluated for non-preference (antixenosis) to larvel establishment in replicated field tests. Converted lines evaluated for panicle resistance to FAW in the field will be evaluated for antibiosis in a meridic diet bioassay test in the laboratory.

Converted lines evaluated in 2 and 3 above will be evaluated in feeding tests with fresh leaf material at two stages of plant development -6 and 8 leaf stages. Leaf consumption and larval weight will be measured in the laboratory.

Early maturity sorghums will be evaluated at 8 and 10 leaf stages for growth response to FAW feeding to determine if the plants can grow through the early, susceptible stages of development in the field.

Tolerance of hybrids infested with different levels of FAW will be measured in field tests to determine yield response of plants infested at 8 and 10 leaf stages; compare infested plants with protected plants in the field.

Maicillo criollos Honduran native sorghum type 2 with AF-28 (genotype with FAW resistance) will be evaluated at whorl stage in the field for antixenosis. Laboratory tests to evaluate antixensosis will be conducted with genotypes showing resistance to feeding damage in the field.

Measures of success

The ecological studies to be conducted with the Langosta complex of lepidopterous pests as well as stem borers and insect pests in southern Honduras will provide information on insect-host and non- host plant associations to be used in developing weed control recommendations and use patterns of limited, selective insecticides and/or biological control recommendations for specific growth periods of seedling, whorl, and panicle stage plants in order to prevent stand losses, stalk damage and seed losses by these insect pests. Crop loss assessments will be the measures of success for management of these destructive insects. Selective use of selective insecticides will allow the practical use of these chemicals on soil inhabiting insects as well as other pest of vegetative and reproductive stages of sorghum and corn. Host plant resistance investigations will identify resistant types and elucidate mechanisms of resistance of cultivars for use into production systems in Honduras. The introduction of these resistant cultivars into production systems will be the measure of success of this approach to insect pest management. The successful integration of biological and selected/selective chemical control methods of insect control in both the U.S. and Honduras will signify success without total reliance on chemical insecticides for insect pest control and will indicate progress toward improved insect pest management and sustainable agriculture. With these insect pest control practices, crop damage by insects will be minimized and additional food grain will be available for human consumption.

Anticipated Reports and Articles

Occurrence and densities of the lepidopterous pests in the Langosta complex on sorghum and maize in southern Honduras Response by sorghum and maize to damage caused by the lepidopterous pests in the Langosta complex and stalk borers in southern Honduras.

Influence of weed management programs on lepidopterous pests in the Langosta complex in southern Honduras.

Honduran native sorghums with resistance to fall armyworm larval feeding.

Mechanisms of resistance to the fall armyworm in Honduran native sorghums.

Resistance to fall armyworm in converted sorghums.

Leaf feeding tests for resistance to fall armyworm in sorghum seedling, whorl and panicle stages.

Susceptibility of lepidopterous larvae in the Langosta complex to insecticides.

General comments

INTSORMIL, MSU-1O5 will continue to emphasize research on insect pest constraints to sorghum and corn production on subsistence farms in Honduras, and to conduct complementary research in the U.S. on pests of economic importance in the southeastern region with the goals of developing practical and economical insect pest control methods which do not rely totally on chemical insecticides. Research emphasis will be placed on the development of insect pest management tactics for integration into integrated insect pest management systems. Progress will continue to be made on developing insect control tactics that are ecologically defined and

safe and are not destructive to the environment. These practices will insure stable crop production for sustainable agricultural cropping systems. Student training will continue with participation by individuals selected form the prime site county, Honduras. This should insure, to some degree, improvements in institution building, a significant part of INTSORMIL. Research coordination with personnel in the Ministry of Natural Resources and Panamerican Agricultural School and collaboration in research activities will continue to be stressed as part of this project. The principal investigator will continue to emphasize reports and publication of research findings in appropriate Latin American literature sources and in other scientific journals.

Progress (last two years)

Soil inhabiting insects were reported by extension personnel of the Ministry of Natural Resources in Honduras to be the principal cause of sorghum and maize seed destruction soon after planting in intercropped systems in southern Honduras. The loss of plant stand requires replanting, but subsistence farmers often can not afford this cost. Ants, wireworms, white grubs, rootworms and millipedes were the most abundant arthropods in fields in hills and plains. Wireworms, rootworms and millipedes were in higher densities in slash and burn than in slash and mulch fields; the increased number of arthropods in burned fields appeared to be related to their establishment on attractive, luxuriant regrowth vegetation following the burning practice. The traditional practice of burning had a negative effect as a control for soil inhabiting arthropod pests of sorghum and maize.

The establishment of a good crop stand is critical for resource poor subsistence farmers in developing countries. Insects, as well as low soil moisture, can influence seed germination and seedling damage. Depth of planting is critical to plant stand establishment and is determined by seed size and type, as well as number of seeds planted. Studies in an area in central Honduras infested with seed and foliage feeding insects showed that sorghum seed size and color did not influence the amount of damage to seeds and seedlings by insect pests. Seedling emergence was greater with increased number of seeds per hill at planting and appears to be related to the greater success of plant emergence with increased number of seeds per hill. Seeds pushed through the soil with less difficulty and more quickly than plants in hills with fewer seeds. Seed planted 2.5 cm deep emerged to establish a plant stand before seed planted 7.5 cm deep, thus the seeds planted deep were exposed to insects and their damage for longer periods than seed that were not planted deep in the soil and emerged faster.

As stated above subsistence farmers incur higher production expenses when additional seed is required for replanting sorghum and maize or they may not replant due to the lack of seeds. Replanting also results in delayed maturity of the maize, which increases its vulnerability to mid-season drought and exposure to additional damage by late season insect pests, e.g. stalk borers. Insecticides can effectively control some soil inhabiting insect pests, therefore insecticide seed treatments were evaluated in sorghum fields with infestations of insect pests living in the soil. Furathiocarb (Promet) provided the greatest protection to the seeds and seedlings from damage by insects during 20 day post planting period. This protection permitted successful plant stand establishment. Kerosene and chloropyrifos provided some protection to the seeds and seedlings. Kerosene cost less than the other chemicals, is easy to apply to the seeds, is not highly toxic and is commonly found in rural households where it is used for illumination and cooking. Protection of the sorghum and maize seed using kerosene is recommended to subsistence farmers in southern Honduras, who can not afford seed treatment with Promet insecticide.

Farmers in Honduras refer to the "langosta" when discussing insects (larvae = worms) that attack sorghum and maize crops. The langosta is particularly damaging to and often destroys the crop plants during the primera (first) growing season. The langosta was determined to be a noctuid lepidopterous complex consisting of the fall armyworm, southern armyworm, the grass looper (*Mocis* sp.) and a forth noctuid, *Metaponpneumata rogenhoferi*. The larvae of these species cause severe damage to young sorghum and maize plants in fields on hillsides and in the plains. The extensive feeding damage by the larvae, often resulting in complete crop destruction, is identified by farmers to be associated with large locust populations, thus the name langosta, which in Spanish means locust. The non-crop vegetation in and around the production fields serves as host plants for these insect pests prior to crop emergence. Removal of this vegetation should influence populations of larvae and crop damage in the production fields. Weed control is recommended as an ecologically sound insect pest management tactic.

Where sorghum is intercropped with maize in many developing countries in Central and South America, the infestations of fall armyworms on both the sorghum and maize plants would be expected to be high and similar due to the closeness of the plants in the system, often the plants are in the same hill. Since maize is preferred over sorghum by the fall armyworm, the effectiveness of a maize trap crop in reducing fall armyworm larval infestations on sorghum in areas where sorghum and maize are grown together in the same field was investigated. The area ratio of 2:1 for sorghum:maize plantings in close proximity did not differentially restrict fall armyworm activity on the preferred maize plants. However, significantly higher fall armyworm larval infestations and damage were observed on maize than on sorghum in pure

stand or when grown together with maize as the trap crop. The initial concentration of eggs and larvae on the maize in a relatively restricted cropping area, the maize trap crop, would provide pest survey information required for recommending the application of some pest control tactics. The early detection of fall armyworm egg masses and small larvae should be made easier on the maize in the area of the concentrated trap crop. The dispersal of larvae and infestation on the sorghum crop can be reduced significantly by timely application and concentration of insecticide on the limited area of the maize trap crop. This will result in restricting the use of insecticides to a relatively small area compared with the total area on which the crop is produced and will represent a reduction in production costs to the farmer. The reduction in insecticide use will be less disruptive to the environment and particularly the associated beneficial organisms in the total cropping system.

There is abundant evidence that plant density affects insect populations. Some insects find host plants more efficiently when plants are closely spaced than when they are farther apart and stay longer periods of time in areas with high plant populations. Tests were conducted using different sorghum planting densities to investigate the effects of host plant spatial patterns on fall armyworm infestation and damage to sorghum plants. This study suggests that the sorghum crop environment may be manipulated by varying planting practices to influence insect pest colonization and subsequent damage to the plants. Although fall armyworm infestations generally were higher in low plant populations, the total number of fall armyworms per unit area was highest in high plant populations. Plant damage ratings by this pest were lowest in the more dense plantings, due in part to the spread of the large insect population over an even larger plant population. These observations indicate that fall armyworm population size is not entirely dependent on host plant density, e.g., higher plant populations ostensibly result in lower fall armyworm infestations and therefore less plant damage. But, reproduction by the insects that develop in increased number (per unit area) in fields with high plant populations may influence fall armyworm population dynamics. The increased populations in subsequent generations could be very damaging to crops later in the growing season or to crops planted late.

The apparent migration of fall armyworm into the United States each year from southern latitudes, the development of insecticide resistance in this pest and the possible existence of host strains and possibly sibling species present the need to determine the relationship of fall armyworm immigration with insecticide control. The differing responses to environmental and biological factors support the need to understand the relationships of geographic location of fall armyworm and their potential as immigrating infestation sources from the Caribbean and Central and South America. Knowledge of the origin of immigrant fall armyworms and their susceptibility to insecticides is important in developing insect pest management strategies in the United States.

Fall armyworm cultures established from larvae collected on corn in Florida and Jamaica and on sorghum in Mississippi and Honduras were tested in the laboratory for susceptibility to carbaryl, permethrin, methomyl, chlorpyrifos, and methyl parathion. Methomyl and chlorpyrifos were effective (85% mortality) against 3rd instar fall armyworm larvae from Jamaica and Mississippi, whereas mortality of similar larval stages from Honduras was 50%. The Florida culture appeared to be about equally tolerant to all the test insecticides. Carbaryl, methyl parathion and permethrin were ineffective against 3rd instar larvae from all test areas. However, preliminary field tests indicated that 1st instar Honduras fall armyworm larvae are susceptible to methyl parathion. Also, materials shown to be ineffective against 3rd instar larvae in the whorl were effective on fall armyworm when applied to the sorghum seed head in a separate study. Susceptibility responses to insecticides indicate that the fall armyworm population from Mississippi was more similar to test populations from Jamaica and Honduras, than to the test population from Florida, suggesting that the fall armyworm source from Florida may not be the source of insects invading Mississippi. These results cannot be interpreted as conclusive evidence of the sources for migratory fall armyworm moths that initiate infestations in the United States because of the small number of larvae originally obtained to start the cultures. Also the level of insecticide susceptibility of laboratory reared fall armyworm from different geographical areas may not be a true indicator of origin. Additional studies are needed to prove this hypothesis. However, the data do indicate differences in fall armyworm responses to insecticides.

A unique group of tropical landrace sorghums called "maicillos criollos" are grown in Central America. Very little is known about their genetics as well as their reaction to insect attack. Because fall armyworm populations decline after a brief build-up on these sorghums, host plant resistance studies were initiated to determine whether antibiosis (a form of plant resistance to pests) was a factor. Various maicillos criollos genotypes were tested in the laboratory using field grown plant material. These genotypes caused different reactions by fall armyworm feeding on the leaf material. Some genotypes produced levels of antibiosis comparable to that expressed by a sorghum known to express antibiosis host plant resistance characteristics. Antibiosis was determined by influence of plant on intrinsic rate of increase (larval developmental rate), larval mortality and pupal weight. Knowledge of this expression of resistance is important in understanding the survival relationship of the insect on the host plant. The longer the time for larvae

to develop, the longer the time a specific instar is vulnerable on the plant to natural enemies. Differential selection among maicillos criollos sorghums has been the common practice for many, many, years. Consequently, these sorghums have accumulated numerous antibiotic alleles which appear to confer a broad level of intermediate resistance through reduced fecundity. The development of antibiosis in the maicillo is an example of crop improvement by primitive agriculturists and peasant farmers. (This host plant resistance research will serve as a basis for expansion of the INTSORMIL breeding program for insect host plant resistance in Honduras.)

Success Stories

Using traditional agricultural practices the subsistence farmer in many areas of Honduras and other countries in Central and South America have not been able to realize optimum plant stands in sorghum-maize intercropping systems year after year. The crops are damaged or destroyed by arthropod pests (mainly insects) while the plants are in the seed stage, seedling stage and young whorl stage (less than 20 days old). This damage may result in replanting, which is often to costly to the farmer. Thus, the crops may not be replanted.

The identification, abundance and occurrence of the insects and other arthropods responsible for damage or destruction of the sorghum and maize seeds and young plants in intercropped systems in several areas of Honduras have provided the basis for developing insect pest management strategies directed against the specific species causing damage to the sorghum and maize crops during the early part of the first growing season.

Recommendation of the practical application of chemical seed treatment, and the identification of the relationships of non-crop host plants with the lepidopterous larval complex, the langosta, providing the basis for recommending weed control practices in and around production fields to reduce or limit damage to the cereal crops by phytophagous insects damaging the seed and/or seedlings, can be considered an insect pest management success story.

Subsistence farmers have recognized the early season problems associated with soil insects and foliage feeding insect pests, but have utilized chemical insecticides only on the foliage for pest suppression, if the chemicals and application equipment are available. Most farmers are not able to apply any insect control practices to eliminate crop losses. If affordable, several chemical insecticide applications may be required for adequate control of the foliage pests. The application of insecticide sprays can be dangerous to the farmers, particularly when considering the high toxicity of these chemicals to the farmer who may be using less than desirable application techniques. The use of insecticide seed treatment to reduce the quantity and general distribution of toxic chemicals in the environment, and proper use of weed control practices are effective pest control tactics that can be utilized in developing integrated, ecologically sound insect pest management strategies, applicable to stabilizing crop production and insuring sustainable agriculture.

Benefits to U.S. and L.D.C. Agriculture

Many of the insect pests that attack sorghum and are emphasized in the MSU-105 INTSORMIL project have wide geographical distribution in the Americas. The research accomplishments of this project can be used for effective and practical insect pest management in sorghum cropping systems on subsistence farms in Honduras and surrounding developing countries employing low technology inputs in agriculture, as well as provide information related to certain insect pest outbreaks on sorghum in the U.S. Bio-intensive insect pest management tactics are developed to enhance stable crop production in sustainable agricultural systems without total reliance of insecticides for pest control, thus providing for ecologically sound and environmentally safe economical crop production programs. The control tactics developed for sorghum-maize cropping systems in Honduras emphasize the use of non-chemical or the use of minimum chemical control in production areas where financial investment in crop production must be held at a minimum.

Identifying the insect pest constraints to sorghum production in areas of southern Honduras where most of the sorghum is produced, has been accomplished, in part. Studies can now be conducted to determine the extent of insect damage caused to sorghum crops. This data will provide the information to critically define the role of pest insects in the economics of the production system. Early season ecological and biological studies have identified the insects responsible for sorghum and maize crop stand losses during the first growing season in Honduras. This information has served as the basis for developing chemical control recommendations (seed treatment) for soil inhabiting insect pests of seed and seedling plants, and advising weed control for suppression of lepidopterous pests that damage or destroy the young plants. The insect control measures employ economical, implementable and practical insect pest control tactics for the resource poor subsistence farmer.

Insect resistance to insecticides is frequently encountered in pest populations in many crop production systems. The movement of insect populations over large areas has a significant influence on the development of effective insect pest control programs, especially if insecticide resistance populations are involved. The MSU-105 project has investigated one such problem involving the migratory fall armyworm, a serious pest of grain crops in

the Americas. Levels of insecticide susceptibility were determined for fall armyworms from sources in the U.S., Central America and the Caribbean. Host plant strain relationships were identified. The information obtained is important in relation to the identification of resistant or susceptible populations in specific source areas of these pests. This is important not only to local farmers (e.g., Honduras), but also to international agriculture as it relates to insect migration and the spread of insecticide resistant populations.

Cropping practices, including planting strategies, can influence the levels of insect pest infestations on sorghum crops in areas using low input agriculture and in areas using high input agriculture. Number of seed and depth of planting influenced the extent of insect damage to sorghum and maize in intercropped systems in Honduras. More damage occurred when seed were planted deep and in small numbers per hill resulting in longer time for emergence, consequently greater exposure to damaging soil inhabiting insect pests. This information can be used in LDC's and in the U.S. where soil inhabiting insects are expected to be a problem.

Planting density can also influence crop damage in LDC's and in the U.S. In LDC's, the low input agricultural practices include widely spaced seed planting patterns which result in sparse plant populations. The sparse plant stands of the sorghum and maize may be heavily colonized by herbivor pest species resulting in serious reductions in harvestable yield.

Research accomplishments in the area of host plant resistance in sorghum to the fall armyworm have been significant in relation to the progress of selection of native landrace sorghums in Honduras, and converted lines and varieties in the U.S. The observed fall armyworm resistance in the maicillo criollo sorghums is a significant accomplishment and will serve to expand this effort to develop non-chemical insect pest control for sorghum and maize in Central America.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: Breeding Pearl Millet for Stability of Performance Using Tropical Germplasm

Project Leader: David Andrews **Project Number:** UNL-118

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=UNL118 -- ----------						
Staff Salaries & Benefits	19.80	20.79	21.78	22.57	23.76	108.70
Post Doctorates	7.60	7.98	8.36	8.66	9.12	41.72
Graduate Students	8.00	8.00	8.00	9.00	9.00	42.00
Other Salaries	9.90	10.40	10.89	11.29	11.88	54.36
Supplies	8.60	9.03	9.46	9.80	10.32	47.21
Equipment	3.10	3.26	3.41	3.53	3.72	17.02
Travel	11.20	11.76	12.32	12.77	13.44	61.49
Other Direct Costs	7.70	8.09	8.47	8.78	9.24	42.28
Overhead	24.40	25.62	26.84	27.82	29.28	133.96
	100.30	104.93	109.53	114.22	119.76	548.74

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=NE118 -- ----------						
University Staff	29.30	30.76	32.30	33.91	35.61	161.87
Staff Benefits	5.88	6.17	6.48	6.81	7.15	32.49
Post Doctorates	14.28	14.99	15.74	16.53	17.36	78.91
Grad Students	9.45	9.92	10.42	10.94	11.49	52.22
Other Salaries	4.52	4.74	4.98	5.23	5.49	24.95
Fringe Benefits	5.67	5.95	6.25	6.56	6.89	31.33
Supplies	2.94	3.09	3.24	3.40	3.57	16.25
Equipment	0.52	0.55	0.58	0.61	0.64	2.90
Travel	4.20	4.41	4.63	4.86	5.11	23.21
Overhead	28.25	29.66	31.14	32.70	34.33	156.07
	105.00	110.25	115.76	121.55	127.63	580.19

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=NE118 -- ----------						
University Staff	27.90	27.90	27.90	27.90	27.90	139.50
Staff Benefits	5.60	5.60	5.60	5.60	5.60	28.00
Post Doctorates	13.60	13.60	13.60	13.60	13.60	68.00
Grad Students	9.00	9.00	9.00	9.00	9.00	45.00
Other Salaries	4.30	4.30	4.30	4.30	4.30	21.50
Fringe Benefits	5.40	5.40	5.40	5.40	5.40	27.00
Supplies	2.80	2.80	2.80	2.80	2.80	14.00
Equipment	0.50	0.50	0.50	0.50	0.50	2.50
Travel	4.00	4.00	4.00	4.00	4.00	20.00
Overhead	26.90	26.90	26.90	26.90	26.90	134.50
	100.00	100.00	100.00	100.00	100.00	500.00

Role of Polyphenols in Sustainable Production and Utilization of Sorghum and Millet

Project PRF-104B
Dr. Larry Butler,
Purdue University

Collaborating Institutions

Host Countries

Dr. A. G. Babiker, Gezira Agric. Research Station, Wad Medani, Sudan
Drs. R. Jambunathan and V. Subramanian, ICRISAT, India
Dr. Pushpamma, Andra Pradesh Agricultural University, Hyderabad, India
Kenya: Newton Ochanda, Director, Alupe Research Station, Busia, Kenya
Ben Kanyenji, National Dryland farming Research Station, Katumani, P.O. Box 340, Machakos, Kenya
Dr. Sam Mukuru, SAFGRAD/ICRISAT, Nairobi, Kenya
Dr. J. Brotherton, Dept. of Chemistry, U. of Zambia, Lusaka, Zambia
Drs. E. Paiva and F. Santos, CNPMS/EMBRAPA, Sete Lagoas, Brazil

U.S.

Drs. Ejeta, Axtell, Kirleis, Nicholson, Rogler and Housley, Purdue University
Drs. L. Rooney, R. Waniska, F. Miller and D. Rosenow, Texas A&M University
Dr. J. Riopel, University of Virginia
Dr. R. Duncan, University of Georgia
Dr. A. Hagerman, Miami University (Ohio)
Dr. D. Netzly Hope College

Project Objectives

1. To elucidate the biochemical basis for the antinutritional effects of sorghum tannins and other phenols and sorghum proteins.

2. To elucidate the biochemical basis for the resistance to predatory birds, fungal pathogens, weathering, stored grain insects, and Striga, which are provided by sorghum tannins and/or other phenols and sorghum proteins.

3. To eliminate or diminish the antinutritional effects of sorghum tannins and other phenols while maintaining or enhancing their agronomic benefits.

4. To minimize the effect of *Striga* on sorghum and millet production in Africa.

Introduction

Major constraints to sorghum and millet production in much of Africa include predatory birds and *Striga*. Major constraints in India include weathering and stored grain insects. In the southeastern U.S., predatory birds and weathering are significant constraints. The evidence indicates that the phenolic materials (including tannins in the case of sorghum) of these plants provide some degree of resistance to these constraints, except for *Striga*. However, it is widely recognized that the presence of these phenolic materials in the seed of sorghum and millet also constitutes a formidable constraint to their utilization as food. Phenolic materials diminish the palatability and digestibility of the food prepared from sorghum, and create undesirable colors in both sorghum- and millet-based foods. Until now it has been considered necessary, in several areas of the world, to accept the utilization constraints in order to overcome the production constraints by growing "high-tannin" sorghums.

Our results suggest that it should be possible to develop cultivars with altered phenolic metabolism which are resistant to the production constraints, yet with high nutritional quality, and thus satisfy our major objective (#3 above). For *Striga*, no effective means of control is available, although a few resistant or tolerant genotypes have been identified.

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Objectives Related to Constraints

As our objectives indicate, our research involves both utilization (Objective 1) and production (Objective 2 & 4) constraints of sorghum. In addition to inhibition of digestion, we have found that utilization constraints of sorghum tannin include systemic inhibition of metabolism, apparently by phenolic materials absorbed from the digestive tract. We have been attacking this possibility directly, by feeding protein we have labeled with 15N, following the fate of the label. We have prepared sorghum tannin labeled with 14C, and will feed it to test absorption from the intestine.

When high tannin sorghums are ground and prepared for food, it is the prolamine fraction of storage protein which binds the tannins most strongly and becomes indigestible. With Drs. Axtell and Kirleis, we would like to alter the amount or the characteristics of these major proteins to improve the lysine content and digestibility of this sorghum protein. This would likely result in lower affinity for tannin and improved digestibility of the storage protein..

Our work on production constraints (Objectives 2 & 4) will continue with our collaborators with work on the Striga germination stimulant from sorghum roots, and with identification of key flavonoid metabolites associated with mold/weathering resistance. Our tissue culture program has developed to the point that we are producing and identifying many somaclonal variants for evaluation of their potential relevance to our production constraints. The Striga work will receive increased emphasis, now that we are receiving outside funding (Rockefeller).

Host country collaboration

Our collaboration with Dr. Babiker of the ARC in Sudan will continue. He showed that our sorgoleone from sorghum root exudate is active against the more virulent S. hermonthica, and that ethylene and sorgoleone act synergistically to stimulate Striga germination. Yearly visits in each other's labs would be very helpful. Funding is being sought to extend the collaboration to Dr. Ramaiah (ICRISAT, Burkino Faso), and eventually Dr. Obilano, Botswana. Collaboration on mold resistance and nutritional quality with Drs. Jambunathan (ICRISAT Center) and Mukuru (SAFGRAD/ICRISAT, Kenya) will continue at a low level. Funds have been requested from PSTC/USAID for collaboration with EMBRAPA (Brazil), Ochanda/Kanyenji (Kenya) and Ejeta (Purdue) to characterize low tannin sorghums reported to be bird resistant.

Research procedures

Much of our work involves fractionation, purification, identification, characterization, metabolism, biosynthesis, absorption, radioisotope labeling, and evaluation of biological activities of sorghum polyphenols including tannins, flavonoids, and quinones (root exudate). The biological activities evaluated are antinutritional effects (inhibitors of digestion and/or metabolism of digested and absorbed nutrients), bird repellancy, mold resistance and stimulation of the germination of Striga seeds. We have established a plant quarantine laboratory and are certified to carry out Striga germination assays. New emphaswes in our work include application of our in vitro tissue culture to the selection in culture for characteristics likely to contribute to resistance to Striga, and the utilization of mutagenesis to produce lines which do not produce sorgoleone, the root exudate which stimulates Striga germination. We are also beginning the preparation of protoplasts from cells in suspension culture. This is a prelude to transforming them with exogenous DNA (eg., genes for drouth resistance obtained from other programs such as the McKnight program at Purdue headed by Dr. Axtell).

Measures of research success:

The overall long-term measure of our research success will be the widespread improvement in the nutritional value of sorghum and the diminished effect of Striga, bird predation, molds and other relevant production constraints as a result of our research program on sorghum polyphenols.

More specifically for the upcoming 5 year period, we will have made satisfactory progress toward our first objective if we obtain direct proof of absorption from the intestine of tannins or other polyphenols which are responsible for the systemic effects of dietary tannin, identify the active material, and develop an effective assay for it. We will have made satisfactory progress toward our second objective if we are able to identify particular flavonoid components, probably derivatives of the flavan-4-ols we previously implicated, which strongly correlate with mold resistance in tannin-free sorghum cultivars, and develop an effective assay for them. We will have made satisfactory progress toward our third objective if we are able, by characterizing the abnormal flavonoid metabolism in variants we have identified from our sorghum tissue culture program or by identifying appropriate variants from other sources, to provide new sorghum germplasm with good nutritional quality and good resistance to the production constraints listed in Objective 2. We will have made satisfactory progress toward our fourth objective if we are able to produce or identify sorghum cultivars which are strongly resistant to Striga because they produce abnormally low amounts of

sorgoleones, high levels of lignin, or other novel characteristics contributing to Striga resistance, or if we develop a sorgoleone analog which can effectively be used to control *Striga*.

Anticipated Reports and Articles

"Sorghum Polyphenols" (Chapter) in P. R. Cheeke (ed): Toxins of Plant Origin: *Glycosides* and *Phenolics*, CRC Press, in press (1989).

"Isolation of a *Striga* Germination Stimulant(s) from *Euphorbia aegyptica*," (with A. G. T. Babiker, N. E. Ibrahim, D. H. Netzly, and W. G. Edwards), submitted to Weed Research.

"Efficient Plant Regeneration from Embryonic Calli Initiated from Immature Inflorescences of Several High Tannin Sorghums," (with T. Cai), Plant Cell, Tissue and Organ Culture, in press.

"To What Extent Do Tannins Reduce Growth Rate by Digestibility Reduction? (with S. Mole, C. Morell, and J. C. Rogler), in preparation, for Biochem. Systematics and Ecology.

"3-Deoxyanthocyanidins of Sorghum: Chemical Characterization and Metabolic Significance," (with D. H. Netzly and B. Daly), in preparation.

"Possible Role of Polyphenol Oxidase in the Final Step of Tannin Biosynthesis in Sorghum," (with L. J. Putman), in preparation.

"Bird-Resistance in Sorghums: A Long-Term Evaluation," (with J. D. Axtell, G. Ejeta and T. Leaming), in preparation.

"Polyphenol Analysis and Bird Repellancy of Several Sorghums Reported to Be 'Bird-Proof'," (with R. Jambunathan and V. Subramanian), in preparation.

"Defense Against Dietary Tannin in Herbivores: A Survey for Proline-Rich Salivary Proteins in Mammals," (with S. Mole, G. Iason and C. McArthur), in preparation.

"Studies of Proline-Rich Proteins in the Biological Context: Techniques and Preliminary Data," (with S. Mole, and K. E. Glander), in preparation.

"Somaclonal Variation in High Tannin Sorghum," (with T. Cai), in preparation.

"Tannin in Betel Quid," (with Pushpamma), in preparation.

"Flavan-4-ols as a Major Factor in Mole Resistance of Sorghum," (with G. Ejeta and D. H. Netzly), in preparation.

General Comment

Additional (non-INTSORMIL) support is being sought for *Striga* research from USDA/OICD, for research on bird-resistant sorghums from USAID/PSTC, and for research on the role of polyphenol oxidase in tannin biosynthesis from the Midwest Biotechnology Symposium. Rockefeller Foundation is providing modest support for our *Striga* research.

Progress (last two years)

Antinutritional Effects of Tannins: We have shown that the major antinutritional effect of tannins is not inhibition of protein digestion as is often assumed, but is a systemic inhibition of the metabolism of nutrients including protein which have already been digested and absorbed. The tannin-induced increase in fecal nitrogen which has been assumed to be due to undigested dietary protein is largely accounted for by endogenous, not dietary, proteins, particularly the proline-rich salivary proteins which strongly bind dietary tannin. The antinutritional effects of dietary tannin such as is present in some sorghums would be much more severe if it were not for these defensive proteins. The antinutritional effects which are observed are likely largely due to small polyphenolic precursors of tannins, which are absorbed from the digestive tract and inhibit the metabolism of digested and absorbed nutrients.

Biochemistry of *Striga* Germination: We now have a sensitive and accurate assay for sorgoleone in sorghum root exudate. All sorghum cultivars tested so far produce approximately the same amount of sorgoleone, and maize and millet do not produce it at all (their germination stimulants may be similar to sorgoleone as quinones, but differ in solubility and/or stability). We have recently been certified as a Plant Quarantine Laboratory authorized to carry out *Striga* germination assays, and are now doing them. INTSORMIL has recently published a colorful illustrated brochure describing the *Striga* problem, our discovery of sorgoleone, and its potential for contributing to a solution of the problem.

In vitro Sorghum Tissue Culture: The progeny of hundreds of the 6000+ plants regenerated from callus cultures of several high tannin sorghum cultivars have now been tested up to the R_4 generation in the field and in the laboratory. Many somaclonal variants have been obtained, and influence of genotype, explant source, length of culture, and meduium composition on the somaclonal variation rate has been determined. Developmental and morphological variants have been

turned over to our breeder colleagues for possible utilization. Variants with respect to the type and/or quantity of polyphenols produced are still being characterized. The results are quite unexpected, and present a clear enigma. Many variants are albinos, a lethal condition, having lost their capacity to produce chlorophyll. But not one variant has been found which has lost its ability to make tannin. This is unexpected because the synthesis of tannin is clearly less important to the survival of sorghum than is the synthesis of chlorophyll. Most of the entries in the world collection of sorghum do not make tannin, so tannin-free cultivars of sorghum are viable, just as are other tannin-free crops and other plants. But the random mutagenic alteration of the genetic apparatus of sorghum to eliminate tannin biosynthesis is obviously very much more difficult than the equivalent elimination of chlorophyll, a truly essential metabolite. We have found a few variants which produce significantly less tannin than the parent, but most of those which differ from the parent produce more tannin, not less.

Success Stories

Our success in identifying sorgoleone, the first and only *Striga* germination stimulant to be identified from a *Striga* host, has been documented in the brochure recently published by INTSORMIL.

Our *in vitro* tissue culture program has been very successful in that we have probably regenerated more sorghum seedlings than all other research groups combined. The screening and characterization of these regenerants is far from complete, so we will not know for some time whether the program has provided the desired alterations in tannin biosynthesis. So the success of the program cannot yet be judged. Moreover, it is being further used to obtain alterations in characteristics contributing to *Striga* resistance. The program has, however, already produced enigmatic results (see the previous section).

Our major success story which remains untold is our development of simple treatments for "detoxifying" high tannin sorghum. We were the first to discover that aqueous alkalies make the tannin in sorghum virtually undetectable by chemical or protein binding assays. We also showed that the nutritional value of the alkali-treated high tannin sorghum was correspondingly improved to essentially the equivalent of low tannin sorghum, but this discovery was simply a rediscovery of what the traditional sorghum consumers of Uganda, Rwanda and Burundi had long practiced. We have not been successful in making this process known and put into practice. Xenon Kabiro, a Burundian student, is carrying out in our laboratory a project intended to make this process practical on a commercial scale in Burundi.

Benefits to U.S. and L.D.C. Agriculture

Our development of a technique for "detoxifying" high tannin sorghum is of potential benefit wherever these sorghums are produced: Uganda, Rwanda, Burundi and to a lesser extent in other locations in Africa. Such sorghums are produced in Latin America, and are potentially useful in the southeastern U. S., where birds and molds are more severe problems than in the western U.S. where sorghum is widely produced.

Our work on *Striga* should lead to much more effective control measures, and would benefit all areas where *Striga* occurs (mainly Africa and India). It should aid in final elimination of the *Striga* infestation in the Carolinas in the U.S., and would lessen the threat of other *Striga* infestation in the U.S.

At this time the major benefit of our *in vitro* tissue culture work on sorghum is to U.S. producers because it mainly shows how sorghum tissue culture can be done on a large scale so that potentially useful somaclonal variants can be produced in significant numbers. Variants from our program may eventually be found to be useful to sorghum producers both in L.D.C.s and in the U.S.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: Role of Polyphenols in Sustainable Production and Utilizatio
of Sorghum and Millet

Project Leader: Larry Butler **Project Number:** PRF-104B

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=PRF104B -- ----------						
Staff Salaries & Benefits	29.70	31.28	32.87	34.25	36.04	164.14
Post Doctorates	11.40	12.01	12.62	13.15	13.83	63.01
Graduate Students	11.00	12.00	13.00	13.00	14.00	63.00
Other Salaries	14.85	15.64	16.43	17.13	18.02	82.07
Supplies	12.90	13.59	14.28	14.88	15.65	71.30
Equipment	4.65	4.90	5.15	5.36	5.64	25.70
Travel	16.80	17.70	18.59	19.38	20.38	92.85
Other Direct Costs	11.55	12.17	12.78	13.32	14.01	63.83
Overhead	36.60	38.55	40.50	42.21	44.41	202.27
	149.45	157.84	166.22	172.68	181.98	828.17

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=PRF104B -- ----------						
University Staff	3.78	3.97	4.17	4.38	4.60	20.90
Staff Benefits	1.02	1.08	1.13	1.19	1.25	5.66
Post Doctorates	27.39	28.76	30.20	31.71	33.29	151.35
Other Salaries	2.51	2.63	2.76	2.90	3.05	13.85
Fringe Benefits	5.41	5.68	5.96	6.26	6.57	29.87
Supplies	2.10	2.21	2.32	2.43	2.55	11.60
Travel	7.12	7.47	7.85	8.24	8.65	39.33
Overhead	24.17	25.38	26.65	27.98	29.38	133.56
	73.50	77.18	81.03	85.09	89.34	406.13

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=PRF104B -- ----------						
University Staff	3.60	3.60	3.60	3.60	3.60	18.01
Staff Benefits	0.98	0.98	0.98	0.98	0.98	4.88
Post Doctorates	26.09	26.09	26.09	26.09	26.09	130.44
Other Salaries	2.39	2.39	2.39	2.39	2.39	11.94
Fringe Benefits	5.15	5.15	5.15	5.15	5.15	25.75
Supplies	2.00	2.00	2.00	2.00	2.00	10.00
Travel	6.78	6.78	6.78	6.78	6.78	33.89
Overhead	23.02	23.02	23.02	23.02	23.02	115.10
	70.00	70.00	70.00	70.00	70.00	350.00

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Disease Control Strategies for Sustainable Agricultural Systems

Project TAM-124
R. A. Frederiksen and R.W. Toler
Texas A&M University

Collaborating Scientists

Host Country

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Godwin Kaula, Mt. Makulu Research Station, Chilanga, Zambia
T. B. Garud, Marathwada Agricultural University, Parbhani 431 402, Maharashtra, India
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Mario J. Garrido, Plant Pathologist, Central University of Venezuela, Maracay, Venezuela

U.S.

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J. Craig, Department of Plant Pathology and Microbiology, Texas A&M Unversity, College Station, TX
Ronnie Duncan, Department of Agronomy, Georgia Agricultural Experiment Station, Experiment, GA
Paul Hepperly, USDA-ARS, South Atlantic Area, Tropical Agriculture Research Station, Mayaguez, P.R.

Project Objective

Sudan

Develop integrated disease management symptoms, combining host resistance, physiology and plant breeding for control of charcoal rot, anthracnose, long smut and Striga.

Over the past few years, screening techniques and methods of evaluating disease resistance have been developed in Sudan. The integration of host resistance procedures through the development of a restriction fragment length polymorphism (RFLP) sorghum map will be used in conjunction with the ongoing domestic research at Texas A&M. Specific RFLP probes will be generated to assist in the identification of sorghum lines (breeding selections) that possess resistances to these major constraints not only for Sudan but other regions in East Africa. The development of DNA probes for charcoal rot resistance will come from the program studying the effect of growth regulators in sorghum maturity. Those sorghums with cytokinin production throughout the growing season have high levels of resistance to charcoal rot as well as late season drought stress. The use of probes can be evaluated in segregating populations in the USA and field tested in Sudan. A similar procedure will be done for *Striga* and long smut resistance. Combining resistances would be done in Sudan with RFLP analysis done at Texas.

Uganda

Develop high quality grain sorghums with resistance to grain mold.

Sorghum with good food quality traits and resistance to grain mold exist. However, in Uganda, most of

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the improved sorghums have a testa which confers resistance to grain mold but lowers the digestibility of sorghum. Working through J. P. Esele, a graduate student at Texas A&M, we will study the inheritance of specific seed quality traits as they relate to the rate of grain mold development. Mr. Esele will complete his dissertation research in Uganda.

Niger/Mali

Develop disease management strategies from control of long smut of sorghum, downy mildew of pearl millet, and Striga on pearl millet and sorghum.

Technologies for the evaluation of long smut were transferred from Sudan to Niger. Studies will be made on the identification of sources of resistance and a screening technique for the genetic improvement of sorghum for resistance to this disease. Studies on the biology of the pathogen, including the survival of the pathogen and rate of increase in the pathogen populations, will be a part of this collaboration. Most of the resistance work will be done in Niger, whereas emphasis on the epidemiology will be done in Mali.

The extent of downy mildew in pearl millet will be investigated. Initially economic thresholds will be established and various management techniques will be implemented to assess their influence on disease development and damage. Strategies will include cultivar mixtures (intra field diversity) plant density and the effect of cropping system.

Studies on the rate of colonization and extent of damage of pearl millet by Striga will be evaluated in off-station plots in areas of endemic Striga infestation. The work will be done in collaboration with the ICRISAT Sahelian Centre.

Zimbabwe/Zambia

Develop sorghum with resistance to downy mildew and anthracnose. To identify and characterize the viruses of sorghum in Zimbabwe, Zambia, and Malawi using host range, symptomology, serology, and electron microscopy and develop sorghum with resistance to the viruses.

Currently we evaluate sources of resistance to downy mildew and anthracnose in Zimbabwe and Zambia. Some of these sorghum lines are candidate materials for incorporation in the program. Isolates of these pathogens (*Colletotrichum sublineolum* and *Peronosclerospora sorghi*) causing anthracnose and sorghum downy mildew, respectively, are present in the US at USDA approved laboratories. Research on the characterization of pathotypes using RFLP's and cDNA probes. Isolates of the downy mildew fungi are present at the USDA plant pathogen containment facility at Frederick, MD, but cDNA libraries were developed at Texas A&M. These biotech tools will simplify the identification of downy mildew fungi and can be used to detect single seeds contaminated with fungal DNA. Genetic differences between races of the pathogen causing sorghum downy mildew using RFLP finger printing will greatly assist in the characterization of pathotypes. Such tools are possible with current technologies. A similar program is under way at Texas A&M to characterize races of the anthracnose pathogen. A goal of this work will be to use "virulence" associations or linkages in the pathogen to design the combinations(s) of host resistance genes for disease control. By combining information on the host resistance genes with virulence patterns in the pathogen, research can be directed toward a selection of stable host plant resistance. Disease resistance remains as the most ecologically sound means of disease management.

The international sorghum virus nursery will be employed in each of the Southern African countries. Develop inoculation procedures for host range studies and evaluation of sorghum for resistance to maize dwarf mosaic virus that has been identified in Zambia. Evaluate the sorghum virus strains using the sorghum virus antiserum bank and electron microscopy. Assess the economic importance of virus diseases in sorghum in this area of Africa.

Identify sources of resistance to sorghum viruses, and assist in the incorporation of multiple sources of virus resistance into usable germplasm. Determine inheritance of resistance to sorghum viruses, and evaluate epidemiology of the new viruses as identified. Produce, distribute, and evaluate the international sorghum virus nursery both domestically and worldwide, and maintain and strengthen the sorghum virus antiserum bank. Employ the new serology technique ELISA to determine virus concentration in sorghum and use virus concentration as a new tool to breed for virus resistance.

Central and South America

Collaborate in the development of disease resistant cultivars of sorghum. To characterize the viruses of sorghum and identify them to type virus and strain. Determine the epidemiology, disease losses, biology, and biotechnology of sorghum viruses in South America.

Essentially the approach in South and Central America will follow those for Southern Africa. Anthracnose and sorghum downy mildew as well as rust, gray leaf spot and grain mold are major disease problems. The utilization of disease resistant sources and monitoring of the pathogen populations will be continued. An in depth characterization of the *Colletotrichum sublineolum*

population will be done to ascertain changes in the population over time within and between growing seasons. Sources of resistance in the host that cause little change in the pathogen population are considered to be stabilizing. A stable pathogen population is easier to manage than one with an especially variable population.

The international sorghum virus nursery will be grown in South America. Venezuela is a prime site since we have identified the Venezuela strain of maize dwarf mosaic virus and the new sorghum yellow banding virus there. Host reaction of Venezuela germplasm to these two viruses will be studied.

Characterization of the sorghum yellow banding virus and finding sources of resistance to this virus will be pursued. Studies to elucidate the ecology, epidemiology, and molecular biology of this virus and the diseases it causes including host range of economic crops and native species and the potential for virus transmission through seed and/or insect vectors will be studied. The vector or vectors will be studied to determine transmission. Potential vector groups and species such as aphids, leaf hoppers, plant hoppers, white flies, mites, and beetles will be tested for their ability to acquire and transmit the virus.

Networking Activities

There is a need to introduce the techniques of air-gun virus inoculation to the scientist and technicians in southern Africa. This technique is important for host range studies and screening germplasm for resistance to viruses. A workshop is proposed to identify the source of inoculum, multiply inoculum, preparation of inoculum, air-gun equipment, compressed air sources, and demonstration and application of the system. The five-day workshop would be held in 1991 possibly in Zimbabwe in collaboration with ICRISAT and INTSORMIL. This workshop should lead to development of ICRISAT, INTSORMIL, and national program collaboration on viruses and virus diseases. The workshop will include the distribution of a manual on air-gun virus inoculation technology. Extra mural funding will be sought.

A sorghum anthracnose retreat

Much progress has been made over the past 5 years in our understanding of the foliar and head blight phase of anthracnose. A brief in depth exchange of research progress between workers in Africa and the Americas is planned for 1991-92.

The global conference on sorghum and millet diseases at Harare, Zimbabwe identified several key workers and their need to coordinate activities. To facilitate the future of this program an anthracnose newsletter and correspondence secretary is being formed. Extra mural funding will be sought; preliminary assessment will be at sorghum in the 90's in Mali.

The all African Long Smut Nursery

Evaluation of sorghum materials among African workers will be encouraged through appropriate correspondence and movement of seed resources used in the nurseries. This nursery program was proposed in 1989-90, but will begin formally among West and East African workers in 1991-92.

A proposal to support ICRISAT staff scientists for a 1-year sabbatical leave was drafted. Two or three such staff members are expected from ICRISAT over the next five years. Such exchanges will greatly enhance the cooperative effects of INTSORMIL and ICRISAT programs.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: Disease Control Strategies for Sustainable Agricultural Systems

Project Leader: Richard Frederiksen **Project Number:** TAM-124

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=TAM124	--	----------				
Staff Salaries & Benefits	25.74	27.13	28.51	29.70	31.28	142.36
Post Doctorates	9.88	10.41	10.94	11.40	12.01	54.64
Graduate Students	10.00	10.00	11.00	11.00	12.00	54.00
Other Salaries	12.87	13.56	14.26	14.85	15.64	71.18
Supplies	11.18	11.78	12.38	12.90	13.59	61.83
Equipment	4.03	4.25	4.46	4.65	4.90	22.29
Travel	14.56	15.34	16.13	16.80	17.70	80.53
Other Direct Costs	10.01	10.55	11.09	11.55	12.17	55.37
Overhead	31.72	33.43	35.14	36.60	38.55	175.44
	129.99	136.45	143.91	149.45	157.84	717.64

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=TAM124	--	----------				
Post Doctorates	14.94	15.68	16.47	17.29	18.16	82.53
Grad Students	21.30	22.37	23.49	24.66	25.89	117.71
Other Salaries	4.20	4.41	4.63	4.86	5.11	23.21
Fringe Benefits	7.71	8.09	8.50	8.92	9.37	42.60
Supplies	8.41	8.84	9.28	9.74	10.23	46.50
Equipment	4.20	4.41	4.63	4.86	5.11	23.21
Travel	13.13	13.78	14.47	15.19	15.95	72.52
Other Direct Costs	1.05	1.10	1.16	1.22	1.28	5.80
Overhead	30.06	31.57	33.14	34.80	36.54	166.11
	105.00	110.25	115.76	121.55	127.63	580.19

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=TAM124	--	----------				
Post Doctorates	14.23	14.23	14.23	14.23	14.23	71.13
Grad Students	20.29	20.29	20.29	20.29	20.29	101.44
Other Salaries	4.00	4.00	4.00	4.00	4.00	20.00
Fringe Benefits	7.34	7.34	7.34	7.34	7.34	36.71
Supplies	8.01	8.01	8.01	8.01	8.01	40.07
Equipment	4.00	4.00	4.00	4.00	4.00	20.00
Travel	12.50	12.50	12.50	12.50	12.50	62.50
Other Direct Costs	1.00	1.00	1.00	1.00	1.00	5.00
Overhead	28.63	28.63	28.63	28.63	28.63	143.16
	100.00	100.00	100.00	100.00	100.00	500.00

Insect Control Strategies for Sustainable Agriculture Systems

Project TAM-125
Dr. George L. Teetes and Dr. Frank L. Gilstrap
Texas A&M University

Collaborating Institutions

Host Country

Mr. Chris S. Manthe, Ministry of Agriculture, Department of Agricultural Research, Gaborone, Botswana
Dr. Klaus Leuschner, SADCC/ICRISAT, Entomologist, Bulawayo, Zimbabwe
Mr. Yacouba Doumbia, Institute of Rural Economy, Entomologist, Bamako, Mali
Dr. H. C. Sharma, ICRISAT, Entomologist, Hyderabad, India.
Dr. Keith Andrews and Dr. Ron Cave, Escuela Agricultura Panamericana, Tegucigalpa, Honduras
Dr. Dan Meckenstock, INTSORMIL/Texas A&M University/ Recursos Naturales, Tegucigalpa, Honduras

U.S.

Dr. Richard Vanderlip, Agronomist, Department of Agronomy, Kansas State University; Manhattan, KS
Dr. Gary Peterson, Texas A&M University Research and Extension Center, Lubbock, TX
Dr. Darrell Rosenow, Texas A&M University Research and Extension Center, Lubbock, TX
Dr. Richard Frederiksen, Texas A&M University, College Station, TX
Dr. Fred Miller, Sorghum Breeder, Texas A&M University, College Station, College Station, TX
Dr. Henry Pitre, Department of Entomology, Mississippi State University, Mississippi State, MS

Project Objectives

To identify and evaluate sorghums resistant to insects, determine resistance mechanisms, investigate plant-pest ecological responses and determine economic injury levels in selected LDC's and the USA.

To identify and evaluate indigenous and/or exotic natural enemies of sorghum/millet insect pests as potential biological control agents in selected LDC's and the USA.

To determine the biology, systematics, behavior, sampling procedures, and seasonal abundance profiles of sorghum/millet insect pests and associated predators and parasites as support tactics in insect control schemes in selected LDC's and the USA.

Host Country and U.S. Constraints

Insect pests of sorghum/millet are a component of the many stresses that contribute to reduced, to unstable yields in many developing countries, and to higher production costs because of insecticide use in the U.S.A. The role that insect pests play as a deterrent to sustainable agriculture is a constraint that must be dealt with in a biologically/ecologically sound manner. The public mandate in the U.S.A. for safe food, clean water, and wildlife conservation requires insect pest control strategies less dependent on insecticides. The species of insect pests that infest sorghum/millet vary geographically, and in intensity and persistence. Sorghum/millet in different production areas encounter at least one key insect pest species, and several occasional insect pest species. All regions require an integrated approach using several control tactics. The Texas Sorghum/Millet Entomology project focuses on developing insect control strategies applicable to subsistence crop production and to modern, high-input agriculture systems. The tactics developed and evaluated include plant resistance to insects, biological control, and manipulation of cultural practices; each tactic is supported with ancillary insect pest biological and ecological research to ensure their proper use and impact in management strategies. The project approach involves on-site collaborative research activities, complementary U.S.A. technology support activities, and training. The collaborative research in Botswana deals with sorghum aphid pests by identifying both resistant sorghum lines and biological control agents. Research in Honduras is directed at biological control of fall armyworm and stalk borers. The research in Mali concentrates on damage assessment and plant resistance to the panicle-feeding bug complex. Research in the U.S.A. involves plant resistance to sorghum midge, and plant resistance and biological control of aphid pests.

Objectives Related to Constraints

The long-range objectives of this project are to develop strategies for controlling insect pests of sorghum/millet that contribute to sustainable systems of agriculture production. Insect pest species and intensity vary by production region. Sites and insect pests are chosen where opportunities for collaboration have the greatest potential, and where national program interest is viable. The goal is to identify, develop and make available insect pest resistant cultivars, biological control agents, and/or cultural practices that can be incorporated into national crop protection programs and into U.S. agriculture. The collaborative research sites, insect pests of focus, and corresponding objectives planned for the next several years are described below. Some modifications of specific objectives will be required in time.

Botswana: Sorghum resistance to sugarcane aphid and biological control agents.

Screen sorghum for resistance

Determine resistance mechanisms

Study the inheritance of resistance

Identify, collect and study biological control agents attacking aphids on sorghum

Malawi: SADCC/ICRISAT/INTSORMIL training for Ms. Harriet Thindwa

Determine the effect of temperature and photoperiod on the injury to different sorghum lines by biotypes C and E greenbug and on aphid reproduction, development, and behavior

Determine the practicality of the use of DNA analysis as a means of quickly identifying greenbug biotypes based on DNA composition

Mali: Sorghum panicle-feeding bug research.

Evaluate practical techniques for screening sorghums for resistance to panicle-feeding bugs and to relate resistance to glume, kernel, and grain-texture characteristics

Relate panicle-feeding bug abundance and kernel damage to pathogen infection

Relate panicle-feeding bug abundance and kernel damage to food quality

Honduras: Biological control of fall armyworm and stalk borers, and sorghum resistance to sorghum midge.

Determine the respective roles of predatory earwig, ants and other enemies on mortality of fall armyworm

Measure the impact of a predatory earwig on fall armyworm at selected densities

Measure the consumption and development rates for a predatory earwig when provided selected numbers and stages of fall armyworm

Identify and measure the impact of biotic mortality agents on eggs and pupae of fall armyworm and stalk borers in plots managed with conventional versus no tillage practices

Field screen and evaluate sorghum midge resistant sorghum lines and hybrids

United States

Texas: Plant resistance to sorghum midge and aphids, and biological control of aphids.

Screen, improve agronomically, evaluate, and release sorghum lines with resistance to sorghum midge, greenbug, and yellow sugarcane aphid

Determine economic injury levels for sorghum midge, and greenbug resistant and susceptible sorghum hybrids

Determine plant to insect and insect to plant responses, and plant/insect interactions of sorghums resistant to sorghum midge, greenbug, and yellow sugarcane aphid

Identify, study biology, and determine efficacy of native and exotic natural control agents of greenbug and other aphids on sorghum

Conduct ancillary biological and ecological research to support control tactics and education of students and scientists from LDC's.

Host Country Collaboration Work Sites

Major collaborative research foci will be in Botswana, Mali, and Honduras. The research in Botswana is currently part of a Ph.D. dissertation, but will be continued with slightly modified objectives after the student receives his degree. Also, a regional element exists with cooperation with the entomologist at the SADCC/ICRISAT Sorghum/Millet Research Center at Bulawayo, Zimbabwe. The research in Mali is in collaboration with the IER entomologist at Bamako, an

ICRISAT Center entomologist, and the ICRISAT Regional Center entomologist. The research in Honduras is in cooperation with the National Program, entomologists at the Panamerican School at El Zamorano, and the INTSORMIL Honduran coordinator. The U.S. technical support element provides germ plasm and biocontrol agents on request, and provides the mechanism for graduate student training.

Research Procedures

The approach to dealing with the identified constraints in general, and the specific constraints and areas of focus described previously will be the direct control tactics of plant resistance to insects, biological control, and cultural practices manipulation; with required ancillary biological and ecological research on insect pests, their natural enemies, and plant/insect interactions and insect host/natural enemy interaction. More specific research procedures are as follows:

Botswana

Resistance screening - Converted, exotic sorghum lines, local varieties, and ICRISAT entries will be evaluated in a greenhouse using seedling plants grown in flats, and infested with cultured aphids. Plant damage is rated for plants by row using established scales. Field trials involve evaluation of seedling and adult plants for resistance. Plants are caged to exclude predators and artificially infested at different stages of growth to compare aphid affect on seedlings and more mature resistant and susceptible plants.

Resistance mechanisms - Nonpreference is determined by free-choice experimentation. Antibiosis is determined by measured effect of resistant plant on aphid reproduction, duration, progeny production and mortality. Tolerance is determined by comparing aphid density to plant damage and growth.

Inheritance of resistance - Patterns of inheritance is determined by comparing damage to F1 plants of resistant x susceptible parents to determine dominance. Also, the ratio of resistant and susceptible plants in F2 segregating rows will be compared to determine inheritance of resistance and gene involvement.

Identify, collect and evaluate bio-control agents of aphids - Predators and parasites attacking sugarcane and other aphids are collected in Botswana and identified. Selected species are exported to Texas A&M University for biology studies. Information obtained in the U.S. is sent to Botswana for improved management of enemies of sorghum aphids.

Malawi

Response of biotypes C and E greenbug to three test sorghum lines in terms of preference, fecundity and longevity to determine antixenosis, antibiosis and tolerance is investigated in the laboratory at College Station. The response of the test sorghums to greenbug biotypes C and E is evaluated in terms of plant damage. Data are collected on sorghum and greenbug response at five different temperatures and three different photoperiods. Standard methods to measure resistance mechanisms are used.

A flow cytometer is used to measure cell DNA content of greenbugs. Tests are based on laboratory cultured known greenbug biotypes C and E and on fresh field-collected greenbug clones from a wide range of host plants. The extent of DNA variation within and between biotypes or clones on these host plants will be determined.

Mali

A screening nursery of 20-50 selected sorghum lines from U.S. and West African sorghum breeders is assembled including local West African varieties and elite susceptible types for comparison purposes. Two identical nurseries will be planted on each of two separate dates, one used to employ a bagging technique to protect 1/2 of the panicles from naturally occurring bugs and 1/2 exposed, and the other 1/2 sprayed and 1/2 not. At harvest, yields of protected and unprotected panicles will be compared. Threshed grain weight per panicle and 1000 kernel weight will be determined. Differences in bug abundance on panicles not receiving protection will be one measure of resistance. Difference in damage between protected and unprotected panicles will be compared to determine resistance level. Floret characteristics will be quantified and related to bug infestation level and kernel damage.

At grain maturity, panicles of sorghums in the nursery will be visually rated for secondary pathogen infection on a scale of 1 to 5. Pathogen infested grain will be collected and pathogen species determination made. Head bug abundance and damage will be related to the level of pathogen infection.

Grain harvest from the yield determination will also be used to determine the effect of bug abundance and kernel damage on food quality based on grain hardness (pearling index) using the TADD system.

Honduras

Enemies of fall armyworm and stalk borers will be identified and studied to determine each enemy's role in causing pest mortality.

Enemies identified as key mortality agents for fall armyworm and stalk borers will be studied for amenability to population manipulation by farmers in LDC's.

Certain enemies with biologies requiring in-depth understanding will be exported to the U.S. for additional study under laboratory conditions. The laboratory studies will be designed to provide information needed to interpret field data, and to provide information needed to conduct further field studies to enhance enemy impact on pest mortality.

Measures of Success

Direct collaborative research will be evaluated by on-site review and comparison of results achieved to objective and specific experiments. Sorghum/millet insect control technology will be compared to traditional crop protection practices. Research results will be published and distributed. Students/scientists trained and placed in research positions in LDC's will be documented as measures of project success. Other quantitative measures of success will be the number of insect resistance cultivars released and the magnitude of resistant cultivar deployment, and the number of natural control agents studied and manipulated.

Anticipated Reports and Articles

- Annual trip and technical reports
- Three dissertations by international students
- Four to five technical journal articles per year.

General Comments

Graduate level training of international students will continue to be a high priority and significant objective of this project. The priority level is high because of the few trained scientists in this speciality in LDC's. Such students are funded several ways, including directly by INTSORMIL funds, SADCC/ICRISAT funds, and other direct support, such as host-country support through USDA or other agencies.

Progress (last two years)

Entomology Project TAM-125, "Insect Control Strategies for Sustainable Agriculture Systems" focuses on developing insect control technology applicable to sustainable, durable sorghum/millet production systems using plant resistance to insects, biological control, manipulation of cultural practices, and insect pest/natural enemy biological and ecological research. International collaborative research activities are in Botswana, Mali, and Honduras. Insects on which major effort is made for development of insect resistant cultivars are sorghum midge, greenbug, sugarcane aphid, yellow sugarcane aphid, and panicle-infesting insects. Insects of major focus for biological control are sorghum and millet stalk borer, millet head girdler, fall armyworm, and aphids. Ancillary support research is conducted on insect pest and natural enemy biology and ecology, sampling, life tables, density/damage relationships, and other related research to support implementation of technology to developing and U.S. agriculture systems, and as a mechanism of student/scientist training. Strong cooperation exists with plant breeders.

Sources of sorghum resistance to the sugarcane aphid in Botswana were identified and biological control agents were shown to suppress population density increases of several aphid species. Panicle-feeding bug research in Niger and Mali has identified predominate species, assessed bug density/ kernel damage relationships, identified floret characteristics related to suppressed bug damage, and initiated a resistance screening activity. In Niger, alternate hosts plants of millet stalk borers were identified and related to the complex of naturally occurring parasite species. Parasite biology was studied, and several related biological habits such as oviposition preference were identified. Parasite efficacy was evaluated. Parasites of the millet head girdler were identified, and damage caused by the insect assessed. In Honduras, predators of fall armyworm and stalk borers were evaluated, and sorghum lines and hybrids resistant to sorghum midge were tested. Three Master of Science programs researched biological control of fall armyworm. Collectively, these programs characterized the capabilities of two naturally occurring predators for causing fall armyworm mortality. Results demonstrated that both predator species have excellent potential as biological control agents. The next set of experiments will focus on demonstrating ways owners of small farms can take optimal advantage of these predators to cause mortality to fall armyworm. The single Ph.D. on stem borers in Niger established a basic understanding of the natural enemies of stemborers and the millet head girdler on millet. The next step towards biological control of stem borers in Niger is to 1) determine biologies of the key stem borer parasites with the goal of learning to manage these parasites for effective control of the stem borers, and 2) seek effective exotic parasites from other parts of the world and establish these in Niger. The information gained in both Honduras and Niger provides understanding for improved management of similar pests in the U.S.A. Technology support research used for graduate student training in the U.S. elucidated aphid parasite biology and efficacy; examined better and faster ways to identify greenbug biotypes; determined methods to im-

prove sampling of sorghum panicle-infesting insects, and identified corn earworm mortality factors. Also, the breeding component of the plant resistance to insects element of the project in the U.S. continued to advance greenbug and sorghum midge resistant germplasm toward agronomic acceptability, and tested the material as lines and in hybrid combination. Exotic, converted sorghums were screened in a continued search for new resistant types.

As examples of success of the project and the benefits to U.S. agriculture, RTX2783, a biotype C and E greenbug resistant restorer line has largely replaced ATX2752, a biotype C greenbug resistant male sterile line as the source of greenbug resistance in commercial hybrids. Sorghum lines resistant to the sugarcane aphid were identified and studied. The sugarcane aphid is not currently in the U.S., but is a likely candidate for introduction as it now occurs in tropical Africa, Asia, and tropical America.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: Insect Control Strategies for Sustainable Agricultural Systems

Project Leader: George Teetes/Frank Gilstrap **Project Number:** TAM-12!

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=TAM125	--	----------				
Staff Salaries & Benefits	25.74	27.13	28.51	29.70	31.28	142.36
Post Doctorates	9.88	10.41	10.94	11.40	12.01	54.64
Graduate Students	10.00	10.00	11.00	11.00	12.00	54.00
Other Salaries	12.87	13.56	14.26	14.85	15.64	71.18
Supplies	11.18	11.78	12.38	12.90	13.59	61.83
Equipment	4.03	4.25	4.46	4.65	4.90	22.29
Travel	14.56	15.34	16.13	16.80	17.70	80.53
Other Direct Costs	10.01	10.55	11.09	11.55	12.17	55.37
Overhead	31.72	33.43	35.14	36.60	38.55	175.44
	129.99	136.45	143.91	149.45	157.84	717.64

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=TAM125	--	----------				
Post Doctorates	17.63	18.51	19.44	20.41	21.43	97.43
Grad Students	26.58	27.91	29.30	30.77	32.31	146.86
Other Salaries	11.55	12.13	12.73	13.37	14.04	63.82
Fringe Benefits	10.30	10.82	11.36	11.93	12.52	56.93
Supplies	6.17	6.48	6.81	7.15	7.50	34.12
Travel	13.13	13.78	14.47	15.19	15.95	72.52
Other Direct Costs	10.43	10.95	11.50	12.07	12.67	57.61
Overhead	40.71	42.75	44.88	47.13	49.48	224.95
	136.50	143.33	150.49	158.02	165.92	754.25

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=TAM125	--	----------				
Post Doctorates	16.79	16.79	16.79	16.79	16.79	83.96
Grad Students	25.31	25.31	25.31	25.31	25.31	126.57
Other Salaries	11.00	11.00	11.00	11.00	11.00	55.00
Fringe Benefits	9.81	9.81	9.81	9.81	9.81	49.07
Supplies	5.88	5.88	5.88	5.88	5.88	29.40
Travel	12.50	12.50	12.50	12.50	12.50	62.50
Other Direct Costs	9.93	9.93	9.93	9.93	9.93	49.65
Overhead	38.77	38.77	38.77	38.77	38.77	193.86
	130.00	130.00	130.00	130.00	130.00	650.00

Development of Plant Disease Protection Systems for Millet and Sorghum in Semi-Arid Southern Africa

Project TAM-128
Gary Odvody
Texas A&M University

Collaborating Institutions

Host Country

B. Matalaote, Plant Pathologist, Department of Agricultural Research, Sebele Research Station, Botswana
D. Carter, Agronomists, INTSORMIL, KSU 107, DAR-Sebele, Gaborone, Botswana
W. Demilliano, SADCC/ICRISAT/ Bulawayo, Zimbabwe
E. Mtisi, Plant Pathologist, Plant Protection Research Institute, Harare, Zimbabwe
G.M. Kaula, Plant Pathologist, Mt. Makulu Research Station, Chilanga, Zambia
B.N. Verma, Sorghum and Millet Breeder, Mt. Makulu Research Station, Chilanga, Zambia
Mamourou Diorte, Plant Pathologist, Institute of Rural Economy, Bamako, Mali

U.S.

R.A. Frederiksen, and R.W. Toler, Plant Pathologist s, Texas A&M University
D.T. Rosenow, Sorghum Breeder and Principal Investigator, TAM 122, Texas A&M University
P.E.Nelson, Plant Pathologist, Department of Plant Pathology, Penn State University
L.E. Claflin/J.F. Leslie, Plant Pathologists, KSU 108, Kansas State University

Project Objectives

Characterization of *Macrophomina phaseolina* from diverse hosts in Southern Africa (primarily Botswana).

Evaluate economic impact of leaf blight on sorghum in SADCC region and identify stable sources of resistance to the causal fungal pathogen, *Exserohilum turcicum*.

Determine stability and sources of resistance to sooty stripe of sorghum through use of greenhouse and field nursery evaluations.

Develop sporulation techniques for *Ramulispora sorghi* and evaluate its use in greenhouse and field inoculations to enhance natural disease screening techniques.

Develop germplasm nurseries specifically adapted to the SADCC region for use in assessing yearly impact of major pathogens and monitoring plant pathogen populations.

Deploy specific germplasm or germplasm nurseries to the SADCC region to most efficiently characterize pathogen populations and identify valuable sources of resistance.

Evaluate naturally-occurring and introduced biological control organisms for potential use in plant protection systems.

Identify and characterize the *Fusarium* species causing disease on pearl millet and sorghum in the SADCC region, assess their involvement in grain mold and potential mycotoxin problems, and identify sources of resistance.

Characterize global and SADCC-area populations of *Colletotrichum graminicola* using RFLP techniques and differential sorghum cultivars and nurseries and use to identify stable sources of resistance for the SADCC region.

Research Procedures

Characterization of *Macrophomina phaseolina* from diverse hosts in Southern Africa (primarily Botswana). Host country collaborators: B. Matalaote and D. Carter, Botswana, E. Mtisi, Zimbabwe, G. Kaula, Zambia,M. Diorte, Mali.

Year 1-2: Tissue of diverse hosts infected with *M. phaseolina* collected in April 1989 in Botswana will be sent to the U.S.A. using quarantine procedures and pure culture isolates will be obtained in the P.I.'s laboratory.

These isolates will be characterized and compared to each other culturally to determine if host preference factors noted with U.S. isolates also occur in African isolates. Preliminary data with a limited number of isolates from Botswana and Zambia indicate fundamental cultural differences between U.S. and African isolates of *M. phaseolina* and these will be further investigated to determine any relationships to virulence on the same or different hosts.

Year 3-4: There will be continued analysis of *M. phaseolina* from diverse hosts from Africa but isolates and infected tissue will be solicited from other collaborators in Africa and elsewhere to characterize and compare sources of *M. phaseolina* regionally within Africa and also globally.

Year 4-5: Determine cross-host virulence of *M. phaseolina* isolated from diverse African hosts on two or three hosts in the field (pearl millet, sorghum, and cowpea) in Africa. The amount of cross-host virulence will indicate the efficiency of inoculum produced on one host in causing charcoal rot in the other hosts; this may be a significant factor in some intercropping systems where one or more crops are subjected to significant and prolonged drought stress during growth.

Evaluate economic impact of leaf blight on sorghum in SADCC region and identify stable sources of resistance to the causal fungal pathogen, *Exserohilum turcicum*. Host country collaborators - W. Demilliano, E. Mtisi, Zimbabwe, G. Kaula, Zambia

Year 1: Isogenic populations differing in reaction to leaf blight (and perhaps other foliar diseases) will be developed by crossing leaf blight susceptible and resistant parents more adapted to Southern Africa than the parents previously used for population development. These populations will be evaluated for leaf blight reaction and adaptation and mixed according to susceptibilities to produce at least 3 isogenic populations having similar yield potential but low, medium,and high susceptibility to leaf blight. Assist in evaluation of introduced and area-developed germplasm for leaf blight resistance at an initial leaf blight endemic location.

Year 2: Use mixtures of leaf blight resistant and susceptible sorghums to assess their efficacy in reducing loss to leaf blight that would occur in pure stands of the susceptible cultivar. Continue development of isogenic populations. Use a systemic foliar fungicide to protect a leaf blight susceptible sorghum from disease at different stages of maturity and compare yields between protected and unprotected plots at a leaf blight susceptible location. Challenge the identified leaf blight resistant sources to leaf blight and other pathogens at other strategic SADCC locations for disease screening.

Year 3-4: Continue development of isogenic populations and use to evaluate impact of leaf blight at a strategic leaf blight screening location where there is reduced interference with other diseases. Repeat evaluation of cultivar mixtures for reduction of leaf blight in another season and evaluate at other SADCC locations where leaf blight is damaging. Repeat fungicide protection study of leaf blight loss but provide protection at the most critical yield-limiting stages of maturity.

Year 4-5: Determine primary areas in the SADCC region where leaf blight resistance is periodically or consistently needed and evaluate the stability and efficacy of the best-adapted leaf blight resistant germplasm to prevalent diseases in each area.

Determine stability and sources of resistance to sooty stripe of sorghum through use of greenhouse and field nursery evaluations. Host country collaborators: W. Demilliano, Zimbabwe; G. Kaula, B.N. Verma, Zambia; Mamourou Diorte, Mali.

Year 1-2: Sources with high resistance to sooty stripe (in Nigeria) showed variable resistance to SADCC locations but resistance to leaf blight must also be present with sooty stripe resistance. Sources with resistance to both pathogens will be evaluated at strategic locations (especially Golden Valley, Zambia) where both diseases are limiting factors on susceptible germplasm. Resident natural inoculum of *R. Sorghi* will be augmented with introduced natural inoculum and possibly conidial inoculation of spreader rows in some experiments.

Year 3-4: The best adapted germplasm from these trials will be incorporated with other germplasm in other more general disease and adaptation nurseries grown throughout the SADCC region and where appropriate will be incorporated into national and other breeding programs. As field-screening techniques for sooty stripe progress, other germplasm being developed for the SADCC region will be evaluated at the strategic locations where sooty stripe occurrence and severity are most consistent.

Develop sporulation techniques for *Ramulispora sorghi* and evaluate their use in greenhouse and field inoculations to enhance natural disease screening techniques. Host country collaborators: W. Demilliano, Zimbabwe, G. Kaula, Zambia; Mamourou Diorte, Mali

Year 1-2: Refine existing laboratory sporulation technique to maximize purity, number,longevity, and efficacy of conidial inoculum produced when used in greenhouse inoculation of sorghum seedlings. Determine if meaningful screening for sooty stripe reaction can be achieved in the seedling stage in the greenhouse.

the predominant *Fusarium* species associated with grain mold of pearl millet and sorghum in Tanzania; 2) determine intraspecific variability of important grain mold Fusaria especially as it may relate to differences in pathogen virulence, epidemiology, variability, reproduction and survival; 3) evaluate the vulnerability of sorghum germplasm to grain mold and specific grain mold fungi (including Fusaria) in Tanzania and 4) determine mechanisms of resistance to *Fusarium* infection of grain. Some aspects of his research will utilize techniques developed by J.F. Leslie of KSU 108 to determine vegetative incompatibility groups within species of *Fusarium*.

Characterize global and SADCC-area populations of *Colletotrichum graminicola* using RFLP techniques and differential sorghum cultivars and nurseries and use to identify stable sources of resistance for the SADCC region. Host country collaborators: W. Demilliano, Zimbabwe; G. Kaula, B.N. Verma, Zambia, P. Guthrie, Great Britain (graduate student at Texas A&M)

Year 1-3: For his Ph.D. research P. Guthrie will obtain isolates of *C. graminicola* from several global locations including the SADCC area and develop RFLP methodology to identify and characterize isolates at the pathogen level. The international sorghum anthracnose virulence nursery (ISAVN) from Texas A&M will be grown along with other differential and anthracnose resistant cultivars at strategic nursery locations in the SADCC region where anthracnose has occurred and where collections of *C. graminicola* were made for RFLP research. These field trials will aid in characterizing the variability and identity of *C. graminicola* in the SADCC region and facilitate RFLP characterization. Potential and known sources of resistance to *C. graminicola* will be evaluated yearly at the most anthracnose conducive locations with locations dependent in part on determined regional variability of the pathogen.

Year 4-5: Elite sources of resistance to anthracnose will be included in other regional nurseries and breeding programs as desired by national and SADCC/ICRISAT programs.

Progress (last two years)

Through collaboration with the national and SADCC/ICRISAT programs many strategic disease nursery locations have been identified in the SADCC region which provide consistent disease pressure to screen germplasm for response to specific diseases. This has allowed the more rapid identification of disease resistant germplasm for cultivar improvement.

A slide set of sorghum and pearl millet diseases developed by the P.I. is a popular resource given to interested LDC graduate students and national scientists especially from Africa.

Evaluation of sorghum diseases at several SADCC locations using differential cultivars within Texas A&M disease nurseries and other introduced germplasm has a) identified areas where host plant resistance is necessary even though economic loss may occur only periodically and b) indicated variable pathogen populations of *Peronosclerospora sorghi* and *Colletotrichum graminicola*. The latter require further identification and characterization.

Benefits to U.S. Agriculture

The identification of disease and drought resistant germplasm in Southern Africa through evaluation of introduced or locally-developed sorghums provides germplasm resources potentially useful in t he U.S. Such germplasm is especially useful in the Southern states like Texas where many of the disease and environmental constraints are similar. The disease response of U.S. developed germplasm to pathogens not occurring in the U.S. provides repository information which may be valuable for the future if the pathogens should occur in the U.S. It also allows a more accurate characterization of differential mechanisms of disease resistance that otherwise appear to be the same.

Future measures of success

Initiation and progression of students' dissertation research on characterization of populations of *C. graminicola*, evaluation and development of biological controls for sorghum downy mildew, and characterization of grain mold and *Fusarium* species associated with this disease on pearl millet and sorghum in the SADCC region.

Further refinement of regional SADCC nurseries and strategic use of introduced TAES and other nurseries to maximize efficiency in nursery number, size, location, and disease data obtained.

Identification of germplasm with adequate, stable resistance to specific pathogens that can be used directly or incorporated into regional and country breeding programs.

Trained plant pathologists through degree attainment at Texas A&M, direct short term training, and technology transfer through SADCC/ICRISAT.

5. Publication of results in appropriate country and project reports, meeting proceedings and scientific journals.

Year 2-3: Utilize the sporulation technique in greenhouse and field inoculations to determine if it provides any advantage over introduced natural inoculum of foliar sclerotia and lesions.

Develop germplasm nurseries specifically adapted to the SADCC region for use in assessing yearly impact of major pathogens and monitoring plant pathogen populations. Host country collaborators: W. Demilliano, E. Mitsi, Zimbabwe; G. Kaula, B. Verma, Zambia; B. Matalaote, Botswana.

Year 1-2: Germplasm introduced for specific SADCC regions is often evaluated for disease response at strategic nursery locations prior to agronomic and other evaluations within the specific region. Cultivars cannot be deployed in certain SADCC regions if they lack disease resistance to one or more endemic pathogens even though economically-damaging levels occur only periodically. This approach will be continued for newly introduced germplasm and, as appropriate, for other germplasm being developed for the SADCC region. This method efficiently identified suitable and unsuitable germplasm and identifies specific cultivars useful in characterizing plant pathogen populations and assessing impact of disease. As this germplasm has and is being identified it is placed in regional SADCC nurseries designed for specific pathogen monitoring and germplasm development goals.

Year 3-5: Germplasm will continuously be incorporated into or deleted from specific nurseries to provide the most efficiency in meeting the disease-monitoring or -screening goals of that nursery. The regional nature of the nurseries contributes to their value in assessing regional impact of diseases, pathogen variability, and adaptation of included cultivars.

Deploy specific germplasm or germplasm nurseries to the SADCC region to most efficiently characterize pathogen populations and identify valuable sources of resistance. Host country collaborators: W. Demilliano, E. Mtisi, Zimbabwe; G. Kaula,B. Verma, Zambia; B. Matalaote, Botswana

Year 1-3: Several sorghum disease nurseries have been developed at Texas A&M to characterize specific and general plant pathogen populations and to provide sources of resistance to several plant pathogens. Some of these nurseries also contain disease resistant sources in agronomically-desirable genetic backgrounds. Many of these nurseries have been grown in strategic areas of the SADCC region and as patterns of disease occurrence and impact become more apparent they and other nurseries will be deployed in other SADCC locations. Sources with needed resistance genes and/or with good adaptation will be utilized in other SADCC regional nurseries or breeding programs.

Year 4-5: Although utility of many sorghums in these nurseries is limited by their adaptation or susceptibility to other pests and pathogens the disease data obtained with them yearly from the SADCC region will be compiled with other global data from these same nurseries. This information will assist in evaluating global variability of pathogens and the stability of genetic resistance in the cultivars. For the SADCC region it also will help identify the most appropriate sources of resistance and adaptation and thus reduce the number of failed introductions.

Evaluate naturally-occurring and introduced biological control organisms for potential use in plant protection systems. Host country collaborators: S. Kunene, Swaziland (graduate student at Texas A&M)

Year 1-3: For her Ph.D. research Ms. Kunene is evaluating the efficacy of a *Gaertnariomyces* spp. as a soil amendment to control sorghum downy mildew (caused by *Peronosclerospora sorghi*) by direct parasitic reduction of initial oospore inoculum. She is conducting both greenhouse and field application tests. She is determining the best methods of *Gaertnariomyces* production in culture, the optimal application and incorporation methods to facilitate hyperparasitic activity, and optimum methods for storage to maintain longevity and activity of the biocontrol agent. In addition to this introduced biocontrol agent, Ms. Kunene is assessing the naturally-occurring biocontrol organisms that occur throughout the lifecycle of *P. sorghi* but especially those that directly infect or negatively influence the viability of oospores.

Identify and characterize the *Fusarium* species causing diseases on pearl millet and sorghum in the SADCC region, assess their involvement in grain mild and potential mycotoxin problems, and identify sources of resistance. Host country collaborators: A. Mansuetus, Tanzania (graduate student at Texas A&M); G. Kaula, Zambia; W. Demilliano, Zimbabwe; B. Matalaote, D. Carter, Botswana.

Year 1: Field-collected seed of pearl millet and sorghum from Zambia, Zimbabwe, and Botswana will be evaluated at the Fusarium Research Laboratory at Penn State University for type and frequency of *Fusarium* species present on the grain to include two recently described species known to produce mycotoxins in culture.

Year 2-4: The initial study from Year1 is projected to form the basis or provide specific direction for the Ph.D. dissertation research of A. Mansuetus of Tanzania. He will conduct at least part of his dissertation research in areas of Tanzania where *Fusarium* grain molds are a recurring problem. Mr. Mansuetus intends to: 1) identify

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: Development of Plant Disease Protection Systems for Millet and Sorghum in Semi-Arid Southern Africa

Project Leader: Gary Odvody **Project Number:** TAM-128

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=TAM128	--	----------				
Staff Salaries & Benefits	14.85	15.64	16.43	17.03	17.82	81.77
Post Doctorates	5.70	6.00	6.31	6.54	6.84	31.39
Graduate Students	6.00	6.00	6.00	7.00	7.00	32.00
Other Salaries	7.43	7.82	8.22	8.51	8.91	40.89
Supplies	6.45	6.79	7.14	7.40	7.74	35.52
Equipment	2.33	2.45	2.57	2.67	2.79	12.81
Travel	8.40	8.85	9.30	9.63	10.08	46.26
Other Direct Costs	5.78	6.08	6.39	6.62	6.93	31.80
Overhead	18.30	19.28	20.25	20.98	21.96	100.77
	75.24	78.91	82.81	86.38	90.07	413.21

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=TAM128	--	----------				
Grad Students	10.37	10.89	11.43	12.00	12.60	57.29
Other Salaries	1.64	1.72	1.81	1.90	1.99	9.05
Fringe Benefits	1.80	1.89	1.99	2.08	2.19	9.95
Supplies	1.05	1.10	1.16	1.22	1.28	5.80
Equipment	3.15	3.31	3.47	3.65	3.83	17.41
Travel	8.40	8.82	9.26	9.72	10.21	46.42
Other Direct Costs	0.32	0.34	0.35	0.37	0.39	1.78
Overhead	10.02	10.52	11.05	11.60	12.18	55.37
	36.75	38.59	40.52	42.54	44.67	203.07

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=TAM128	--	----------				
Grad Students	9.88	9.88	9.88	9.88	9.88	49.38
Other Salaries	1.56	1.56	1.56	1.56	1.56	7.80
Fringe Benefits	1.72	1.72	1.72	1.72	1.72	8.58
Supplies	1.00	1.00	1.00	1.00	1.00	5.00
Equipment	3.00	3.00	3.00	3.00	3.00	15.00
Travel	8.00	8.00	8.00	8.00	8.00	40.00
Other Direct Costs	0.31	0.31	0.31	0.31	0.31	1.53
Overhead	9.54	9.54	9.54	9.54	9.54	47.72
	35.00	35.00	35.00	35.00	35.00	175.00

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Sustainable Production Systems

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Modelling Millet and Sorghum Establishment and Growth For Sustainable Crop Production

Project KSU-106
Richard L. Vanderlip
Kansas State University

Collaborating Institutions

Host Country

Botswana

Elijah Modiakgotla, D. Lesolle and O. Mmolawa,Department of Agricultural Research, Botswana
Naraine Persaud, INTSORMIL/KSU, Gaborone, Botswana

Mali

Adama Coulibaly, Institut Economie Rurale, Cinzana Research Station, Mali

U.S.

W. D. Stegmeier, Ft. Hays Experiment Station, Kansas State University, Hays, KS
Babrak Khaleeq, Fort Hays Experiment Station, Kansas State University, Hays, KS
Max Clegg, Department of Agronomy, University of Nebraska, Lincoln, NE

Research Objectives

Determine the environmental conditions responsible for erratic stand establishment of pearl millet and sorghum under the stress conditions normally found where they are grown in the tropics and in Kansas.

Evaluate genetic and seed quality differences for improved stand establishment.

Incorporate the effects of environmental conditions on stand establishment into existing pearl millet and sorghum growth models and test their usefulness with LDC and Kansas climatic data.

Mali--Adama Coulibaly agronomist at the Cinzana Research Station is interested in evaluating plant growth models utilizing climatic data for Mali to evaluate crop maturity and planting dates for a range of tall zones in Mali.

Introduction

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. Social and economic constraints add to the difficulties of crop management. 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.

Host Country Collaboration and Worksites

Botswana--Elijah Modiakgotla, Agronomist with the DAR, is being transferred from Mahalapye back to Sebele and is interested in collaboration both on stand establishment and other agronomic practices. Dr. Lesolle from the Department of Meteorological Services is interested in collaborating on climatic data analysis and utilization. O. Mmolawa, seed technologist, may be interested in seed quality evaluations.

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Research Procedures

Millet seed of different size and densities will be germinated under a wide range of temperature and moisture stress. Similar experiments under growth chamber, greenhouse, and field conditions will be conducted to look at coleoptile and mesocotyl growth and establishment capability.

A range millet of genetic materials identified at the Fort Hays Branch Experiment Station which differ in mesocotyl and coleoptile growth will be tested under a range of environmental conditions.

Results from procedures A and B above will be incorporated into pearl Millet (SUNMILL) and sorghum (SORKAM) plant growth models.

Pearl millet (SUNMILL) and sorghum (SORKAM) plant growth models will be tested utilizing Botswana, Mali, and Kansas climatic data to determine their applicability under those conditions.

Measure of Success

Measures of success can be readily determined by differences in seed quality, differences in genetic response to environment, and success in producing seed with improved size and density. Incorporation of improved establishment routine is into existing plant growth models will be evaluated on the basis of agreement between simulated and actual field establishment both in the LDC's and under Kansas growing conditions. Agreement between simulated and actual yields or between simulated and actual yield responses to variables, such as planting date, soil characteristics, or varietal characteristics, would indicate the potential for crop growth model use.

Anticipated Reports and Articles

Scientific paper on genetic differences in mesocotyl and coleoptile lengths and their relationship to depth of planting.

Popular article on producing millet seed of high quality.

Scientific paper on temperature effects on mesocotyl and coleoptile lengths of pearl millet and its importance in stand establishment.

Scientific papers on evaluation of pearl millet and sorghum growth models utilizing readily available LDC climatic data.

Scientific paper on evaluating planting strategies for sorghum and pearl millet in Mali.

Progress (last two years)

Genetic differences in mesocotyl and coleoptile lengths were found. Temperature differentially affected the growth of the mesocotyl and coleoptile, with higher temperatures producing longer mescotyls and shorter coleoptiles. These differences in temperature response could be important in stand establishment of pearl millet and differences in genetic responses depending upon soil temperatures occurring at planting.

Continued experiments on seed characteristics, seed size and seed density, resulted in variable affects on establishment and grain yield. Where yield differences were found, large high density seeds produced higher yields than small low density seeds. However, the yields from the large high density seed frequently were not significantly higher than yields from the unseparated control seed. The evaluation of seed size and density effects on stand establishment and yield under severe drought conditions in Botswana produced no benefits.

Preliminary results from plant population and date of planting experiments comparing sorghum and pearl millet show no differences in response to planting date and even less differences among populations for pearl millet than sorghum. When pearl millet becomes a commercial grain crop in the U.S., it would then appear we could use much of the known production practices and could depend upon the pearl millet plant to compensate even more than sorghum does for differences in plant population.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: Modelling Millet and Sorghum Establishment and Growth for Sustainable Crop Production

Project Leader: Richard Vanderlip **Project Number:** KSU-106

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=KSU106 -- ----------						
Staff Salaries & Benefits	13.86	14.65	15.44	16.04	16.83	76.82
Post Doctorates	5.32	5.62	5.93	6.16	6.46	29.49
Graduate Students	5.00	6.00	6.00	6.00	6.00	29.00
Other Salaries	6.93	7.33	7.72	8.02	8.42	38.42
Supplies	6.02	6.36	6.71	6.97	7.31	33.37
Equipment	2.17	2.29	2.42	2.51	2.64	12.03
Travel	7.84	8.29	8.74	9.07	9.52	43.46
Other Direct Costs	5.39	5.70	6.01	6.24	6.55	29.89
Overhead	17.08	18.06	19.03	19.76	20.74	94.67
	69.61	74.30	78.00	80.77	84.47	387.15

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=KS106 -- ----------						
Grad Students	9.74	10.23	10.74	11.28	11.84	53.82
Other Salaries	7.35	7.72	8.10	8.51	8.93	40.61
Fringe Benefits	0.22	0.23	0.25	0.26	0.27	1.23
Supplies	3.68	3.86	4.05	4.25	4.47	20.31
Equipment	7.04	7.40	7.77	8.15	8.56	38.92
Travel	7.88	8.27	8.68	9.12	9.57	43.51
Other Direct Costs	3.15	3.31	3.47	3.65	3.83	17.41
Overhead	13.44	14.12	14.82	15.56	16.34	74.29
	52.50	55.13	57.88	60.78	63.81	290.10

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=KS106 -- ----------						
Grad Students	9.28	9.28	9.28	9.28	9.28	46.38
Other Salaries	7.00	7.00	7.00	7.00	7.00	35.00
Fringe Benefits	0.21	0.21	0.21	0.21	0.21	1.06
Supplies	3.50	3.50	3.50	3.50	3.50	17.50
Equipment	6.71	6.71	6.71	6.71	6.71	33.54
Travel	7.50	7.50	7.50	7.50	7.50	37.50
Other Direct Costs	3.00	3.00	3.00	3.00	3.00	15.00
Overhead	12.80	12.80	12.80	12.80	12.80	64.02
	50.00	50.00	50.00	50.00	50.00	250.00

Resource Efficient Crop Production

Project UNL-113
Max D. Clegg
University of Nebraska

Collaborating Institutions

Host Country

Botswana

Dr. Lucas Gakale, Department of Agriculture, Botswana
Dr. Douglas Carter, INTSORMIL/KSU/Botswana
Dr. Naraine Persaud/INTSORMIL/Botswana

Niger

Mr. Bachir Mahanan Maman Nouri, INRAN, Niger
Dr. Chandra Reddy, INRAN/NAAR Project, Niger
Dr. John Clark, INRAN/NAAR Project, Niger

Honduras

Dr. Francisco Gomez, Secretaria de Recursos Naturales, Choluteca, Honduras
Dr. Leopoldo Alvarado, Secretaria de Recursos Naturales, Choluteca, Honduras
Dr. Dan Meckenstock, INTSORMIL/Honduras, Tegucigalpa, Honduras

U.S.

Dr. Steve Mason, Department of Agronomy, University of Nebraska, Lincoln, NE
Dr. Richard Vanderlip, Department of Agronomy, Kansas State University, Manhattan, KS
Dr. Gebisa Ejeta, Department of Agronomy, Purdue University, West Lafayette, IN

Project Objectives

Sorghum and millet are usually grown in stressful environments with high temperatures and the lack of a predictable water supply. Generally lack of water is considered the most influential environmental factor controlling plant growth and yield in these environments. The next most influential environmental factor affecting plant growth and yield is often adequate nitrogen. The importance of nitrogen is becoming even greater with more intensive cropping practices used when availability of new land is limited. Legumes become a viable means for improving soil fertility (especially nitrogen status) as monetary constraints for purchasing fertilizer occurs in many developing countries. Improved nitrogen fertility also improves water use efficiency of grain crops.

Determine the nitrogen fertility relationships in intercropping and rotation systems involving sorghum or millets with grain legumes under temperate and tropical conditions and the influence of environmental factors (water, light, and temperature) on nitrogen transformations involved before, during and after cropping with cereals and legumes.

Evaluate the influence of cereal and legume genotypes in contributing to the yield and nitrogen efficiency of intercropping and rotation systems, and land use efficiency of intercropping systems.

Evaluate the use of sorghum and millet crop residues for forage and for soil improvement (water, nutrients, erosion control, stand establishment). This will include cooperative research with projects PRF-107, KSU-106, UNL-114, and UNL-116.

Introduction

There are many constraints involved with cropping systems studies. First, they are long term investments.

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For instance, once a rotation or intercropping study is started it takes time to stabilize. These systems cannot be stopped and restarted. Second, a host scientist must be genuinely interested in these long term projects and they will need added funding. Third, training of scientists in crop production and continued support of their work after return to home countries is needed to improve presently used cropping systems.

Research Procedures

Botswana: A collaborative program in the area of legume nitrogen (grain and legumes) for a following cereal crop is being developed. This program will incorporate phosphorus fertilization to the legume for enhanced productivity, enhanced productivity of the sorghum in quality of grain and forage following the legume, and improved animal performance using the higher quality forage and grain. Additional funds from SACCAR will be requested to link with the animal research.

Niger and Mali: A three-year field study to determine nitrogen contribution to millet by intercropped cowpeas harvested for grain and forage will be completed during the 1989 growing season in Niger. In 1990 research efforts in resource-efficient crop production systems will expand with collaboration with Minamba Bagayoko upon his return to IER, Mali (M.S. University of Nebraska, Dec. 1989) and the naming of Bachir Mahaman by INRAN, Niger as collaborator for this project. At present planning for 1990-1995 research is being conducted and is focused on improved cultivar selection responses (interactions with) to residue and intercrop production management practices. Efforts will be made to network these studies between Mali and Niger and with TROPSOILS and ICRISAT scientists.

Sudan: Sorghum/millet-cowpea research is being done by Mirghani Mohamed for his thesis research in Sudan. This research has been leveraged from the obtaining of a $25,000 internship from Rockefeller Foundation to partially support this research. This research was initiated in 1988 and is in collaboration with UNL-116.

Honduras: Agronomy research in Honduras will be initiated. The problem was discussed at the 1989 INTSORMIL conference in Scottsdale, AZ. Dr. Francisco Gomez has been approached for an on site visit to determine the direction of the research. Identification of a student is needed and support will be an assistantship with INTSORMIL.

Nebraska: The domestic research will continue in the direction of determining the mechanism and quantity of nitrogen contributed by legumes within cereal/legume rotational systems. Much of the research is being done by students from the LDCs as these experiments serve as a laboratory for training INTSORMIL and other international students in cropping systems research. This includes planting, weed control, harvesting, as well as studying soil biological and physical characteristics in relation to crop growth and yield.

Studies on nitrogen fertility contribution of legumes in intercropping and rotation systems to cereal crops will be conducted in Nebraska. Studies in Nebraska will utilize two on-going sorghum-soybean rotations located at the Research and Development Center, Mead, NE. One of these, under the direction of Dr. Clegg, has a 16 year history with treatments of continuous sorghum, sorghum rotated with soybeans and 4 nitrogen treatments 0, 57, 114, and 171 kg/ha N applied only to sorghum. In addition to continuous monitoring of yield, plant growth, and soil properties (soil nutrient status, dehydrogenase, soil biomass, aggregation, bulk density and volumetric water content), as in the past, emphasis will also be on determining the water use, growth and development and photosynthesis of sorghum grown continuously or in rotation.

The second rotation study, under the direction of Dr. Mason, has a nine year history with three nitrogen regimes (0, 66.7 kg/ha to sorghum and 33.3 kg/ha to soybeans, and feedlot manure). Research activities at present focus on the residual effect of soybean to sorghum after termination of the rotation. At the same time nodulating and non-nodulating soybean isolines have been incorporated into other plots. After establishing adequate cropping history with these treatments, these plots will be used to separate the nitrogen and other rotational effects on grain yield, soil nitrogen levels, root distribution, soil water usage, and microbial biomass.

Millet-soybean rotation research in Nebraska will continue. Mr. Charles Maliro (Malawi) has been assigned the responsibility for this experiment. This study will determine the nitrogen contribution of the legumes to the succeeding millet crop and its influence on water use efficiency.

The contribution of soybean and cereal roots to cereal productivity was initiated in 1989. This is being conducted by Ruth Onyango (Kenya, Miac project) and involves maize as the cereal. Results will be applicable to sorghum and millet rotations.

Anticipated Reports and Articles

Co-sponsor one or more workshops emphasizing crop production management (residues, fertility and other aspects). Collaborators will be encouraged to publish research results in national research and exten-

sion bulletins, INTSORMIL technical series reports and scientific journals.

Progress (last two years)

Botswana: Serere 6A (pearl millet) was about 5 days earlier, had a greater number of heads reach anthesis, and had greater grain and stover yields than Segaolane (grain sorghum) in environments with rainfall less than 350mm in Botswana. Greater tillering in Serere 6A was observed and this compensated somewhat for a lower plant population. Under conditions where rainfall is less than 350mm, millet would be a better crop and suggests emphasis should be given to production and improvement of this crop. Columbus grass produced from 2-3 times more stover than millet or sorghum.

DMD of sorghum forage was greater than either pearl millet or grain sorghum. Crude protein was greater and phosphorus was less than the minimum requirement for young animals or lactating cows. Calcium was about three times higher than P levels. Calcium/phosphorus ratios were greater than recommended for animal nutrition. Nutritional aspects of this research suggest that quality of grain and forage should be addressed.

Niger: In 1987 and 1988 application of nitrogen from 0 to 100 or 150 kg/ha increased yield quadratically from 800-900 kg/ha to approximately 1200 kg/ha. Intermediately and intensively managed intercropping systems produced 300 to 350 kg/ha more pearl millet and 250 to 400 kg/ha more cowpea grain. Intercropping reduced pearl millet yields 100 to 200 kg/ha in both years, while cowpea yields were reduced 450 (1988) to 1000 (1987) kg/ha by intercropping. Preliminary 1988 results on residual effects of intercropping indicated the highest millet yields were produced following cowpea sole crop harvested for forage and the lowest yield following the traditional intercropping system.

During the period of 1986-89 research was conducted in collaboration with junior INRAN scientists (B.S. level) and Dr. Chandry Reddy, NAAR Project. Starting in 1990 Mr. Bachir Mahanan (M.S. Purdue) will become the principle collaborator of this projects research efforts providing the potential for long-term collaborative research on resource-efficient crop production systems in Niger.

Mali: Mr. Minamba Bagayoko will complete his M.S. degree in Dec. 1989 at the University of Nebraska. A preproposal for resource-efficient crop production systems has been submitted to IER, Mali and approved. The specific detail of the research will be determined in 1990 upon return of Minamba to Mali.

Sudan: Mr. Mirghani Mohamed has started a Ph.D. He was able to obtain a Rockefeller Foundation Internship to partially support his research in Sudan. This rotation was established in Sudan last summer (1988). This study will continue for two more summers.

Nebraska: Sorghum. From the long term rotation (16 years), a model was used to normalize the effects of environment to compare sorghum grown continuously or after soybeans. Yields of sorghum were higher after soybeans over all environments (yield range of 2-10 Mg/ha). The regressions were linear and slopes indicated a higher rate of grain increase for sorghum in rotation ($a = 1.10$) than continuous ($a = 0.91$) as environments improved. In more stressful environments (index of 2.0 Mg/ha), the benefit of rotation was 120% greater than growing grain sorghum continuously as compared to a less stressful environment (index of 8.0 Mg/ha) where the benefit was 39% greater. This greatly increases the yield potential in developing countries where fertility is limiting and fertilizer is unavailable or to costly.

Sorghum-soybean rotation resulted in grain sorghum yield increases of 17 to 60% and the increases were associated with "nitrogen contribution equivalent of 90 kg/ha nitrogen applied" of the previous crop. The soybean yield increases were from 5 to 15% and were related to soil water received before planting. Root densities of both grain sorghum and soybean were reduced at most depths with soybean as a previous crop, but cropping systems with soybeans as the present or previous crop had greater soil water extraction from the soil profile. Grain sorghum as either the present or previous crop and manure resulted in greater microbial biomass in the 0-30cm depth interval.

Preliminary results suggest that the rotational benefits of soybean on grain sorghum yield and soil nitrogen levels is still present at least two years after the soybean crop.

Millet. Grain yield, number tillers and heads, and leaf, stem and grain nitrogen increased with applied nitrogen to millet grown continuously or in rotation with soybeans. Application of 0 and 45 kg/ha N to millet grown in rotation resulted in crop changes similar to 45 and 90 kg/ha N applied to continuously grown millet. This indicates that millet is benefiting by approximately 45 kg/ha N from the legume-cereal system.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: Resource Efficient Crop Production Systems

Project Leader: Max Clegg/Steve Mason **Project Number:** UNL-113

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=UNL113 -- ----------						
Staff Salaries & Benefits	16.83	17.62	18.41	19.21	20.20	92.27
Post Doctorates	6.46	6.76	7.07	7.37	7.75	35.41
Graduate Students	6.00	7.00	7.00	7.00	8.00	35.00
Other Salaries	8.42	8.81	9.21	9.60	10.10	46.14
Supplies	7.31	7.65	8.00	8.34	8.77	40.07
Equipment	2.64	2.76	2.88	3.01	3.16	14.45
Travel	9.52	9.97	10.42	10.86	11.42	52.19
Other Direct Costs	6.55	6.85	7.16	7.47	7.85	35.88
Overhead	20.74	21.72	22.69	23.67	24.89	113.71
	84.47	89.14	92.84	96.53	102.14	465.12

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=NE113 -- ----------						
Grad Students	18.90	19.85	20.84	21.88	22.97	104.43
Other Salaries	5.25	5.51	5.79	6.08	6.38	29.01
Fringe Benefits	4.83	5.07	5.33	5.59	5.87	26.69
Supplies	3.00	3.15	3.30	3.47	3.64	16.55
Equipment	1.05	1.10	1.16	1.22	1.28	5.80
Travel	17.12	17.97	18.87	19.81	20.80	94.57
Other Direct Costs	17.22	18.08	18.99	19.93	20.93	95.15
Overhead	21.89	22.98	24.13	25.34	26.61	120.95
	89.25	93.71	98.40	103.32	108.48	493.16

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=NE113 -- ----------						
Grad Students	18.00	18.00	18.00	18.00	18.00	90.00
Other Salaries	5.00	5.00	5.00	5.00	5.00	25.00
Fringe Benefits	4.60	4.60	4.60	4.60	4.60	23.00
Supplies	2.85	2.85	2.85	2.85	2.85	14.27
Equipment	1.00	1.00	1.00	1.00	1.00	5.00
Travel	16.30	16.30	16.30	16.30	16.30	81.50
Other Direct Costs	16.40	16.40	16.40	16.40	16.40	82.00
Overhead	20.85	20.85	20.85	20.85	20.85	104.24
	85.00	85.00	85.00	85.00	85.00	425.00

Nutrient Use Efficiency in Sorghum and Pearl Millet

Project UNL-114
Jerry W. Maranville
University of Nebraska

Collaborating Institutions

Host Countries:

Mali

Dr. Moussa Traore, Physiologist and INTSORMIL Coordinator, Bamako, Mali
Mr. Abdoulaye Traore, Agronomist, Bamako, Mali
Dr. Omar Niangado - Millet Breeder and Director, Cinzana Station, Mali

Niger

Mr. Goube Gaoh - Soil Fertility Agronomist and Director, Maradi Station, Niger
Mr. Cherif Oumarou Ari - Head, Agronomy Division, Maradi Station, Niger
Mr. Seyni Serifi, Agronomy Division, Maradi Station, Niger
Dr. Abdel Berrada - Agronomist, Maradi Station, Niger

U.S.

Dr. Charles Sullivan - USDA Physiologist, University of Nebraska
Dr. Jerry Eastin - Crop Physiologist, University of Nebraska
Professor Dave Andrews - Sorghum and Millet Breeder, University of Nebraska
Dr. Steve Mason - Agronomist, University of Nebraska
Dr. Max Clegg - Crop Physiologist, University of Nebraska
Dr. Darrell Rosenow - Sorghum Breeder, Texas A&M University
Dr. John Clark - Sorghum Breeder, Purdue University, Niamey, Niger

Project Objectives:

Identify sorghum and millet genotypes which are capable of producing good growth, high grain yield and grain quality under limiting soil fertility, particularly nitrogen and phosphorus.

Determine the physiological mechanisms which allow sorghum and millet genotypes to be nutrient use efficient.

Determine the influence of environment and management on genetic response to various soil fertility regimes.

Identify management practices which help genotypes utilize their full potential in nutrient use efficiency.

Introduction

Low soil fertility, particularly nitrogen (N) and phosphorus (P), may be limiting to crop production world-wide. This can be a problem equal in magnitude to the highly visible and more often researched problem of drought. The two stresses, however, interact readily in that nutrient healthy plants are much better able to cope with low soil moisture supply than those which are not healthy due to nutrient starvation. There is also evidence that nutrient efficient genotypes are water use efficient and vice versa. The exact nature of the interaction is not known nor is the physiological mechanism(s) by which stress tolerance occurs. Research in this area is needed for improvement of crops and agronomic systems on a world-wide basis.

Objectives addressed

The work plan will address all objectives to some degree. Identification of nutrient use efficient genotypes is an ongoing process and will take place in both the host countries and the U.S. Determining the mechanisms which the genotypes use for efficiency often requires more controlled conditions and will be done primarily in the U.S. Objectives addressing genetic response to environment as well as management will center in host countries. Mathematical models developed to predict drought/nutrient genotype interactions will be developed in the U.S. and tested in host countries.

Research procedures

Mali: Genotype screening will be accomplished under low fertility in both Mali and the U.S. At least two and possibly 3 sites will be used in Mali (Samanko, Ntarla, Cinzana, or other). Response will initially center on nitrogen efficiency as the primary nutrient, and phosphorus as secondary. Efficiency will be based on dry matter or grain produced per unit of nutrient taken up in above ground biomass.

Upon completion of an M.S. degree, Mr. Abdoul Toure will return to Mali and set up pearl millet (a sorghum) studies related to nitrogen management. These studies (to be determined) will include physiological measurements and will relate to nutrient/genotype (and perhaps drought) interactions. They could potentially become part of a Ph.D. dissertation.

In the latter phases of the work, attempts will be made to develop mathematical models for predicting water use as a function of fertility level. Some models are already in place, but need refined for conditions in Mali. It is the intent to utilize this type of prediction in a more regional basis as well.

Niger: Experiments will be conducted primarily in the Maradi region and will center on pearl millet fertility management. The nutrients in question are nitrogen and phosphorus, and how they influence pearl millet growth. Emphasis will be placed on developing and using mathematical models for water balance calculations over a range of fertilities and genotypes. Instrumentation for microclimatological measurements at the Maradi station and those purchased by this project for critical physiological measurements will provide much of the data used to formulate models.

Another area of anticipated research will be residue management and how that interacts with different soil fertilities. Pearl millet response to residues is already documented, but not understood. Several INTSORMIL scientists and others will cooperate on this research.

One other research thrust will be to conduct experiments in pearl millet legume rotations. This project will concentrate primarily on the beneficial effects derived from increased fertility in these rotations.

Measures of Success:

Development and use of sorghum and pearl millet genotypes which are superior in nutrient use efficiency in order to best utilize limited fertility resources and soil moisture.

Improvement of agronomic practices through a broader understanding of how fertility can be matched in the field to expected moisture supply.

Eventually, technology transfer systems must be developed so that farmers respond to suggestions on agronomics and genotype choice developed in the research.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: Nutrient Use Efficiency in Sorghum and Pearl Millet

Project Leader: Jerry Maranville **Project Number:** UNL-114

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=UNL114	--	----------				
Staff Salaries & Benefits	14.85	15.64	16.43	17.03	17.82	81.77
Post Doctorates	5.70	6.00	6.31	6.54	6.84	31.39
Graduate Students	6.00	6.00	6.00	7.00	7.00	32.00
Other Salaries	7.43	7.82	8.22	8.51	8.91	40.89
Supplies	6.45	6.79	7.14	7.40	7.74	35.52
Equipment	2.33	2.45	2.57	2.67	2.79	12.81
Travel	8.40	8.85	9.30	9.63	10.08	46.26
Other Direct Costs	5.78	6.08	6.39	6.62	6.93	31.80
Overhead	18.30	19.28	20.25	20.98	21.96	100.77
	75.24	78.91	82.61	86.38	90.07	413.21

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=NE114	--	----------				
Grad Students	8.12	8.52	8.95	9.40	9.87	44.85
Other Salaries	18.84	19.78	20.77	21.81	22.90	104.10
Fringe Benefits	5.39	5.66	5.94	6.24	6.55	29.78
Supplies	15.40	16.17	16.98	17.83	18.72	85.11
Travel	5.25	5.51	5.79	6.08	6.38	29.01
Overhead	15.25	16.01	16.81	17.66	18.54	84.27
	68.25	71.66	75.25	79.01	82.96	377.12

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=NE114	--	----------				
Grad Students	7.73	7.73	7.73	7.73	7.73	38.65
Other Salaries	17.94	17.94	17.94	17.94	17.94	89.71
Fringe Benefits	5.13	5.13	5.13	5.13	5.13	25.67
Supplies	14.67	14.67	14.67	14.67	14.67	73.35
Travel	5.00	5.00	5.00	5.00	5.00	25.00
Overhead	14.52	14.52	14.52	14.52	14.52	72.63
	65.00	65.00	65.00	65.00	65.00	325.00

Physiologically Derived Cultural and Genetics Enhancements of Water and Temperature Stress Induced Limitations.

Project UNL-116
J. D. Eastin
University of Nebraska.

Collaborating Institutions

Host Countries

A. Alou, Chandra Reddy, Ouendeba Botorou, John Clark, INRAN, Niger
Saeed Farah, Gandoul I. Gandoul, Osman Ibrahim, Sudan
Louis Mazhani, Lucas Gakale, Botswana
Leopoldo Mendoza, Manuel Livera, Victor Gonzalez, Ciro Valdez, Francisco Zavala, Mexico
Dr. Obilana, Zimbabwe

U.S.

David Andrews, Max Clegg, Jerry Maranville, Steve Mason, University of Nebraska
Paula Bramel-Cox, M. T. Witt, Richard Vanderlip, Kansas State University
D. T. Rosenow and Ed Clark, Texas A&M University
John Sanders, John Axtell, Purdue University

Project Objectives

The essential limiting components of sustainable production systems can be appropriately analyzed in terms of factors which influence both water and nutrient use efficiencies.

Seasonal water use efficiency (WUE) is defined as grain or dry matter production/unit of water used. The numerator, grain produc tion, is influenced mainly by fertility level, crop genotype adapta tion to the specific stress environments involved, weed control and water level. The denominator, units of water used, is influenced by rainfall level, soil infiltration rate (tillage and residue factors) and soil water losses (evaporation, deep percolation, etc.). Obviously a wide variety of factors influence WUE. A similar set of factors influence nutrient use efficiency (NUE). The main emphasis in this project is on factors influencing WUE with attention being directed to water x nutrient interaction influences on WUE through cooperation with Drs. Max Clegg. Jerry Maranville, Saeed Farah and G. I. Gandoul (Sudan), and A. Alou (Niger). These cooperators are pro duction/physiology scientists. Also, genotype stress adaptation research bearing on WUE is being done cooperatively with Paula Bramel- Cox and Merle Witt (KSU), David Andrews (NE), John Clark (Niger) and Osman Ibrahim (Sudan). Specific research objectives follow:

Continue stress screening and development of breeder stress screening techniques for sorghum cooperatively with Kansas State University scientists and Professor David Andrews. Research on millet stress screening methodology was initiated in Niger with Mr. Ouendeba Botorou but has been stopped until he returns in 1991. Sorghum stress screening will be explored in Niger in 1990 for the 1991 or 1992 seasons. Stress screening initiated in 1989 in Mexico is being expanded.

Measure crop water use, seasonal and instantaneous WUE, and canopy carbon balance in relation to yield in sorghum (US) and in legumes in sorghum and millet-cowpea cropping systems in Niger. Instantaneous water use and WUE measurements will be initiated in Sudan in 1990/1991.

Investigate millet stand establishment problems (germination and seedling vigor) especially under sandblasting in Niger.

Continue residue management research in Niger and initiate similar research in Sudan in 1991 if tillage equipment funds become available. Residue management research is ongoing in Western NE.

Begin rotation research in Sudan to establish sound economic low input sustainable production systems in the dryland mechanized (Gedarif, Gadambolia, etc.) areas.

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Introduction

A frequent major constraint in the host countries of Niger, Sudan, Senegal, Botswana and India is poor utilization of generally very limited water resources. Low WUE is a function of a host of suboptimal agronomic practices associated with soil erosion and low fertility. Usually the most limiting nutrients are N and P. Increasing WUE is often a function of improving the growth of the legume component of an intercropping or rotation system to optimize N status of the soil. Therefore, we are evaluating different cereal (sorghum and millet)/legume associations to optimize both legume and cereal growth and minimize transpiration. This is being researched primarily in Niger (cowpea/millet) and the US (soybean/sorghum). A plan for Sudan has been initiated and is being expanded. Similar research for Senegal is under discussion.

WUE can also usually be increased by judicious addition of N and other commercial fertilizers which is being evaluated cooperatively with others.

A second constraint is the relative shortage of improved germplasm in stress prone areas in both developing nations and the US. Therefore stress screening programs are being devised and tested in the USA, a program is pending in India, and a program is pending in Sudan with Dr. O. Ibrahim. Germplasm is being sent to Niger, Sudan, Zimbabwe, Botswana, and Mexico.

Cropping system improvement, WUE research, fertility research and stress screening efforts are all key inputs for developing and optim izing sustainable, safe agricultural production systems.

Objectives

Stress screening methodology is being studied in Niger, NE and KS. Screening efforts will be expanded in these countries plus Mexico. Screening interest has been expressed in Sudan (O. Ibrahim) Germplasm testing is in effect in the above countries plus Botswans and Zimbabwe.

Measure water use, seasonal WUE and instantaneous WUE as influenced by agronomic practices, particularly those practices influencing fertility and soil erosion control. The use of Veteveria grass in place of mechanical terraces is being discussed in Niger to help alleviate excessive water runoff.

Investigate stand establishment problems in terms of germination, seedling vigor and wind erosion. Gas exchange of seedlings is being used in an attempt to quantify the seriousness of sand blasting in millets.

Excessive runoff and general nutrient shortages in Niger lead to residue management experiments in (1988) which increased millet yields 200-300% using normal production residue levels returned to the soil. Higher than normal rainfall was received in 1988 so several more years of data are needed. It appears that proper residue management will permit maintaining adequate livestock numbers from increased production levels and improve the current highly fragile soil environment where millet is cultured in sandy soils. If coupled with other sound conservation practices such as vegetative bunds and agroforestry desertification could possibly be reversed. A broader agronomy/animal science cooperative program needs to be initiated. A. Alou and Chandra Reddy are cooperators.

Residue studies to improve nutrient status and water infiltration need to be initiated in the Gedarif region of Sudan. Heavy black soils persist there compared to the sandy soils of Niger Coopera tors will be G. I. Gandoul and Saeed Farah.

Monocropping sorghum over the past 30 years in the Gedarif in Sudan has reduced nutrient levels and yields by 50% and more. Research on new cropping systems including legumes, better residue management and judicious use of limited ferti lizer inputs will be necessary to establish economically feasible sustainable production systems at production levels above current monocropping practices.

Collaborators, Research Sites and Procedures by Objective as Listed

Collaborators are mentioned in the Introduction with brief reference to procedures which are expanded below.

Sorghum stress screening primarily for mid season stress in the dry Western KS climate is accomplished by overplanting to get a higher than normal water use canopy by panicle initiation and maintaining stress from the floret differentiation stage until anthesis. Determining stress mechanisms operating in resistant genotypes involves using an infrared thermometer to determine canopy minus air temperature differentials. Also transpiration and carbon balance determinations are made with a LICOR 7200 analyzer system.

Seasonal crop water use measurements are made with a neutron probe in the US, Niger and Sudan. Instantaneous water use efficiency measurements are made with a LICOR 7200.

Standard methods are used in germination and seedling growth.

Residue management research in Niger involves hand tillage only and is being adequately managed with current equipment. Standard subtillage and chemical tillage research tools are used in Western NE for student training. Residue management research will be limited in the Gedarif mechanized region in Sudan until tillage equipment can be arranged for in the future probably through the Khartoum AID Mission.

Rotation research has been discussed with ARC scientists and will be initiated in 1990. Two years of N response data plus one year with P have demonstrated good fertilizer responses in sorghum suggesting good expectations from legumes in rotations. P response in sorghum has been good and will now be tested on the legume in rotation with sorghum. Both seasonal water use (neutron probe) and instantaneous water use (with a LICOR) will be moni tored on potential rotation crops (sorghum, cowpea, dolichos and sesame) in 1990 while new rotations are being set up. G. I. Gandoul will do this research as part of his Ph.D. dissertation program. He is currently learning the techniques in tillage/rota tion experiments in NE. Tied ridge tillage work has been initi ated in Sudan to evaluate water x nitrogen interaction effects on WUE. Again, however, extensive residue management work must await a tillage equipment input from a major contributor.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: Physiologically Derived Enhancements to Sustainable Production Limitation

Project Leader: Jerry Easin **Project Number:** UNL-116

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=UNL116 -- ----------						
Staff Salaries & Benefits	14.85	15.64	16.43	17.03	17.82	81.77
Post Doctorates	5.70	6.00	6.31	6.54	6.84	31.39
Graduate Students	6.00	6.00	6.00	7.00	7.00	32.00
Other Salaries	7.43	7.82	8.22	8.51	8.91	40.89
Supplies	6.45	6.79	7.14	7.40	7.74	35.52
Equipment	2.33	2.45	2.57	2.67	2.79	12.81
Travel	8.40	8.85	9.30	9.63	10.08	46.26
Other Direct Costs	5.78	6.08	6.39	6.62	6.93	31.80
Overhead	18.30	19.28	20.25	20.98	21.96	100.77
	75.24	78.91	82.61	86.38	90.07	413.21

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=NE116 -- ----------						
Post Doctorates	14.70	15.44	16.21	17.02	17.87	81.23
Other Salaries	4.73	4.96	5.21	5.47	5.74	26.11
Fringe Benefits	4.10	4.30	4.51	4.74	4.98	22.63
Supplies	2.63	2.76	2.89	3.04	3.19	14.50
Equipment	4.50	4.72	4.96	5.21	5.47	24.86
Travel	9.45	9.92	10.42	10.94	11.49	52.22
Other Direct Costs	5.25	5.51	5.79	6.08	6.38	29.01
Overhead	15.03	15.78	16.57	17.40	18.27	83.05
	60.38	63.39	66.56	69.89	73.39	333.61

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=NE116 -- ----------						
Post Doctorates	14.00	14.00	14.00	14.00	14.00	70.00
Other Salaries	4.50	4.50	4.50	4.50	4.50	22.50
Fringe Benefits	3.90	3.90	3.90	3.90	3.90	19.50
Supplies	2.50	2.50	2.50	2.50	2.50	12.50
Equipment	4.29	4.29	4.29	4.29	4.29	21.43
Travel	9.00	9.00	9.00	9.00	9.00	45.00
Other Direct Costs	5.00	5.00	5.00	5.00	5.00	25.00
Overhead	14.32	14.32	14.32	14.32	14.32	71.58
	57.50	57.50	57.50	57.50	57.50	287.50

-116

Mechanisms of Environmental Stress Resistance in Sorghum and Millet

Project UNL-123
Charles Y. Sullivan
University of Nebraska

Collaborating Institutions

Host Country

Mali

Dr. Moussa Traore, IER, INTSORMIL-MALI Coordinator, Bamako, Mali
Dr. Oumar Niangado, IER, Director, Cinzana Research Station, Mali.

U.S.

Dr. Jerry Maranville, University of Nebraska
Dr. John Leslie, Kansas State University
Bekaye Coulibaly and Siriba Dione, Graduate Students at University of Nebraska from Mali.

Project Objectives

Define plant physiological characteristics which are most affected by drought and high temperature stress and identify mechanisms which may be selected or managed for improved stress resistance.

Develop and implement practical selection techniques for genotypes with desirable physiological responses, and identify cultural methods which will improve yield or yield stability in stressful situations.

Introduction

Drought, which is often accompanied by high temperatures, is a major constraint to crop production in many developing countries. Plant breeding programs have had some success in improving plant performance in these stressful environments, but the progress has been slow and an understanding of the mechanisms involved in improved stress resistance are completely lacking. This is partly due to the fact that yield and adaptation to stress both involve quantitative inheritance factors which vary with relatively small changes in the timing and intensity of the stress. One of the difficulties in using empirical methods to improve productivity in stressful environments is the lack of knowledge on which mechanisms to improve on, and they may change from year to year and differ in different areas of the country.

This project will be concerned with identification and manipulation of various mechanisms which contribute to growth, adaptation, resistance, and productivity of local and introduced genotypes. It is expected that expression of certain mechanisms will be more prominent when the stress is more severe or when it occurs at different stages of plant development. The project will also strive to define a stress index so the magnitude of stress that the plants have experienced at any point of time can be defined.

Objectives Planned to Work On

Define root growth and development as related to stress, including deep rooting.

Define leaf appearance and leaf area with time and relate to plants grown with minimal or nonstressed conditions.

Assess ability to osmotically adjust when exposed to stress and correlate with heat and desiccation tolerance as measured by membrane stability.

Evaluate stomatal responses to stress, maintenance of photosynthesis, and relate to stress avoidance.

Study effects of abscisic acid (ABA) and other growth substances on germination, stand establishment, tolerance to desiccation, partitioning of photosynthate, and development of screening techniques for differences in natural endogenous levels of ABA.

Field evaluate stress resistance of introduced and domestic genotypes using infrared thermometry to measure leaf temperatures as a general evaluation of stress avoidance.

Measure crop evapotranspiration and relate to physiological mechanisms of stress resistance, water use efficiency, and genotype differences in sustainable production.

Investigate effects of cultural practices and fertility levels on physiological responses to environmental stress responses of different genotypes.

Develop a stress index for different stages of growth and development for defining current stress levels and prediction of effects on final yield.

Host Country Collaboration and Sites of Research

Collaboration will be primarily with Mali, under the direction of Moussa Traore, Malian principal investigator, who has jointly planned the physiological research to be conducted in Mali with the U.S. principal investigator. Selections from the Collections of Sorghums and Millets of Mali (CSM and CMM) will be grown at three sites in Mali: Samanko, Cinzana, and Koporo, and Bema which represent, respectively, on the average 900, 650, 400 and 300 mm precipitation annually. Plantings will also be made in Bema for testing under more severe drought stress conditions. It is also planned that development of the station at Same near Kayes for INTSORMIL use will facilitate stress research. This station was until recently operated cooperatively by Mali, Senegal and Mauritania, but is now controlled entirely by Mali.

Some selections from the Nebraska program will also be included in these plantings, which have been identified as having some desirable stress resistance characteristics. The sorghums and millets grown at these three locations will be investigated for resistance mechanisms in terms of those that cause escape, avoidance, or tolerance to the stress.

Included in the studies will be Malian sorghums and millets which have previously been investigated for root development, desiccation and heat tolerance, ability to osmotically adjust, maintenance of photosynthesis, stomatal response and responses to exogenously applied ABA, which in some cases significantly increased their drought resistance, yield, and harvest index. These genotypes will serve as references for other genotypes being investigated.

Research procedures.

In the field a general evaluation of drought resistance will be made on selected genotypes which will be partially irrigated or grown on dryland. Leaf number and leaf area development will be recorded periodically. The infrared thermometer will be used to scan these entries for leaf or canopy temperatures. Maintenance of cool leaves will indicate avoidance of stress. On contrasting types, stomatal diffusive resistance, water potentials and osmotic potentials will be measured. Turgor potentials will be calculated. Leaf rolling will be assessed and epicuticular wax levels measured on selected genotypes.

Generally, plants will be measured during the vegetative, floral and grain filling stages. Measurements will be made more frequently as stress severity increases.

Photosynthesis and respiration rates will be measured and related to other field stress responses. Shoot dry weights, grain yields, and yield components will also be recorded. Neutron accessed tubes will be placed in selected field locations and neutron gauges will be employed for determination of soil water status and use. General meteorological data will be recorded with automatic dataloggers for definition of the environment.

Nodal length and leaf area will be measured on a regular basis on selected genotypes, including malian locals, when grown on dryland and fully irrigated soils. This and other growth and physiological data will be used to develop a stress index for different locations and environmental conditions.

We previously found that presoaking sorghum seeds in ABA solutions increased germination, and markedly increased seedling desiccation tolerance. Since seedling emergence and stand establishment is a major problem in Mali and other drought prone countries, the potential beneficial effects of ABA presoaked seeds will be tested under variably stressful conditions. In Nebraska a rainout shelter will be used to protect from possible rains during the experiments.

In other experiments, the effects of ABA presoaked seed on grain yield of drought stressed plants will be tested. Previous results have shown increased yields with some genotypes with added ABA, and the drought stressed areas of Mali will be ideally suited for testing the response of this treatment. Concomitantly plants will be tested for similar response under controlled conditions In Nebraska. Also in Nebraska, genotypes will be assayed for endogenous levels of ABA. There have been indications that the highly drought resistant Malian sorghums have naturally higher levels of ABA prior to the onset of drought stress.

Root growth and development will be studied in hydroponic cultures and the results related to field responses. Drought stress will be slowly imposed by water depletion. Selected Malian and U.S. genotypes will be assessed for depth of rooting, numbers of roots, root branching, rate of root growth, function of upper and lower roots, and cellular tolerance to stress. Water use and water use efficiency will be measured. Plants grown from seeds presoaked in ABA solutions will also be evaluated for possible differences in root growth and effects on water use and water use efficiency.

Measures of success

The project will be considered successful if several important mechanisms of sorghum and millet, that are grown in the harsh environment of the sub-Sahara, are identified that contribute to their high levels of heat and drought resistance.

Development of pools of genotypes with specifically identified resistance mechanisms which may be incorporated into other higher yielding, disease and insect resistant, types by plant breeding techniques may also be a measure of success.

Demonstrating the ability to increase yields of field drought stressed plants by manipulation of a growth substance (ABA) may also indicate a measure of success, but ultimate success will be realized only when the results of experimentation are reflected in increased productivity of sorghum and millet under stressful conditions.

Also, the development of a stress index which is applicable to local conditions will be exceedingly useful in evaluating current plant performance and in predicting ultimate production.

Reports and articles anticipated

It is anticipated that at least one journal article and two reports will be completed annually during the period of the project.

General comments

The enthusiasm of the scientists in the collaborating country is very high. There is strong desire to increase their knowledge of plant response to environmental stress which surrounds them, while continuing efforts to solve practical problems in production. There is a realization that problem solving is best done when knowledge of the system is at maximum. A considerable amount of equipment has been acquired for use is the collaborating country which is necessary to successfully conduct the proposed research. Additional equipment and supplies will be purchased from project funds as needed to conduct the research.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: Mechanisms of Environmental Stress Resistance in Sorghum and Millet

Project Leader: Charles Sullivan **Project Number:** UNL-123

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=UNL123 -- ----------						
Staff Salaries & Benefits	14.85	15.64	16.43	17.03	17.82	81.77
Post Doctorates	5.70	6.00	6.31	6.54	6.84	31.39
Graduate Students	6.00	6.00	6.00	7.00	7.00	32.00
Other Salaries	7.43	7.82	8.22	8.51	8.91	40.89
Supplies	6.45	6.79	7.14	7.40	7.74	35.52
Equipment	2.33	2.45	2.57	2.67	2.79	12.81
Travel	8.40	8.85	9.30	9.63	10.08	46.26
Other Direct Costs	5.78	6.08	6.39	6.62	6.93	31.80
Overhead	18.30	19.28	20.25	20.98	21.96	100.77
	75.24	78.91	82.61	86.38	90.07	413.21

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=NE123 -- ----------						
Grad Students	7.56	7.94	8.33	8.75	9.19	41.77
Other Salaries	2.63	2.76	2.89	3.04	3.19	14.50
Fringe Benefits	2.04	2.14	2.25	2.36	2.48	11.26
Supplies	3.59	3.77	3.96	4.15	4.36	19.83
Equipment	4.10	4.30	4.51	4.74	4.98	22.63
Travel	3.15	3.31	3.47	3.65	3.83	17.41
Other Direct Costs	5.25	5.51	5.79	6.08	6.38	29.01
Overhead	5.82	6.11	6.42	6.74	7.07	32.15
	34.13	35.83	37.62	39.50	41.48	188.56

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=NE123 -- ----------						
Grad Students	7.20	7.20	7.20	7.20	7.20	36.00
Other Salaries	2.50	2.50	2.50	2.50	2.50	12.50
Fringe Benefits	1.94	1.94	1.94	1.94	1.94	9.70
Supplies	3.42	3.42	3.42	3.42	3.42	17.09
Equipment	3.90	3.90	3.90	3.90	3.90	19.50
Travel	3.00	3.00	3.00	3.00	3.00	15.00
Other Direct Costs	5.00	5.00	5.00	5.00	5.00	25.00
Overhead	5.54	5.54	5.54	5.54	5.54	27.71
	32.50	32.50	32.50	32.50	32.50	162.50

Technology Evaluation for Profitablity, Sustainability and Farmer Acceptance

Project PRF-105
John H. Sanders
Purdue University

Collaborating Institutions

Host Country:

Dr. Kimsey Savadogo, University of Ouagadougou, Burkina Faso
Dr. Taladidia Thiobiano, Univeristy of Ouagadougou, Burkina Faso
National Agricultural Research Organization (INERA, Burkina Faso
Onchocerciasis Control Program Burkina Faso
Dr. Hamed Fakki, ARC Economist, Sudan
Dr. Daniel Meckenstock, Zamorano-INTSORMIL, Honduras
Dr. Leopoldo Alvarado, MNR, Honduras
Dr. Francisco Gomez, MNR, Honduras
Mr. Maliki Kadi, DECOR, INRAN, Niamey, Niger
Dr. Akin Adesina, ICRISAT, Bamako, Mali

U.S.

Dr. John H. Sanders, Agricultural Economics, Purdue University, West Lafayette, IN
Dr. Timothy G. Baker, Agricultural Economics, Purdue University, West Lafayette, IN
Mr. Mohamed Ahmed, ARC Economist, Purdue University, West Lafayette, IN
Mr. Mohamed K. Habash, Agricultural Economics, Purdue University, West Lafayette, IN
Mr. Miguel Lopez-Pereira, Agricultural Economics, Purdue University, West Lafayette, IN
Mr. Sunder Ramaswamy, Economics, Purdue University, West Lafayette, IN
Mr. Barry I. Shapiro, Agricultural Economics, Purdue University, West Lafayette, IN
Mr. Tennassie Nichola, Agricultural Economics, Purdue University, West Lafayette, IN
Dr. Gebisa Ejeta, Breeder, Purdue University, West Lafayette, IN
Dr. Walter Butcher, Agricultural Economics, Washington State University

Project Objectives

Evaluate the economic and sustainability impacts of different new technologies at the farm level and identify the farm-level constraints to new technology introduction.

Evaluate the farm-level impacts of alternative agricultural policies for their effects on technology introduction and on the sustainability of these production systems.

Collaborate with other agricultural scientists in evaluating characteristics of new cultivars and in identifying other constraints relevant to the technology development process.

Estimate the economic and sustainability impacts of new INTSORMIL technologies in various regions.

Identify and evaluate the economic factors involved in marketing new sorghum/millet cultivars and new products from these cereals.

Objectives of Research

New technology evaluation utilizing farm-level modeling.

Integrating a sustainability component into the farm-level analysis.

Expansion of the project into marketing concerns with new cultivars and new sorghum/millet products.

As technologies are successfully introduced, quantifying their regional and national impacts.

Host Country Collaboration and Work Sites

Sudan

One principal research focus is on new technology introduction into the Sudan. This research is coordinated with the Economics Unit of the ARC. The field research is concentrated in the principal rainfed cereal production region of the Sudan.

Niger

Two Ph.D. theses have been done (one to be finished in December 1989) on new technology introduction in rainfed regions of Niger. Further synthesis work integrating these theses with the results from the large cereal research contract is now being undertaken.

Honduras

A Ph.D. thesis will be completed shortly on new technology introduction in southern Honduras. This research is concerned with a critical sustainability problem of developing economic alternatives for small farmers on the fragile hillsides.

Burkina Faso

The principal institutional contacts are with the University of Ouagadougou and secondly with INERA, the national agtricultural research institute. Substantial farm modeling has already been undertaken on the Central Plateau. This activity is now being extended into the Southwest and into the highly fertile river vallleys, recently cleared of river blindness. Institutional collaboration is also underway with the Onchocerciasis Control Program in Ouagadougou.

Mali

Future activity: ICRISAT located a new sorghum team in Mali in 1988, including an agricultural economist recently graduated from Purdue (Akin Adesina). We will utilize this contact to explore new activities there.

Research Procedures

Farm-level modeling is supplemented with survey data when there are sufficient other national financial resources. The basic research procedure is to incorporate various new technologies into the farm models to evaluate their potential effects on farm incomes and to identify the impact of various constraints in impeding the introduction of these new technologies. Mathematical programming incorporating risk can be utilized to analyze the potential effects of new technologies and alternative agricultural policies. This is a low-cost method of technology evaluation which is less data-demanding than econometric analysis. In Niger, Honduras, and Sudan, Shapiro, Lopez-Pereira, and Habash have been able to obtain other financial resources to undertake farm interviewing. This interviewing provides more reliable estimates for the farm modeling and expands the scope of the research. The supplementary resources enable this project to look at other farm-level constraints in more detail, such as farmers' objectives, credit, farm-size differences in technology adoption, regional variations in technology performance, and alternative agricultural policies.

Over time, as technologies become successful, there will be more efforts to quantify the costs and benefits of the successful technologies at a national level.

Also there is increasing interest from INTSORMIL researchers in quantifying the marketing factors associated with new cultivars, new processes, or new types of utilization of sorghum and millet. So this will become a more important activity over time.

Measurement of Success

The most concrete measurement is through finished theses, technical papers, and journal articles.

Integration with national programs: Obtaining supplementary funds for field research and increased collaboration with national researchers are both indicators of successful performance.

Impact on INTSORMIL scientists: This may be the most important function of economic research on new technologies. The other INTSORMIL national and international scientists continue to be one of our most important audiences. Measurement may be most appropriate through published articles and technical bulletins directed to this clientele.

Progress (last two years)

For Burkina Faso, three journal articles report the results of new technology evaluation. Those results have been widely disseminated in conferences and informally. Several more articles are in progress. A report was made to the West Africa Division of the World Bank on new technology development in Burkina and Niger.

In Niger, a Ph.D. thesis was completed in 1988 evaluating new technologies tested in the farm trials of DECOR-INRAN. These farm trials involve the collaborative efforts of agricultural scientists of INRAN and the economists of INRAN and Purdue. Ultimately, the new cultivars and improved agronomic practices associated with INTSORMIL scientists will also be in-

tegrated into these farm trials. Meanwhile, the economic component is being incorporated into this analysis and farmer decision-making studied. Moreover, useful feedback from the economic analysis is being provided to the agricultural researchers of INRAN and INTSORMIL. A second Ph.D. thesis on this same subject, reflecting 18 months of fieldwork in Niger, is almost finished.

Eight months of fieldwork on new technology introduction in southern Honduras has been finished and this Ph.D. thesis will be completed shortly. It will estimate the farm-level impact of new sorghum cultivars and other improved agronomic practices.

A main research area in 1989 has been the vertisol region of the Sudan. Two theses will be completed by the end of 1989 on the introduction of new technologies into this region.

Success Stories

Since 1973 there has been concentration in Sahelian agricultural technology development on breeding to resolve all problems without increasing the expenditures of low-income farmers on purchased inputs. This strategy has not been successful in producing new cultivars of sorghum and millet adopted by farmers. Reviewing the results from a large number of farm trials over three years has shown the consistent high returns and risk-reducing nature of introducing the combined agronomic measures of water-retention techniques and soil-fertility improvements. These practices also increase the sustainability of these agricultural systems. New cultivars then have a higher probability of success if introduced into these improved agronomic environments.

Further field research showed the rapid introduction of some of these improved agronomic practices in the Central Plateau of Burkina Faso and helped identify the seasonal labor constraint to water-retention techniques undertaken during the crop season. One method to overcome this seasonal labor constraint is with the introduction of animal-traction implements. The economic analysis also considered the profitability of this innovation.

In 1987 the fieldwork in Burkina documented a critical problem for technology introduction in the Sahel. In good weather years the sorghum/millet prices collapse. Then farmers lose interest in technology introduction and public officials and researchers in cereal-technology production. Sahelian public policy needs to include a policy instrument to moderate or cushion these price collapses. Research on improved cereal technology is a long-run process.

Field data and economic evaluations in Niger, Sudan, and Honduras are enabling an improvement in understanding of the technology-development processes in different agro-economic environments. The benefits of the sorghum-breeding program are being estimated on farmers' fields in southern Honduras. In Niger the returns to technology improvement of both new cultivars and improved agronomy have been estimated for the sandy-dune soils.

Benefits to U.S. and L.D.C. Agriculture

The principal benefit to LDC agriculture is the field-level documentation of the progress of the agricultural scientists in INTSORMIL and the national research centers in producing technologies which farmers adopt. There are always many claims in the process of developing technologies. It is critical that the benefits of the new technologies be quantified and that the constraints to farmer introduction be identified.

Specific output of the program for LDCs:

Estimates of returns to the combined water-retention/soil-fertility increasing innovations in Burkina Faso and Niger.

Identified problems of the breeding strategy in the Sahel.

Recommendtions for research in agronomy and physiology in the Sahel.

Estimates of the economic impacts of new sorghum cultivars in Honduras.

Identification of constraints to new cultivar introduction in the vertisol regions of the Sudan.

One of the principal benefits to LDC agriculture is the training of graduate students who can work with agricultural scientists and LDC farmers in evaluating the farm-level impacts and the constraints to the introduction of new technologies.

As developed countries become middle-income countries, such as Brazil, Mexico, Portugal, Spain, Taiwan, and South Korea, rapid economic and agricultural growth lead to even more growth in dietary improvements. Their consumers demand more livestock products, fruits, and vegetables. Hence, agricultural imports of feedgrains and these other products accelerate. Ultimately the poorest countries will enter this phase and U.S. agricultural exports to them will rapidly increase.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: Technology Evaluation for Profitability, Sustainability and Farmer Acceptance

Project Leader: John Sanders **Project Number:** PRF-105

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=PRF105	--	----------				
Staff Salaries & Benefits	15.84	16.63	.7.42	18.22	19.21	87.32
Post Doctorates	6.08	6.38	6.69	6.99	7.37	33.51
Graduate Students	6.00	6.00	7.00	7.00	7.00	33.00
Other Salaries	7.92	8.32	8.71	9.11	9.60	43.66
Supplies	6.88	7.22	7.57	7.91	8.34	37.92
Equipment	2.48	2.60	2.73	2.85	3.01	13.67
Travel	8.96	9.41	9.86	10.30	10.86	49.39
Other Direct Costs	6.16	6.47	6.78	7.08	7.47	33.96
Overhead	19.52	20.50	21.47	22.45	23.67	107.61
	======	======	======	======	======	=======
	79.84	83.53	88.23	91.91	96.53	440.04

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=PRF105	--	----------				
Grad Students	38.65	40.58	42.61	44.74	46.97	213.55
Other Salaries	6.09	6.39	6.71	7.05	7.40	33.65
Fringe Benefits	7.54	7.91	8.31	8.73	9.16	41.65
Travel	5.73	6.02	6.32	6.64	6.97	31.68
Overhead	25.99	27.29	28.66	30.09	31.59	143.63
	======	======	======	======	======	=======
	84.00	88.20	92.61	97.24	102.10	464.15

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=PRF105	--	----------				
Grad Students	36.81	36.81	36.81	36.81	36.81	184.03
Other Salaries	5.80	5.80	5.80	5.80	5.80	29.00
Fringe Benefits	7.18	7.18	7.18	7.18	7.18	35.90
Travel	5.46	5.46	5.46	5.46	5.46	27.31
Overhead	24.76	24.76	24.76	24.76	24.76	123.78
	======	======	======	======	======	=======
	80.00	80.00	80.00	80.00	80.00	400.00

Crop Utilization and Marketing

Physical, Chemical, and Nutritional Aspects of Sorghum Utilization

Project PRF-103B
Allen W. Kirleis
Purdue University

Collaborating Institutions

Host Country

Drs. Sitt Badi and Laila Monawar, ARC Food Research Centre, Khartoum North, Sudan
Dr. Osman El Obeid Ibrahim, Sorghum Breeder, Gezira Research Station, Wad Medani, Sudan
Dr. Abdel-Mageed Mohamed, Lecturer in Food Technology, University of Gezira, Wad Medani, Sudan
Moussa Oumarou, INRAN Chemist, Niamey, Niger
Issoufou Kapran, INRAN Sorghum Breeder, Maradi Research Station, Niger
Dr. John Clark, NAAR Sorghum Breeder, Kolo Research Station, Niger
Dr. Arun Chandrasekhar, Central Food Technological Research Institute, India
Dr. R. Jambunathan, Head Biochemistry Section, ICRISAT, India
Dr. Knud Erik Bach Knudsen, National Institute of Animal Science, Foulum, Denmark

U.S.

Drs. John Axtell, Larry Butler, Gebisa Ejeta, and John Sanders, Purdue University, West Lafayette, IN
Dr. Lloyd Rooney, Texas A&M University, College Station, TX
Ronald Tribelhorn, Colorado State University

Project Objectives

Develop screening procedures for use in LDC breeding programs to evaluate sorghum/millet food quality.

Conduct basic studies to determine what grain components are related to good processing, food, and nutritional qualities of sorghum/millet.

Identify sorghum grain processing and cooking procedures that lead to improved protein and food quality by using both chemical and biological methods.

Train LDC personnel in cereal chemistry.

Introduction

Food Quality: In the developing world sorghum and millet are used for food in many different ways. Therefore, no single criteria for grain quality is universally satisfactory. Furthermore, useful definitions for food quality cannot be developed without a good understanding of indigenous grain utilization methods. During the last ten years, considerable new information on traditional sorghum and millet foods, and on grain properties required to produce good quality food products has been determined by collaborative efforts among research groups around the world. However, many of our current definitions for sorghum and millet food quality are based on empirical knowledge without an adequate understanding of the biochemical basis of food quality.

In both Sudan and Niger sorghum vitreousness (proportion of vitreous to opaque endosperm) has been used to screen early generation material from the national breeding programs for quality. At the present time, quality of advanced breeding lines are evaluated by conducting full-scale milling and food preparation tests. While good progress is being made using grain vitreousness to evaluate early generation material, full-scale testing procedures are slow and laborious. Thereby limiting the number of samples that can be evaluated for quality. Accordingly, until rapid techniques are developed for intensive quality screening of advanced breeding lines most agronomically improved cultivars will continue to have poor quality compared to the lower yielding locals.

In order to develop a more useful quality testing program for advanced breeding lines in Sudan and Niger it will be necessary to establish relationships between currently available micro testing methods and consumer acceptability of local sorghum/millet foods. As the quality testing program progresses new testing methods must be developed. This will require the identification and characterization of the biochemical components in

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the grain that are directly related to end-use quality. This information will also be useful when developing new food and non-food uses for sorghum and millet.

Protein Quality: Sorghum proteins react differently than the proteins from other cereals when heated. Their digestibility is most negatively affected by cooking compared to other cereals. We have found that the storage proteins or kafirins make up the majority of the indigestable proteins in cooked sorghum preparations. We know that when sorghum proteins are cooked an extensive amount of intermolecular crosslinking occurs by formation of disulfide linkages and that sorghum gruels can be made substantially more digestible by cooking with a reducing agent. We have proposed a theory to explain why kafirins are less digestible after cooking. We believe the lowered digestibility may simply be caused by the inaccessibility of the protein bodies to enzymatic attack. Protein bodies are well defined structures found in sorghum endosperm that contain kafirin proteins. By scanning electron microscopy, it was found that protein bodies remain intact after cooking and are even present after pepsin digestion. It is possible, that cooking makes the protein body kafirin more resistant to digestion by formation of a disulfide-bound protein polymers produced by 1) interaction of proteins surrounding the protein body, 2) interaction between proteins surrounding the protein body and the protein body kafirins, or 3) an intraaction of the protein body kafirins. Work is needed to identify the specific proteins responsible for lowering the protein digestibility of cooked sorghum. With this information it should be possible to develop processing methods that result in highly digestible sorghum foods or alter the expression of genes encoding these proteins.

Mutations have been identified that cause a reduction in kafirin protein synthesis in sorghum. One of these, P-721 opaque, causes about a 50% reduction in kafirin proteins compared with the normal genotypes. This mutation results in grain with high lysine content and a very floury or soft endosperm. The floury endosperm character of the high lysine grain has limited its usefulness. Dr. John Axtell is developing modified quality protein sorghums which are both high lysine and vitreous or hard endosperm types. We will screen the quality protein sorghums for hardness and identify the proteins related to grain hardness in these lines. As malnutrition is common in the sorghum consuming regions of the world, the potential benefits for improving sorghum protein digestibility and quality is great.

Objectives Related To Constraints

a. Develop rapid laboratory procedures to evaluate the traditional food (kisra and tuwo) qualities of advanced sorghum breeding material. Kisra is a fermented flat bread and tuwo is a thick porridge consumed daily in Sudan and Niger, respectively.

b. Conduct consumer surveys in Niger to determine the major grain characteristics of millet that affect food quality and price differentials.

c. Establish the relationship between proteins made in developing sorghum endosperm and the vitreous or hard characteristics of mature seeds.

d. Determine the protein interactions that take place during cooking that are responsible for the poor protein digestibility of sorghum gruels.

Host Country Collaboration and Work Sites

Objectives a, and b will require close collaboration with INTSORMIL/LDC programs in Sudan and Niger, respectively. Collaboration will include working with both plant breeders and cereal chemists in order to develop an integrated quality improvement program in these countries. Past LDC linkages established in India (ICRISAT and CFTRI) will be continued but our efforts will be concentrated in West and East Africa. Objectives c and d will primarily be done at Purdue University, West Lafayette, IN.

Research Procedures

* Evaluating sorghums for kisra making quality. In Sudan the major staple sorghum food is a fermented flat bread called kisra. Experienced kisra bakers can reliably predict finished product acceptability by running their hands through a fermented kisra batter. We believe their predictions are based on the consistency and smoothness of the fermented batter. We are, therefore, evaluating the usefulness of measuring the consistency of fermented sorghum batters for determining the kisra making quality of sorghum. Preliminary results with a Bostwick consistometer have been promising. The reliability of this technique must, however, be confirmed with field data from Sudan on a large number of sorghum samples. This work will be done collaboratively with Drs. S.M. Badi and O. Elobeid Ibrahim in Sudan.

Evaluating sorghums for tuwo making quality. Tuwo is a thick sorghum porridge consumed in Niger. A number of simple laboratory gel and hardness tests, have been suggested for evaluating sorghums for porridge quality. As grain quality evaluation procedures are time consuming compared to agronomic rating techniques used by breeders there is a need to limit the number of laboratory quality tests when evaluating breeders samples. We must, therefore, determine which of the currently available grain quality tests are related to consumer acceptability of tuwo. This will be done by cor-

relating sensory analysis rating with laboratory quality test results. The sensory work will be done with Nigerien tuwo consumers in collaboration with Moussa Oumarou, Issoufou Kapran, and Dr. John Clark in Niger.

* Millet quality surveys. Consumer preference surveys will be conducted in Niger to collect data on the major grain characteristics of millet that affect food quality and market price. Information on price differentials according to cultivar quality characteristics should be very useful for establishing a millet quality evaluation program in Niger.Moussa Oumarou and Dr. John Sanders will collaborate on this objective.

* Characterization of hard and soft endosperm proteins. A procedure for quantitative extraction of endosperm proteins will be used on hard, intermediate, and soft sorghums. Qualitative differences in proteins will be determined by SDS polyacrylamide gel electrophoresis. We will also separate the most vitreous from the floury parts of the endosperm by manual dissection for comparison of proteins found in these regions. Since we can establish which proteins of the total arise from various subcellular fractions, this should provide an indication of which proteins are associated with vitreous regions of the endosperm.

To determine if kernel hardness is correlated with the amount and type of storage proteins present in the protein bodies we will quantitate the levels of the these proteins among the different sorghums studied. This can be done by using antisera against each type of protein in the protein body to measure its relative level. We are currently preparing antisera for the protein body kafirin proteins and will later develop an enzyme-linked immunoabsorbent assay (ELISA) that will allow us to quantitate these proteins.

While there may not be a correlation in the total amount of specific proteins among genotypes differing in kernel hardness, there could be differences in the distribution of these proteins within the endosperm. Therefore, in addition to measuring the amounts of specific kafirin proteins among the different sorghum genotypes, we will also examine the distribution of these proteins in various regions of the endosperm. For this analysis, endosperms at middle to late stages of development will be fixed and analyzed by light microscopy. The distribution of zein proteins will be determined immunologically.

We are in the process of crossing several genotypes that synthesize large amounts of the high cysteine-containing proteins (Mr 16 and 30 kD) into soft endosperm genotypes to determine if there are high levels of these proteins in the enotypes and whether or not they elicit a harder endosperm phenotype. This approach can be used in both normal and quality protein sorghums. This should eventually lead to the ability to genetically control kernel hardness by either conventional or genetic engineering techniques.

* Protein digestibility. The storage proteins of sorghum or kafirins were found to be the least digestible in cooked sorghum preparations when assayed with an in vitro pepsin system. The in vitro digestibility of these proteins can be substantially increased by cooking with a sodium bisulfite ($NaHSO_3$) solution. Our in vitro findings will be confirmed in an in vivo system using rats. However, the bisulfite level used to improve in vitro protein digestibility exceeds the chronic toxicity level for rats. Therefore, a means of detoxifying the residual bisulfide in the cook sorghum must be used. We propose to do this by using hydrogen peroxide to oxidize the residual bisulfite to a non-toxic sulfate form.

To examine the protein digestibility of intact protein bodies we will isolate free and matrix bound protein bodies from developing seeds at 40 days post anthesis. Quantitative and quantitative differences in protein present in these two types of protein bodies will be determined by SDS- polyacrylamide gel electrophoresis and ELISA procedures. Pepsin in vitro protein digestibility will be determined on the two types of isolated protein body before and after cooking using a model system consisting of 10% protein and 90% starch. These experiments should provide an indication of whether there are significant differences in the type of protein body kafirins that correlate with digestibility.

To determine which proteins are interacting during cooking and their effect on protein digestibility sorghum flour will be cooked, digested with pepsin, and subjected to gel filtration chromotography. We will quantitate the kafirin content of the fractions collected from the column using the ELISA technique. The indigestible protein residues will also be examined by SDS polyacrylamide gel electrophoresis for the possible involvement of other non-kafirin proteins.

Measures of Success

All of the project objectives are long term. A basic understanding of the structure and function of sorghum grain components relative to food quality will provide the necessary information for developing simple and useful screening tests to evaluate quality. Thus, success for objectives a, and b, can be measured by our ability to develop reliable procedures for measuring food quality (short term) and for our LDC collaborators to use these procedures for screening sorghum lines from their national breeding programs (long term).

Objective c, and d addresses the biochemical basis of food and nutritional quality of sorghum. An under-

standing of the processing and cooking conditions which produce a more nutritious sorghum food addresses the malnutrition problem in LDC's. Identifying processing and cooking technologies that lead to sorghum foods with better protein digestibility would be considered a measure of short term success. However, until the newly developed technologies are in use in LDC's, real success will not be achieved.

Anticipated reports and Articles

Research findings will be published in scientific journal articles.

Research reports will be written on the food quality work in Sudan and Niger.

Progress (last two years)

Human feeding studies indicate that some foods prepared from sorghum have poor protein digestibility compared to the same type of food made with other cereal grains. We have therefore, 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 storage proteins, how they react when cooked, and how protein associations may influence protein digestibility.

We have found that the protein digestibility of sorghum depends on the method and/or conditions under which the grain is prepared and cooked. The protein digestibility of a heat extruded decorticated sorghum was found to be much improved compared to the digestibility of a sorghum gruel when fed to children. In addition we have shown that a traditional Sudanese fermented sorghum food called nasha had protein digestibilities similar to maize and higher than rice and potato. This indicates that appropriate processing, either modern or traditional, can make sorghum a satisfactory food. In fact with lysine supplementation nasha is a satisfactory weaning food.

Using an *in vitro* pepsin digestibility method to estimate sorghum protein digestibility we found that digestibility decreased significantly after cooking. This indicated that cooking alters some of the sorghum proteins to make them less digestible. Recently we showed that cooking preferentially decreased the pepsin digestibility of the alcohol soluble storage proteins in sorghum called kafirins. During cooking an extensive amount of inter-molecular crosslinking occurs in sorghum proteins this can be prevented when sorghum is cooked with a reducing agent. Furthermore, the addition of a reducing agent, such as 2-mercaptoethanol, dithiothreitol, or sodium bisulfite, to the sorghum before cooking results in little or no decrease in *in vitro* protein digestibility. As malnutrition is not uncommon in the sorghum consuming regions of the world, the potential benefit from these findings could improve the nutritional status of poor people in the semi-arid tropics.

Our work on protein digestibility has also contributed to a better understanding of the kafirin proteins of sorghum. The kafirin proteins are located in structures found in the endosperm called protein bodies and constitute approximately 50% of the protein in sorghum. These proteins can be separated into several groups based on differential solubility in alcohol in the presence or absence of reducing agents. We have used antibodies made against the zein proteins from maize to identify the presence of alpha, beta and gamma type kafirins in sorghum. The gamma zeins are highly cross-linked by disulfide bonds and cannot be extracted in the absence of reducing agents. These proteins are also capable of forming disulfide linkages with other proteins and, therefore, could provide the mechanism that causes sorghum protein digestibility to decrease during cooking. While at present we have only indirect evidence that this occurs, work is underway to determine how heating changes the gamma-kafirins and to analyze their disulfide cross-linking patterns.

The nutritional properties of sorghum flour and traditional sorghum porridges were evaluated in balance trials with rats. These studies confirmed our *in vitro* results by showing that sorghum protein digestibility was significantly reduced by cooking. Cooking also decreased the digestible energy of the porridge diets compared to the flour diets. The lower energy digestibility of cooked sorghum porridge compared to uncooked flour was due to a higher excreation of carbohydrate (resistant starch) and protein in the feces. The nutritional implications of resistant starch and its interaction with protein in sorghum based foods is not well understood and will be studied in the future.

In collaboration with Moussa Oumarou (INRAN, Niger), Jeannette Shull (Peace Corp Volunteer, Niger) and John Clark (NCRP/INRAN, Niger) we published a "Sorghum Quality Laboratory Manual for Use in West Africa". The manual is a comprehensive edition of the most useful methods for evaluating the inherited properties of sorghum that contribute to its processing and food quality. Sections on physical, chemical and food quality testing methods are included in the manual as well as a section describing traditional West African dishes made from sorghum. The manual is available from Purdue University in both English and French.

Success Stories

In 1987 we published a "Sorghum Quality Laboratory Manual for Use in West Africa." The publication resulted from collaborative effort by a number of

projects and individuals which include Moussa Oumarou (INRAN, Niger), Jeannette Shull (U.S. Peace Corp volunteer posted in Niger), John Clark (NCRP/INRAN, Niger) and Allen Kirleis (Purdue University). The manual is a comprehensive edition of the latest methods for evaluating the inherited quality properties of sorghum that contribute to its processing and food qualities Procedures for analyzing physical, chemical, and food making properties of sorghum as well as a section describing traditional West African sorghum dishes are given in the manual. The manual is available from Purdue University in both English and French. The manual is being used by a number of LDC laboratories at the present ime.

Our work on the sorghum storage proteins called kafirins has provided useful information about food quality and nutritional value of the grain. We found that the amount of kafirin protein in the endosperm is associated with the hardness of the grain. Grain hardness has a direct influence on the milling and food making properties of sorghum. Harder sorghums give higher decorticated grain yields when milled and make better quality porridges. We also know that the kafirin proteins are a major factor in sorghum protein digestibility. After cooking the kafirin protein are the least digestible protein fraction and may be responsible for the changes that occur during cooking that make sorghum protein digestibility low compared to other cereal proteins.

We have identified a number of techniques for improving the protein digestibility of sorghum. These include heat extrusion, natural fermentation, and treatment with reducing agents. As we develop a better understanding about the chemical changes taking place during cooking which decrease sorghum protein digestibility other techniques to improve protein digestibility can be developed.

Benefits to U.S. and LDC Agriculture

Compared to wheat, maize, and rice relatively little effort has gone into the improvement of sorghum as a human food. As a result in many parts of the world sorghum is regarded as an inferior grain to wheat, maize, and rice. We have learned a great deal about the chemistry, composition, and structure of the grain that influence its processing, food-making and nutritional quality. As we share these findings with our LDC collaborators involved in sorghum improvement programs the utilization level of sorghum should increase. Through our work on improving the protein digestibility of sorghum by heat extrusion a commercial venture is being established in Sudan to produce a heat extruded sorghum weaning food. It must also be remembered that any improvements in the utilization of sorghum as a food also results in an improvement of its value as livestock feeds and thereby benefiting U.S. agriculture.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: Physical, Chemical and Nutritional Aspects of Sorghum Utilization

Project Leader: Allen Kirleis **Project Number:** PRF-103B

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=PRF103B -- ----------						
Staff Salaries & Benefits	17.82	18.81	19.80	20.59	21.58	98.60
Post Doctorates	6.84	7.22	7.60	7.90	8.28	37.84
Graduate Students	7.00	7.00	8.00	8.00	8.00	38.00
Other Salaries	8.91	9.41	9.90	10.30	10.79	49.31
Supplies	7.74	8.17	8.60	8.94	9.37	42.82
Equipment	2.79	2.95	3.10	3.22	3.38	15.44
Travel	10.08	10.64	11.20	11.65	12.21	55.78
Other Direct Costs	6.93	7.32	7.70	8.01	8.39	38.35
Overhead	21.96	23.18	24.40	25.38	26.60	121.52
	90.07	94.70	100.30	103.99	108.60	497.66

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=PRF103B -- ----------						
University Staff	6.27	6.58	6.91	7.26	7.62	34.65
Staff Benefits	1.70	1.78	1.87	1.97	2.07	9.39
Post Doctorates	4.20	4.41	4.63	4.86	5.11	23.21
Grad Students	19.60	20.58	21.61	22.69	23.82	108.30
Other Salaries	1.26	1.32	1.39	1.46	1.53	6.96
Fringe Benefits	4.77	5.00	5.25	5.52	5.79	26.33
Supplies	15.42	16.19	17.00	17.85	18.74	85.21
Travel	8.93	9.37	9.84	10.33	10.85	49.32
Other Direct Costs	2.58	2.71	2.85	2.99	3.14	14.28
Overhead	29.77	31.26	32.83	34.47	36.19	164.52
	94.50	99.23	104.19	109.40	114.87	522.17

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=PRF103B -- ----------						
University Staff	5.97	5.97	5.97	5.97	5.97	29.86
Staff Benefits	1.62	1.62	1.62	1.62	1.62	8.09
Post Doctorates	4.00	4.00	4.00	4.00	4.00	20.00
Grad Students	18.67	18.67	18.67	18.67	18.67	93.34
Other Salaries	1.20	1.20	1.20	1.20	1.20	6.00
Fringe Benefits	4.54	4.54	4.54	4.54	4.54	22.70
Supplies	14.69	14.69	14.69	14.69	14.69	73.43
Travel	8.50	8.50	8.50	8.50	8.50	42.50
Other Direct Costs	2.46	2.46	2.46	2.46	2.46	12.31
Overhead	28.36	28.36	28.36	28.36	28.36	141.79
	90.00	90.00	90.00	90.00	90.00	450.00

Utilization and Quality of Sorghum and Millet

Project TAM-126
Dr. Lloyd W. Rooney
Texas A&M University,

Collaborating Institutions

Host Country

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Dr. Oumar Niangado, Millet and Sorghum Breeder; I.E.R., DRA; Cinzana, Mali
Ms. Coulibaly, Sorghum Breeder; IER; D.R.A. Bamako, Mali
Ms. Haidara, Food Quality Lab; Bamako, Mali
Dr. Francisco Gomez, Sorghum Breeder; Recursos Naturales, Choluteca,
Dr. D. Meckenstock, Sorghum Breeder; INTSORMIL; Tegucigalpa, Honduras
Dr. C. Paul, ICRISAT-Mexico
Dr. S. Bedolla, Head; Dept. of Grades & Standards, State of Sonora, Hermosillo, Sonora Mexico.
Dr. R. Bressani, INCAP, Guatemala City, Guatemala
Dr. Moussa Oumarou, Deputy Director, National Food Quality Lab; Kolo, Niger.
Dr. Da Sansan, Sorghum Breeder; Burkina Faso.
Dr. D.S. Murty, ICRISAT, Nigeria
Drs. L. Mughogho, R. Jambunathan and Subramanian, R. Bandyopadhyah, ICRISAT: India
Ms. Manel Gomez, ICRISAT, Bulawayo, Zimbabwe
Dr. L. House, Director ICRISAT-DADCC Bulawayo, Zimbabwe
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Dr. David Andrews, University of Nebraska, Lincoln, NE
Dr. Bill Stegmier, Kansas State University, Hays, KS
Dr. Singh, Peanut CRSP, Alabama A&M University, Normal, Alabama
Dr. Phillips, Bean Cowpea CRSP, University of Georgia, Experiment, GA

Constraints

Major constraints to sorghum and millet production include weathering, insects, molds, drought, disease and others. Breeding to improve the agronomics, disease and insect resistance and other properties of sorghum and millet must include selection of grain with good characteristics for use in traditional foods. An improved cultivar without acceptable, traditional food quality will not be accepted by local farmers. Thus, plant breeders must include selection for food quality in addition to all the other desirable features.

Moulds, weathering and head bugs significantly, adversely affect the food and feed properties of sorghums in all areas of the world at times. This complex is especially important in West Africa where head bugs attack most new improved cultivars and produce soft grain which cannot be processed into acceptable traditional food products. Very hard grain that develops quickly after pollination may be answer. Continued progress requires major inputs from entomologists, pathologists, utilization and plant breeders.

Sorghum is utilized mainly as human food in a variety of traditional foods that must be prepared daily. Unlike maize, wheat and rice, no stable processed products from sorghum & millet exist. Thus, the urban consumer uses ever increasing quantities of corn, rice and wheat because millet & sorghum products are unavailable. The development of low technology processes to convert sorghum & millet into shelf stable edible foods

for village and especially urban tenters could lead to value added processing by small village entrepreneurs which could generate cash income for producers and stabilize markets. For example nearly all consumers like rice but it is much higher priced than sorghum & millet. Conversion on sorghum/millet into milled stable food product(s) that could offer an alternative to rice will be evaluated. Many other possibilities exist to improve the value of sorghum & millet foods thru production of new unique foods.

Progress has been made in defining grain characteristics that affect food quality; but, simple tests to predict quality are still needed. Information on the chemistry, composition, structure and processing properties of sorghum and millet is required to permit more efficient tests to be developed. Sorghum varieties with excellent milling quality and white grain may be processed into acceptable foods.

The nutritional value of processed sorghum and millet is of major concern since it is often a major part of the food intake of sorghum and millet consumers. New food products will be monitored to determine the changes in nutritional value.

Sorghum production is expanding in Central and Latin America. The development of food quality sorghums for processing as food or feed could help provide a more consistent food supply. The demonstration of the high quality and good acceptability of properly processed sorghum for use in tortillas, atoles, processed foods, i.e. breads, cookies, pasta, etc., can lead to significant improvement in sorghum for use in Latin America.

New policies in Africa prohibit importation of wheat and barley, i.e. Nigeria, which increases the demand for sorghum with improved industrial processing properties. The need to improve sorghum for use in fermented beverages by increasing its malting properties is significant. Quick screening tests of malt quality are needed to evaluate breeding materials to enable selection of sorghums for malt. More information on how to select for mold resistance and malting properties of sorghum is needed to permit progress in this area.

Project Objectives:

Refine, use and continue to develop simple tests to predict food quality in plant breeding programs and to determine which characteristics of sorghum and millet limit food and nutritional quality.

Determine physical, chemical and structural factors that affect food and nutritional quality of sorghum and millet.

Develop methods to process sorghum into acceptable food products by com- bining processing methods with improved sorghum varieties.

Determine factors affecting malting quality of sorghum and how to select for it.

Determine the factors that affect resistance to grain molds and field deterioration in sorghum and devise laboratory procedures to detect geno- types with resistance.

Objectives Related to Constraints

Our objectives relate to both utilization and production constraints of sorghum. More information on the role of chemical constituents in the quality of sorghum and millet for traditional foods will lead to better screening and selection methods for use in sorghum and millet breeding programs. The identification of the critical chemical, physical and structural factors affecting food quality can lead to improved efficiency in developing new varieties and improved utilization technology. For example, we have some evidence that dry milling properties of sorghum vary among varieties with a thin pericarp; hence, the identification of sorghum lines with a thin pericarp which is easily removed by dry milling could lead to improved milling quality accompanied by better resistance to weathering and molds. More understanding of the chemistry of to^ keeping quality and the interaction of grain hardness, head bugs, molds, kernel structure and plant type to to^ quality in W. Africa is essential.

The objectives include research on pearl millet to determine its food and nutritional value. The techniques that we have developed for evaluating sorghum quality will be applied to pearl millet to assist millet breeders in developing critically needed information on how to breed and select for millet quality. The pearl millet research will be directly related to milling and to^ production in W. Africa through our relationship with the Food Technology laboratory in Mali and with the new ICRISAT West African Sorghum research center located in Nigeria as it develops.

Host Country Collaboration and Work Sites

Mali

Drs. Niangado (Mali), Stegmier-Kansas State University and Andrews (UNL-118) will provide samples of pearl millet representing the significant variation among pearl millet cultivars. The grain will be utilized in chemical, physical and structural analyses to determine the variation among pearl millets. The milling properties of some major types of pearl millet will be evaluated in village trials in Mali. Sublots of the same

samples will be analyzed at Texas A&M. Additional equipment for the new Food Quality Lab in Mali will be purchased and put into operation. Research efforts on tô quality evaluation will be expanded. Work on preparation of composite tô flours based on sorghum/millet is underway in the Malian Food Technology laboratory. Experiments to determine the potential use of parboiling for production of sorghum "rice-like" products will be continued in Mali. Work on parboiled sorghums at Texas A&M suggests it has excellent potential for converting softer sorghums into an excellent rice substitute. Millet will also be parboiled into MILRI.

Honduras

The properties of sorghum required for production of high quality tortillas will continue to be documented in trials in our lab and village cooking trials at La Lujosa, Honduras. Dr. F. Gomez, in Honduras, will select for sorghum food quality (tortillas). His evaluation will be done on sorghum lines derived from previous food quality studies. A good opportunity to develop a photosensitive sorghum with better tortilla making properties to replace existing local varieties (Maicillo Crillos) exists. The work in Mexico has demonstrated that pearled sorghum has potential value for food use and has shown that sorghum can be used effectively in mixtures with maize in mechanized tortilla preparation. Dr. Gomez is using simple procedures for selecting sorghums in Honduras which will be backed up by work in the Cereal Lab at Texas A&M.

Mexico

Work will continue through former graduate students, Ms. P. Torres (MSci) and Dr. B. Ramirez (PhD), who completed degrees in Food Technology at Texas A&M University in early 1989 and returned to the University of Sonora Food Science faculty.

ICRISAT & Other Cooperators

Studies on malting quality of sorghum will be continued in cooperation with SADDCC/ICRISAT. Collaborative tests initiated in our laboratory will be done on ICRISAT samples once a standard test is developed. Additional studies on phenols, starches, and changes in components during grain maturation will be conducted to assist ICRISAT collaborators. For example, our research on isolation and characterization of the nontannin phenols of sorghum has provided useful information relating to mold and insect resistance which affects quality significantly.

Cooperation occurs with numerous other personnel including researchers from Tanzania, Kenya, Egypt, S. Africa, Argentina, France, Zimbabwe, and Great Britain.

Research Procedures for Work in the USA

We have had a strong research program on sorghum for 20 years that has been supported by state, federal and private resources. Funds from INTSORMIL are used mainly to support graduate student training through stipends and support items such as supplies, equipment, travel and other expenses. International students and domestic students are paired to work closely together in related projects. We try to have plant breeders working with food technologists and cereal chemists to evaluate sorghum quality. The results provide information of practical and theoretical use in sorghum breeding programs and students gain irreplaceable experience in multidisciplinary research activities.

Sorghum and Millet Food Quality Evaluation/Screening

Samples from the sorghum food quality nursery, the international food sorghum adaptation trials, the grain weathering test, advanced food hybrid tests and special increases are evaluated for milling and food processing properties to provide information on progress made by breeders to develop new food type sorghums. Simple tests used for screening preliminary lines continue to provide information at early stages in the breeding program.

Physical & Chemical Characteristics related to Processing Quality

The relation between grain characters ie hardness and processing quality will be determined and incorporated into the improvement plans using practical field techniques for selection wherever possible.

Sorghums containing waxy and nonwaxy endosperms will be evaluated for their nutritional value using "in vitro" tests. These lines are from Rosenow and Miller's advanced materials.

The research on tô quality conducted by Mr. T. Bello (Ph.D. Candidate Food Technology - Nigeria) and U.S. student(s) will be completed and summarized. Samples of millet and sorghum used in village cooking trials in Mali will be the basis for research here in our laboratory to insure that we are examining meaningful samples. Determination of milling, physical, chemical and nutritional properties of raw and processed grains, will use existing procedures and experienced personnel here in our laboratory.

The characterization of starches and endosperm of sorghum and millets will continue but will emphasize differences in starch properties that relate to keeping properties and texture of to^ and tortillas for sorghum. New techniques using HPLC will be applied.

Develop New Food Products from Sorghum & Millet

Parboiling properties of several sorghum varieties from West Africa will be determined to evaluate the potential of parboiling to improve the utilization of sorghum as a rice-like product. Parboiled soft sorghums have shown increased decortication yields and acceptable cooking properties for rice-like products.

Pearl millet will be parboiled to produce MILRI. Proper procedures for cooking and drying millet will be evaluated and a method for processing millet into MILRI will be designed. The storage stability i.e. flavor, odor, acceptability will be evaluated to determine if MILRI can be stored for reasonable times under African conditions.

New low technology methods of processing sorghum & millet with dry heat ie parching, popping & puffing will be evaluated to produce new foods or food ingredients for producing higher value products ie weaning foods.

The potential for meaningful interaction among the INTSORMIL, the Peanut and the beans & Cowpea CRSP utilization projects is great and will be explored especially in West Africa.

Promising food products will be subjected to economic and marketing studies to determine how they can be exploited most efficiently within specific countries with emphasis on West Africa.

Processes to eliminate tannins will be evaluated and potential benefits determined.

Malting Quality of Sorghum

Malting quality of sorghum is of major importance in production of fermented traditional foods in Africa and for industrially processed products. Sorghums generally have low diastatic power which may be improved thru breeding. However, a selection technique is required. Current methods of determining malting properties are time consuming, and tedious.

Sixty sorghums representing a range of malting properties were grown at College Station and Halfway, Texas in 1988 for malting quality evaluations. Selected samples from one location will be utilized to develop basic information on variation in malting properties. Then, methods of quickly screening sorghum malt quality will be evaluated. When successful screening methods are developed, genetic and environmental factors affecting malting quality can be determined.

Travel to Nigeria to collaborate with ICRISAT to collect information on previous research on sorghum malting is planned. Travel to Zimbabwe, Zambia and Botswana to collaborate with ICRISAT and review private industrial operations and procedures will be included.

Factors Affecting Grain Deterioration

Factors affecting the interaction of head bugs, mould and grain determination on food quality will be determined through an inter disciplinary approach. New genotypes with resistance to head bugs may be developed since Malisor 7 shows some tolerance to head bugs.

The research on phenols related to disease and insect resistance will continue. Research on the effect of glume and plant color, pericarp characteristics and other factors on phenol kind and quantity will be continued with existing collaborators. New techniques will be developed and applied to determine the effect of phenols and related compounds on weathering and molds.

Black sorghums originating in the Sudan contain very high levels of phenols with some condensed tannins. Information on the level and kind of phenols in black sorghums during development will be related to changes in kernel structure. The potential utilization of tannins and phenols from black sorghums will be investigated. Milling and fractionation studies to concentrate the phenols will be evaluated.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: Utilization and Quality of Sorghum and Millet

Project Leader: Lloyd Rooney **Project Number:** TAM-126

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=TAM126	--	----------				
Staff Salaries & Benefits	18.61	19.60	20.59	21.58	22.57	102.95
Post Doctorates	7.14	7.52	7.90	8.28	8.66	39.50
Graduate Students	7.00	8.00	8.00	8.00	9.00	40.00
Other Salaries	9.31	9.80	10.30	10.79	11.29	51.49
Supplies	8.08	8.51	8.94	9.37	9.80	44.70
Equipment	2.91	3.07	3.22	3.38	3.53	16.11
Travel	10.53	11.09	11.65	12.21	12.77	58.25
Other Direct Costs	7.24	7.62	8.01	8.39	8.78	40.04
Overhead	22.94	24.16	25.38	26.60	27.82	126.90
	======	======	======	======	======	=======
	93.76	99.37	103.99	108.60	114.22	519.94

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=TAM126	--	----------				
Post Doctorates	10.50	11.03	11.58	12.16	12.76	58.02
Grad Students	18.38	19.29	20.26	21.27	22.34	101.54
Other Salaries	3.15	3.31	3.47	3.65	3.83	17.41
Fringe Benefits	5.96	6.26	6.57	6.90	7.24	32.93
Supplies	16.63	17.46	18.33	19.25	20.21	91.89
Equipment	2.63	2.76	2.89	3.04	3.19	14.50
Travel	12.85	13.50	14.17	14.88	15.62	71.03
Other Direct Costs	1.68	1.76	1.85	1.94	2.04	9.28
Overhead	26.93	28.27	29.69	31.17	32.73	148.78
	======	======	======	======	======	=======
	98.70	103.64	108.82	114.26	119.97	545.38

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=TAM126	--	----------				
Post Doctorates	10.00	10.00	10.00	10.00	10.00	50.00
Grad Students	17.50	17.50	17.50	17.50	17.50	87.51
Other Salaries	3.00	3.00	3.00	3.00	3.00	15.00
Fringe Benefits	5.68	5.68	5.68	5.68	5.68	28.38
Supplies	15.84	15.84	15.84	15.84	15.84	79.19
Equipment	2.50	2.50	2.50	2.50	2.50	12.50
Travel	12.24	12.24	12.24	12.24	12.24	61.21
Other Direct Costs	1.60	1.60	1.60	1.60	1.60	8.00
Overhead	25.64	25.64	25.64	25.64	25.64	128.22
	======	======	======	======	======	=======
	94.00	94.00	94.00	94.00	94.00	470.00

Host Country Program Enhancement

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Improved and Sustainable Dryland Cereal Production Technology for Smallholder Farmers in Botswana

Project KS-107
Dr. Richard Vanderlip
Kansas State University

Collaborating Institutions

Host Country

Department of Agriculture Research (DAR): Private. Bag 0033, Gaborone, Botswana
F.A.O. Soil Survey Project: Private Bag 003, Gaborone, Botswana
Department of Meteorological Services: Box 10100, Gaborone, Botswana
Farming Systems Southern Region (FSSR): Regional Agricultural Office, P.O. Box 0032, Kanye, Botswana
SACCAR, Land & Water Management Project (L&WMP): Pvt. Bag 00108, Gaborone, Botswana
Arable Lands Development Project (ALDEP): Private Bag 003, Gaborone, Botswana
Thusano Lefatsheng: Private Bag 00251, Gaborone, Botswana.
Naraine Persaud, Sebele Research Station, Botswana
Lucas Gakale, Sebele Research Station, Botswana

Project Objectives

1. Develop improved and sustainable dryland sorghum and millet production practices which increase rain and soil-moisture use efficiency in the following catenary pathway.

(infiltration) (soil-moisture uptake) (transpiration)
Rainfall--------- soil----------plant----------atmosphere
(runoff)
(evaporation)

This will be achieved through manipulation of the crop/cropping system x cultural practice x soil interrelationships.. Specifically:

a. Evaluate on-farm rainfall harvesting systems.

b. Evaluate improved soil moisture-conservation tillage systems in conjunction with fertiliser application across various rainfall conditions and soil types in Eastern Botswana.

c. Evaluate the longterm effects of manure and crop residues on crop yields and stability and on maintaining and enhancing soil productivity.

2. Collaborate with and support relevant national research objectives and efforts to improve and stabilize dryland sorghum and millet crop production. Specifically by:

a) Enhancing institutional capacity through informal training.

b) Facilitating access to U.S. sources of information and expertise.

c) Facilitating linkages with U.S. institutions, other CRSPs, and other USAID-funded projects.

d) Responding to specific requests for technical input by participating in planning sessions, committee meetings, field days, etc.

Introduction and Constraints

Food security continues to be a major goal for Botswana and its partners of SADCC: the Southern African Development Coordination Conference. Since 1983 INTSORMIL - the International Sorghum and Millet CRSP, has sought to contribute to this goal by collaborative studies with Botswana's agricultural research scientists in their efforts to develop improved crops and soil and crop management technology for dryland sorghum and millet production. Currently, USAID/Botswana, through the Agricultural Technology Improvement Proejct (ATIP), and the Ministry of Agriculture are supporting these efforts both financially and logistically.

Dryland agriculture is possible on lands along a narrow north/south strip of Botswana's eastern border and around the Okavango delta. This arable zone represents about 15 to 20 % of Botswana's 580,000 sq. km. of land and receives 400-600 mm. rainfall annually. Crops produced include sorghum, maize, millet, jugo beans,

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groundnuts, cowpeas, sunflower, and various melons. In Botswana the chief environmental contraints in arable agriculture are rainfall and the rainfall/soil interaction. The low, irregular, and low-efficiency rainfall pattern contributes to a high risk of intra-seasonal drought and crop stress. This rainfall pattern results in low, variable yields, low planted-to-harvested area ratios, and high-risk, economically marginal cereal farm enterprises. Farmers traditionally invest a low level of labor and other resources because they expect a fair return only in the infrequent years with high and well- distributed seasonal rainfall. Sorghum is mostly grown on soils which have a low capacity to retain moisture, low organic matter, low N and P content, broadly graded sand fractions, and unstable surface structure. These last two properties result in a high bulk density, a massive hard structure when dry, and surface sealing and crust formation. This tends to impede rain infiltration, deep root penetration and expansion, and to further aggravate the risk of moisture stress. Primary tillage is necessary to improve structure and rainfall infiltration, to obtain good seedbed and rootbed tilth, weed control, crop establishment and crop stands. The annual cost for primary tillage operations for the national sorghum crop is currently estimated at close to 6 million USD.

About 70-80% of the food produced in Botswana, including about 90 to 95 % of the sorghum, come from traditional, small-holder, subsistence- oriented dryland farms. Annual cereal requirements in Botswana are estimated at 250,000 metric tonnes of which about one third is usually satisfied in years of moderate rainfall. Ninety per cent of rural households produce harvests which are insufficient for subsistence, taking the average size of 6 people per household. One half of all farms in Botswana produce under 320 kg. of cereals per year. There is, therefore, a strong motivation for increasing traditional farm yields and output. In addition, production costs need to be minimised to maintain producer prices at parity with those of neighbouring South Africa in order to prevent illegal marketing across the border. The government of Botswana is currently placing considerable emphasis on increasing arable production. The Ministry of Agriculture, with technical assistance from USAID, has recently completed the Botswana Agricultural Sector Assessment study. It is being used as the basis for framing Botswana's agricultural programs and policies in the 7th. 5-yr. National Development Plan currently being designed. This study has specifically identified an urgent need for improved soil and water management as a vital factor in enhancing national and household food security, promoting crop diversification and expansion, and conserving the soil resource base. The development of technological packages appropriate to the specific local ecological and social conditions would require increased human and institutional capacity within the DAR. There appears to be little doubt that improved practices on traditional farms can result in higher yields and generate employment and income for traditional rural households. This statement is supported by the ICRISAT experience in India and by the Barolong farmers in Botswana whose improved dryland farms out-yield traditional subsistence farms by 2 to 3 times. This orientation also is reflected in USAID's current assistance to agricultural sector development in Botswana. Employment and income generation in the agricultural sector benefits the U.S. since, historically, rising incomes and higher standards of living in many countries have resulted in increased economic and trade links with the U.S. INTSORMIL/Botswana identifies closely with the government of Botswana and USAID agricultural sector development strategy.

Similar conditions affect lesser areal portions, totalling about 4.8 million hectares, in other countries of the SADCC grouping. Results and experience developed in Botswana may therefore find regional applicability.

Objectives

a. Evaluation of on-farm rainfall harvesting systems

i) measurement of off-farm runon volumes and soil moisture status and use as influenced by seasonal rainfall patterns

ii) evaluation of cropping patterns to make efficient use of harvested rainfall.

iii) assess replicability of design components and agronomic benefit of rainfall harvesting systems under different conditions.

iv) analysis of autographic rainguage data to facilitate rational design of rainfall harvesting systems.

b. Evaluation of improved soil moisture-conservation tillage/fertility management technology.

i) Continue recently initiated multi-locational field trials in Eastern Botswana to test several soil moisture-conservation animal, and tractor implemented, tillage practices in conjunction with fertiliser application to specifically evaluate:

- longterm effects on sorghum growth and yield across soil types and seasonal rainfall conditions
- longterm effects on soil quality and soil physical properties
- soil moisture/soil fertility interactions in Botswana soils.

ii) Initiate efforts to develop a preliminary adaptability classification of various tillage-planting/soil-fertility improvement systems to soils of Botswana.

iii) Updating existing information covering soil resources, soil moisture/climate relationships, soil-fertility management, and soil-moisture and fertility conservation in Botswana.

c. Evaluation of longterm effects of manure and crop residue on sorghum and millet yields and on soil productivity.

i) Continue evaluation of the effect of manure and stover use on sorghum and millet yields on common arable soils found in Eastern Botswana.

ii) Assess the economic viability of manure use for sorghum production.

iii) Examine yield stability as it is affected by manure use.

iv) Monitor the soil moisture balance for different manure and mulch treatments.

Host Country Collaboration and Work Sites.

a) Rainfall harvesting: Rainfall harvesting research encompasses various interventions which seek to enhance a crop's water balance by manipulating rainfall runoff. There are two major research categories; microcatchment and macrocatchments. Microcatchments manipulate runoff in the immediate vicinity of the crop. This usually involves tillage and landshaping in the field. Macrocatchments intercept and direct runoff from watershed or defined catchment areas which are generally some distance from the cropping site. DAR maintains a strong emphasis on water management with research responsibilities for different types of water management delegated to various DAR staff. INTSORMIL collaborates with DAR by focusing its research on macrocatchment system.

The collaboration and sites of research for each objective stated in section 2.a are:

i) L&WMP monitors runoff volume at one on-farm site near Sebele and INTSORMIL monitors soil moisture.

ii) Thusano Lefatsheng, a non-governmental organisation (NGO), identifies on-farm sites in Gabane village and Thusano Lefatsheng and INTSORMIL implement on-farm water harvesting systems.

iii) Agronomic data collection at on-farm sites jointly by DAR, INTSORMIL, and Thusano Lefatsheng.

iv) Kansas State and Meteorological Services analyzes historic autographic raingauge data. L&WMP analyzes recent autographic raingauge data and hydrographs from water harvesting site.

b. Moisture-conservation tillage/soil-fertility management: Research objectives stated in section 2b, items i and ii, are part of the National Tillage Research Program initiated by DAR in August 1988. INTSORMIL has taken a lead role in the design and implementation of this program. Specific sites are the Central Research Station at Sebele, farmers fields in the ATIP/FSR case-study villages in the Francistown and Mahalapye areas, fields of case-study farmers selected by the farming system team and ALDEP in the southern region. Specific host country collaboration in implementation of the NTRP is as follows:

i) DAR, ALDEP : provision of technicians, equipment, logistical support, and supervision of field operations.

ii) Soil survey and mapping unit, Land Utilisation Division: Assistance with site selection and characterisation.

iii) FSSR farming systems teams: supervision of field operations. (At Sebele in collaboration with senior DAR and MOA personnel.)

iv) Dept. of Agricultural Field Services, MOA: monitoring of field trials, liason with owners of onfarm sites, arranging field visits.

v) Land and Water Management Project, SACCAR: help with planning and intensive monitoring of moisture relations.

c. Manure and crop residue management: INTSORMIL/DAR research on the use of manure and stover started in 1984/5. Based on the results of this long-term study, ATIP initiated an on-farm assessment of manure use in the Mahalapye area. The collaboration and sites of research for objectives stated in 2.c are:

i, ii and iii) ATIP, INTSORMIL and DAR conduct manure use experiment at sites in the ATIP/Mahalapye area, Sebele area, and Goodhope Research sub-station. ATIP had collected agronomic and economic data in ATIP/Mahalapye sites.

iv) INTSORMIL and DAR collect agronomic and soil-moisture data at Sebele Research Station sites.

Research Procedures:

a. Rainfall runoff management: The following procedures will be followed for objective 2a:

i) An H-flume with auto-recorder was installed and monitored during 1988-9. This monitoring will continue.

ii and ii) Suitable on-farm sites within the project area of Thusano Lefatsheng are identified. Water harvesting systems are constructed based on recommendations from INTSORMIL and DAR. Agronomic monitoring at all sites conducted by Thusano Lefatsheng staff and INTSORMIL.

iii) Standard rainfall analysis procedures to produce probabilities of specific rainfall events which are likely to produce runoff with various combinations of soil and degree of groundcover.

b. Moisture conservation tillage/soil-fertility management: The following procedures will be followed for objectives 2b: items i and ii:

i) Work closely with the working group on tillage research to design multi-locational on-station and on-farm experiments taking into account results from the 1988/89 National Tillage Trials. Design will specify tillage and fertility treatments, operational details, data collection procedures etc.

ii) Make measurements of bulk density, soil moisture status etc. throughout the season, plant stands, height, and nutrient status, weed counts, root system growth etc.

iii) Conducting a joint literature search and compilation of existing information on the stated subject matter areas.

c. Manure and crop residue management: The following procedures will be followed for objectives outlined in section 2c.

i) Continued agronomic data collection from on-farm and on- station replicated experiments to evaluate yield response to manure and crop residue treatments. Soil moisture monitored on on-station trials.

ii) Stability analysis to include results from recently conducted trials of INTSORMIL and ATIP. Additional data sets included are historic DAR trials.

iii) ATIP economic data collected using farmer surveys.

iv) Same as i.

Measures of success

Usefulness of outputs from experiments and field studies: Will these have an impact on sorghum and millet production? Do participating farmers at onfarm sites perceive the practices as potentially beneficial? Are the practices potentially extendable? Have they contributed to an understanding of production factors in the semiarid environment?

Degree of support and collaboration: Does the host country feel the research objectives and procedures relevant and beneficial? Are they willing to continue support for the research? Is there a good degree of interest and collaboration from host country counterparts and institutions?

Anticipated Reports and Articles

Annual reports on National Tillage Trials, Rainfall Harvesting system and Manure and Stover use for crop production in Botswana.

Special Reports and Articles on Soil resources and their management in Botswana; Rainfall intensity, frequency, and duration characteristics in Botswana; Manure and Stover use for crop production in Botswana; Design considerations for macrocatchment water harvesting system in E. Botswana; and, other reports and journal articles arising from research results as appropriate.

General Comments

INTSORMIL/Botswana currently enjoys excellent support and relationships with host country institutions and their personnel. USAID/Botswana is very supportive of INTSORMIL/Botswana's efforts. The in-country scientists are making as much effort as time permits to consolidate, interpret, and generalize the significant results from the past three years of collaborative research. In addition INTSORMIL/Botswana has actively sought opportunities to asssist the DAR in building their research capacity through informal training of staff, actively participating on DAR professional committees and forums, stenghtening linkages etc. Recently INTSORMIL/Botswana has actively helped to prepare several sections of the USAID-funded Agricultural Sector Assessment for the Ministry of Agriculture. Plans presented are subject to review and possible revision by DAR senior staff, although previous plans of work generally have been acceptable without major revisions.

INTSORMIL KSU-107's presence can continue to play an effective and key role in future sorghum and millet

production research in Botswana. The following recent developments will significantly enhance the effectiveness of KSU-107's presence in Botswana:

The overall objectives of the regional SADCC/SACCAR Land and Water Management project initiated in 1987 are closely aligned with those of INTSORMIL KS-107. This project has moved towards closer collaboration with INTSORMIL. In June 1989 they received close to 2.5 million USD in funding from EEC for their activities.

The soil survey for Botswana undertaken by the FAO for the past 9 years is now close to completion. KSU-107's soil and water management program builds and draws directly upon the soil data base and other outputs of this project.

The Botswana Agricultural Sector Development study completed in June 1989 has specifically identified KSU-107's water harvesting and tillage/fertiliser themes as urgent and relevant and recommended their emphasis in future programs.

The creation of a Faculty of Agriculture at the Univ. of Botswana has added another dimension and opportunities for collaboration.

Several BS level graduates trained in the U.S. through ATIP are now taking up positions in the DAR and strengthening its capacity. This will facilitate greater and more effective collaboration for INTSORMIL within the DAR.

Several DAR personnel are scheduled for advanced training under the SADCC/ICRISAT/INTSORMIL training program. This can provide added opportunities for their participation in achieving KS-107's objectives.

.Progress (last two years)

The INTSORMIL/Botswana collaborative research program during the last 2 years has become integrated and centered around three main themes:

- Rainfall harvesting.
- Soil-moisture conservation tillage and soil fertility improvement.
- Manure and crop residue management.

In implementing their collaborative program researchers utilise both onstation and onfarm research sites. All sites are characterised to permit extrapolation, extendability, and transferability of the results. The few years of research on these themes have produced significant achievements in development of improved technologies. For example:

Onfarm studies of macrocatchment rainfall harvesting systems have shown that natural runoff can be used to triple sorghum yields by increasing seasonal soil-moisture availability.

Onfarm trials are being conducted on several promising soil- moisture conservation tillage/soil fertility improvement systems that can promote deeper moisture and root penetration, give better weed control, better crop establishment, and healthier crops. Some of these systems may have potential to conserve sufficient moisture to permit growing of maize.

Crop residues used in conjunction with manure and fertilizers have been shown to have a favorable effect on crop growth by moderating the impact of environmental constraints. Yields can thus be stabilised at a higher level.

As a measure of the success, recognition, and acceptance of the INTSORMIL/Botswana KSU-107 project:

The SADCC/SACCAR Land and Water Management Project has recently incorporated rainfall harvesting research as an integral part of their regional program.

The IFAD/ADB-funded Arable Lands Development Project (ALDEP) is supporting the National Tillage Research Program with nearly 50,000 USD worth of tillage and soil moisture monitoring equipment. In addition, ALDEP has recruited several technical assistants to specifically help with these trials. INTSORMIL helped to initiate the National Tillage Program and plays a leading role in its coordination and implementation.

ATIP/DAR farming systems teams have initiated onfarm adaptive testing and evaluation of manure and crop residue management practices.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: Improved and Sustainable Dryland Cereal Production Technology for Smallholder Farmers in Botswana

Project Leader: Richard Vanderlip **Project Number:** KSU-107

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=KSU107 -- ----------						
Staff Salaries & Benefits	29.70	40.19	42.17	43.96	46.13	202.15
Post Doctorates	11.40	15.43	16.19	16.87	17.71	77.60
Graduate Students	11.00	15.00	16.00	17.00	18.00	77.00
Other Salaries	14.85	20.10	21.09	21.98	23.07	101.09
Supplies	12.90	17.46	18.32	19.09	20.04	87.81
Equipment	4.65	6.29	6.60	6.88	7.22	31.64
Travel	16.80	22.74	23.86	24.86	26.10	114.36
Other Direct Costs	11.55	15.63	16.40	17.09	17.94	78.61
Overhead	36.60	49.53	51.97	54.17	56.85	249.12
	149.45	202.37	212.60	221.90	233.06	1019.38

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=KS107 -- ----------						
University Staff	78.81	82.75	86.89	91.23	95.79	435.47
Staff Benefits	20.49	21.52	22.59	23.72	24.91	113.22
Overhead	21.45	22.52	23.65	24.83	26.07	118.52
	120.75	126.79	133.13	139.78	146.77	667.22

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=KS107 -- ----------						
University Staff	75.06	75.06	75.06	75.06	75.06	375.29
Staff Benefits	19.52	19.52	19.52	19.52	19.52	97.58
Overhead	20.43	20.43	20.43	20.43	20.43	102.14
	115.00	115.00	115.00	115.00	115.00	575.00

Sustainable Production of Sorghum and Pearl Millet in Fragile, Tropical Acid Soils

Project MSU-111 (Colombia)
Dr. Lynn Gourley
Mississippi State University

Collaborating Institutions

Host Country

Dr. Manuel Torregroza, Director of Annual Crops, ICA, Apartado Aereo 15248, Bogota, Colombia
Dr. Dorance Munoz, Director Genetics and Plant Breeding, FEDEARROZ, Piso ll, Bogota, Colombia.
Mr. Cesar Ruiz, Sorghum Breeder, ICA, La Libertad, Apartado Aereo 2011, Villavicencio, Colombia
Mr. Luis de Angulo, Arauca Project, Occidental de Colombia, Inc., Bogota, Colombia
Dr. Fabio Polania, Technical Director, FENALCE, Bogota, Colombia
Dr. Gilson Pitta, Soil Scientist, CNPMS/EMBRAPA, Caixa Postal 151 35.700 Sete Lagoas, M. G., Brazil
Dr. Gabriel Alves Maciel, Breeder, EUP-PI, Serra Talhada, Brazil
Mr. Hector Mena, Director of Cereal Research, CENIAP-FONAIAP, Maracay (Aragua), Venezuela
Dr. Mauricio Riccelli M., Central University of Venezuela, Protinal, C.A., Valencia, Venezuela
Dr. Dale Bandy, North Carolina State University, Mission/INIPA and TROPSOILS, Lima, Peru
Mr. Pedro Carrasco, Leader of INIPA's Selva Program, INIPA-Yurimaguas, Peru
Dr. Antonio Pinchinat, Research Specialist, IICA-Lima, Peru.

U.S.

Dr. Guillermo Munoz, Department of Agronomy, Mississippi State University, CIAT, Cali, Colombia
Dr. Henry Pitre, Department of Entomology, Mississippi State University, Mississippi State, MS
Dr. Jerry Maranville, David Andrews, Department of Agronomy, University of Nebraska, Lincoln, NE
Mr. Bill Stegmeier, Kansas State University, Ft. Hays Experiment Station, Hays, KS
Dr. Darrell Rosenow, Texas A&M University Agriculture and Research Center, Route 3, Lubbock, TX
Dr. Pedro Sanchez, TROPSOILS Coordinator, North Carolina State University, Raleigh, NC.

Research Objectives

To develop sustainable minimum-input technology strategies for the evaluation of sorghum and pearl millet germplasm for tolerance to Al and manganese (Mn) toxicities, and low phosphorus (P) availability.

To incorporate sources of tolerance to Al and Mn toxicities, and low P availability into elite U.S. and tropical sorghum genotypes.

To establish a regional network for the development and exchange of sorghum and pearl millet germplasm with tolerance to tropical acid soils with phytotoxic levels of aluminum (Al) among national programs in Latin America.

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

Assist other INTSORMIL PI's in the conduct of research in Colombia.

Introduction

The most important constraint to the increase of sorghum and pearl millet areas of production in South America is soil acidity. South America has the largest acid soil areas in the world. These unproductive acid soils contain toxic levels of Al and sometimes Mn, enough to inhibit the growth of major cereal crops. In addition, they are characterized by low P content and availability due to high chemical fixation. They are also deficient in various other plant nutrients. The second most important constraint of sorghum and pearl millet production is drought. In many parts of the South American ecogeographic zone drought due to variable rainfall patterns is an annual problem. In addition to acid soil constraints, specific long-range research goals in Colombia now include pearl millet, drought tolerance, pathology and grain quality investigations.

Research on acid soil constraints could benefit both the LDC's and the U.S. in several ways. Al-tolerant germplasm will help increase sorghum production in acid soils in both areas with less inputs, but the 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 in U.S. hybrids will come if there is a large enough market demand for this product. The demand for the improved varieties and hybrids in Latin America and Central Africa should be high for these food and feed grain deficient countries.

Objectives Related to Constraints:

The five project objectives relate directly to acid soil constraints to sorghum production discussed for Colombia and other acid soil areas in South America. They include: (a) screening and identification of new sources of tolerance; (b) development of improved sorghums with enhanced levels of acid soil tolerance with selection and evaluation in both the U.S.A. and LDC's; (c) distribution of new germplasm sources, improved breeding lines, early generation breeding germplasm, and standard regional yield trials for use and selection by LDC's; and (d) regional training and assistance to Latin American scientists in the use of effective breeding and screening methods for the adaption of sorghum and pearl millet to acid soils.

Host Country Collaboration and Work Sites

The main breeding and evaluation research will be accomplished at CIAT-Palmira, CIAT-Quilichao, ICA-La Libertad, and Arauca, Colombia and at Mississippi State University. Breeding effort by ICA will be conducted at Nataima and La Libertad with evaluation at La Libertad and other acid soil sites in the region. INTSORMIL breeding and screening activities will be conducted via collaboration with MS-104 winter nursery research in Colombia and other evaluation efforts in Africa.

Uniform regional yield trials will be conducted at the following sites: Colombia-Quilichao, La Libertad, and Arauca; Venezuela, Peru, and Brazilian sites as determined by National Programs staff.

In cooperation with other INTSORMIL Projects, drought tolerant sorghum germplasm (TAM-122) will be evaluated in Motilonia (collaboration with FENALCE) on the Atlantic Coast of Colombia and at Nataima. Pearl millet germplasm (UNL-118 and KSU-101) will be evaluated at regional test sites used for sorghum. Phosphorus efficiency research will be conducted in cooperation with UNL-114. Studies concerning sorghum in food products will involve direct consultation between ICA and INTSORMIL Food Quality Projects.

Research Procedures to be Followed:

Detailed annual workplans are developed among ICA, INTSORMIL, FENALCE, and El Alcaravan and become a formal part of INTSORMIL's collaborative effort. An operating budget is developed to support the research to be conducted as formalized in the workplans.

Breeding material will be generated from crosses among Al-tolerant sources, agronomically elite lines, and new sources of tolerance. The material will be screened in the field in Colombia for Al tolerance and agronomic type, and in the U.S. for agronomic type, maturity, plant height, and photoperiod sensitivity. Yield trials of the most agronomically acceptable Al-tolerant lines identified will be conducted by ICA at several locations in the Piedmont areas of the Llanos. Several of these trials will be on-farm-trials as a doublecrop following rice. ICA will conduct economic analyses on these trials in preparation of release of Al-tolerant varieties. ICA agronomists will also conduct fertilizer, plant population, and other agronomic triais at La Libertad. The most Al-tolerant selections will be distributed to regional collaborators as yield trials. Winter and seed increase nurseries will be conducted in cooperation with MSU-104.

The research to be conducted in Arauca in collaboration with El Alcaravan will be totally funded by the El Alcaravan Foundation. This is a new research site for INTSORMIL and both normal and acid soils are found in this area of Colombia. Selected advance material as well as regional yield trials will be evaluated at this site.

Measures of Success:

This project has stimulated and assisted many Latin American national programs to establish research activities to adapt sorghum to acid soils as measured by the many requests for Al-tolerant sorghum germplasm. Two INTSORMIL trained sorghum breeders have returned to Colombia, one as PI of MSU-111 and the other as the principal ICA sorghum breeder for acid soils at La Libertad.

The long-range objectives are to develop food and feed grain A, B, and R-lines which will produce hybrids tolerant to Al and Mn toxicities and are efficient in extracting P from soils in which low-input techniques are used. The ultimate success of this project will be when seed of these Al-tolerant varieties and hybrids are provided to farmers for commercial sorghum production on acid soils in Colombia and other countries with acid soil production constraints. Another important measure of success is the use made in the U.S. of the germplasm identified or developed in this project.

Anticipated Reports and Articles

A number of journal articles, proceedings of workshops and other publications developed from research conducted under this project will be published in the next five years. In cooperation with MS-104, attempts will be made to release one B-line and one R-line Al-tolerant, random-mating populations; five Al-tolerant, photoperiod sensitive, high yielding R-lines; and three Al- tolerant, photoperiod insensitive R-lines.

General Comments

The INTSORMIL Colombian collaborative site project is using INTSORMIL and outside funds to aid 10 Colombian students working toward their B.S. degrees with their thesis research in sorghum. This helps INTSORMIL and ICA to conduct sorghum research at a very reasonable cost. It also has the positive benefit of identifying students for graduate programs at INTSORMIL institutions.

Progress (last two years)

INTSORMIL research in the collaborative site of Colombia operates under two formal agreements. In 1981 a Memorandum of Intention was signed by the Directors of INTSORMIL, ICRISAT, and CIAT. Sorghum germplasm enhancement research started in 1982 was formalized by a Memorandum of Agreement between the National Program of Colombia (ICA) and INTSORMIL which was signed in 1988. Specific long-range goals in Colombia now include research on pearl millet, drought tolerance, plant pathology, entomology and grain quality.

The acid soil breeding and screening research on sorghum and pearl millet conducted under this project and MS-104 has attracted outside funding to INTSORMIL. The El Alcaravan Foundation, a consortium of petroleum companies operating in Colombia which includes Oxidental Petroleum, is providing INTSORMIL funds for five years to conduct sorghum and pearl millet breeding and evaluation research in the territory of Aranca. The production and extension oriented organization, FENALCE, is also providing funds in the area of drought tolerance research. This outside funding will not only benefit overall sorghum and millet research in Colombia, but will also assist ICA scientists by supplying equipment and other support of research goals in the acid soil Eastern Plains (Llamos) of Colombia.

Two recent graduates, financially supported by INTSORMIL, have returned to Colombia to continue acid soils research and to strengthen ICA and INTSORMIL collaboration. Dr. Guillermo Munoz (Ph.D., MSU, May 88) was appointed INTSORMIL PI for the Colombian collaborative site in July 1988. Mr. Cesar Ruiz (M.S., MSU, Dec. 87) is ICA's sorghum breeder at the main acid soil research station at La Libertad. Both of these graduates strengthen the Colombian National Sorghum Improvement Program.

The INTSORMIL Colombian collaborative site is using INTSORMIL and outside funds to help 10 Colombian students working toward their B.S. degrees with their thesis research on sorghum. This allows INTSORMIL and ICA to conduct sorghum research at a very reasonable cost. It also has the positive benefit of identifying students for graduate programs in INTSORMIL institutions. Additional trained individuals will assist ICA and agricultural industry in their research activities in Colombia and adjacent countries.

Success stories

INTSORMIL acid soil breeding and screening research on sorghum and pearl millet has attracted outside funding. El Alcaravan Foundation, a consortium of petroleum companies operating in Colombia, has supplied equipment to ICA and has agreed to fund sorghum and millet germplasm enhancement efforts in the territory of Aranca for five years. This commitment has resulted in a 2:1 leveraging of INTSORMIL funds to support research in Colombia which is consistent with the mission of INTSORMIL.

The INTSORMIL Colombian collaborative site project is using INTSORMIL and buy-in funds to help 10 Colombian students complete their B.S. degree thesis research on sorghum. This allows INTSORMIL and ICA to conduct sorghum research at a very reasonable cost. Additional trained individuals will assist ICA and agriculture industry with research activities in Colombia and adjacent countries.

Benefits to U.S. and L.D.C. Agriculture

Outside funding has strengthened INTSORMIL institution building activities by providing human resources, equipment, and facilities to ICA. Research on acid soil constraints could benefit both L.D.C. and U.S. agriculture in several ways. Al-tolerant germplasm will help increase sorghum and millet production in acid soils in both areas with less inputs. High yielding hybrids with acid soil stress tolerant characteristics will be of benefit to U.S. farmers in acid soil areas in the Southeastern U.S. Multinational Seed Companies are more interested in hybrids for their U.S. and overseas operations than varieties. The demand for these stress tolerant hybrids should also be high for the food and feed grain deficient countries in Latin America and Central Africa.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: Sustainable Production of Sorghum and Pearl Millet in Fragile, Tropical Acid Soils

Project Leader: Lynn Gourley **Project Number:** MSU-111

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=MSU111	--	----------				
Staff Salaries & Benefits	24.95	26.14	27.52	33.46	35.05	147.12
Post Doctorates	9.58	10.03	10.56	12.84	13.45	56.46
Graduate Students	10.00	10.00	11.00	13.00	13.00	57.00
Other Salaries	12.47	13.07	13.76	16.73	17.52	73.55
Supplies	10.84	11.35	11.95	14.53	15.22	63.89
Equipment	3.91	4.09	4.31	5.24	5.49	23.04
Travel	14.11	14.78	15.57	18.93	19.82	83.21
Other Direct Costs	9.70	10.16	10.70	13.01	13.63	57.20
Overhead	30.74	32.21	33.92	41.24	43.19	181.30
	126.30	131.83	139.29	168.98	176.37	742.77

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=MS111	--	----------				
University Staff	35.28	37.04	38.90	40.84	42.88	194.94
Staff Benefits	6.70	7.04	7.39	7.76	8.15	37.04
Post Doctorates	6.30	6.62	6.95	7.29	7.66	34.81
Other Salaries	2.52	2.65	2.78	2.92	3.06	13.92
Supplies	1.26	1.32	1.39	1.46	1.53	6.96
Travel	4.73	4.96	5.21	5.47	5.74	26.11
Other Direct Costs	12.60	13.23	13.89	14.59	15.32	69.62
Overhead	13.04	13.69	14.37	15.09	15.85	72.04
	82.43	86.55	90.87	95.42	100.19	455.45

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=MS111	--	----------				
University Staff	33.60	33.60	33.60	33.60	33.60	168.00
Staff Benefits	6.38	6.38	6.38	6.38	6.38	31.92
Post Doctorates	6.00	6.00	6.00	6.00	6.00	30.00
Other Salaries	2.40	2.40	2.40	2.40	2.40	12.00
Supplies	1.20	1.20	1.20	1.20	1.20	6.00
Travel	4.50	4.50	4.50	4.50	4.50	22.50
Other Direct Costs	12.00	12.00	12.00	12.00	12.00	60.00
Overhead	12.42	12.42	12.42	12.42	12.42	62.08
	78.50	78.50	78.50	78.50	78.50	392.50

Tropical Sorghum Conservation and Enhancement in Honduras and Central America

Project TAM-131
Dan Meckenstock
Texas A&M University

Collaborating Institutions

Host Country

Dr. Francisco Gomez, SRN, National Sorghum Program (NSP), breeder, Honduras
Ing. Lindolfo Fernandez, SRN, NSP, Agronomist, Comayagua, Honduras
Ing. Evelyn Oviedo, SRN, NSP, Agronomist, Choluteca, Honduras
Ing. Alejandro Palma, EAP, Sorghum Project, Agronomist, El Zamorano, Honduras
Dr. Keith Andrews, EAP, MIPH, Entomologist, El Zamorano, Honduras
Ing. Sonia Morales, CENTA, NSP, Breeder, San Andres, El Salvador
Agr. Manuel Santos, CENTA, NSP, Breeder, San Andres, El Salvador
Ing. Edgar Salguero, Head, ICTA, NSP, Breeder, Jutiapa, Guatemala
Ing. Oscar Martinez, ICTA, NSP, Breeder, Zacapa, Guatemala
Ing. Jose Marquez, ICTA, NSP, Agronomist, Escuintla, Guatemala
Dr. Compton Paul, CIMMYT/ICRISAT, Agronomist, El Batan, Mexico
Dr. Tom Hash, CIMMYT/ICRISAT, Breeder, El Batan, Mexico
Agr. Rene Clara, CIMMYT/ICRISAT, Breeder, El Batan, Mexico

U.S.

Dr. Darrell Rosenow, Texas A&M University Agricultural Experiment Station, Lubbock, TX
Dr. Gary Peterson, Texas A&M University Agricultural Experiment Station, Lubbock, TX
Dr. Fred Miller, Sorghum Breeder, Texas A&M University, College Station, College Station, TX
Dr. Lloyd Rooney, Cereal Chemist, Texas A&M University, College Station, College Station, TX
Dr. Richard Frederiksen, Pathologist, Texas A&M University, College Station, College Station, TX
Dr. Frank Gilstrap, Entomologist, Texas A&M University, College Station, College Station, TX
Dr. Henry Pitre, Entomologist, Mississippi State University, Mississippi State, MS
Dr. Max Clegg, Agronomist, University of Nebraska, Lincoln, NE
Dr. John Sander, Agricultural-economist, Purdue University, West Lafayette, IN

Project Objectives

To increase the quality of life of rural people via the conservation of sorghum biodiversity and its enhancement to reduce yield loss and increase productivity and utilization.

To support sorghum research in the region through joint planning and implementation, collection and evaluation of local landrace populations, development and distribution of new technologies, joint release of enhanced germplasm, and training of local scientists.

To transfer new sorghum technologies to local farmers via on farm demonstrations and publication of research results.

Introduction - Host Country Constraints

More than 170,000 hectares or 90% of the sorghum grown in Honduras and El Salvador is landrace tropical sorghum called "*maicillo criollo*." This tall, late maturing, food type sorghum is preferred by resource poor farmers who traditionally intercrop sorghum with maize on marginal land--sorghum serves as "drought crop insurance." Although maicillo almost always guarantees a harvest, the primary constraint to its production is low yield potential--national yield in Honduras and El Salvador oscillates around one metric ton per hectare. Foliar diseases, sorghum downy mildew, soil insects pests, and a complex of lepidopterous defoliators called "*langosta*" are also production constraints.

Attempts to replace maicillo with introduced varieties and hybrids in the 1960's and 1970's failed be-

cause exotic germ plasm is not adapted to intercropping with maize. Consequently, TAM-131 has focused on the conservation of local genetic diversity and its enhancement rather than its replacement. This approach has identified unexpected constraints like lack of technical information on sorghum-maize intercropping and an inadequate photoperiod sensitive sorghum germ plasm base which would provide a rapid solution to the problem. These deficiencies have necessitated base line studies on maicillo growth and development, intercropping performance, and creation of a working collection of photoperiod sensitive sorghum.

Maicillo has an unique aggregation of genes that imparts a distinct sensitivity to photoperiod and low respiration rate that enable it to survive under the maize canopy. Because day lengths of 12 h or less are necessary for floral differentiation, improvement of maicillo must be carried out in the region where it is grown (between Lat. 12° to 15° N). This photoperiod sensitivity requirement also dictates that only one generation per year can be advanced under normal field conditions. These constraints to improvement connote that the development of enhanced maicillo is a long term endeavor and that considerable investment in time and resources will be required before impact is felt at the farm level.

Objectives Related to Constraints

The overall aim is to increase real income earned from producing sorghum and thereby increase purchasing power and the quality of life of rural people in Honduras. To reach this objective, a three part strategy based on near term, intermediate range, and long range goals has been adopted. Taken together, this design will deliver a succession of impacts over a five to fifteen year period. This approach will also allow farmers to choose the level of technology best accommodated by their economic situation and insures that germ plasm will not be a limiting factor to production.

Near term goals focus on the introduction and release of improved varieties and hybrids. This effort deals with the screening of existing photoperiod insensitive material for adaptation to the region and recognizes that considerable gain can be made in a brief period of time and with little investment by tapping these resources. Although this activity addresses only 10% of the sorghum acreage in Honduras, it serves to build the seed production and extension network that will be used to deliver enhanced maicillos to target groups. Also, introduced releases will provide a measure of success while maicillo enhancement is in an early stage.

To date near term goals have been met with the introduction and SRN joint release of three food type sorghum cultivars: "Tortillero" (1983), hybrid "Catracho" (1984), and "Sureño" (1985). The next planned release is a forage sorghum hybrid with resistance to sorghum downy mildew. Follow-up studies of these released cultivars in forty-seven on farm demonstrations in pure stand in 1988 indicate that Sureño and Catracho increase grain yield over traditional cultivars 23% and 38%, respectively. These results strike a blow against the belief that improved germplasm does not perform as well as the varieties they replace when grown under traditional agricultural management. The magnitude of their yield advantage increases considerably when seed is treated with a systemic insecticide and 60 kg/ha nitrogen is applied at floral differential. Utilization of these additional inputs boost yield 68 and 113%, respectively. These results demonstrate the superiority of improved germplasm at both high and low input levels. Catracho also exhibits the quantum jump in productivity that can be achieved with hybrids. Family income increases on average from \$1.60 per day ha^{-1} to \$2.70 with Sureño and \$4.40 with Catracho. Both Sureño and Catracho are widely adapted. In Mexico, they have produced test plot yields as high as 10.1 and 11.4 t/ha, respectively (TAM-121). In Ghana, Sureño is used extensively by Global 2000 and has produced spectacular results.

Intermediate range goals focus on conservation and enhancement of tropical sorghum landrace populations in Central America called "*maicillo criollo*" (MC). The midterm goal calls for the release of enhanced traditional varieties designated "*maicillo mejorado*" or "*maicillo enano*" (ME). This task builds on the collection and evaluation of landrace populations, and their transformation via hybridization with exotic germplasm. Enhanced maicillos will upgrade small farmer food production for self-sufficiency and sustain the conservation of local germplasm *in-situ* via an informal network of village level landrace custodians. The perceived *in-situ* conservation will forge a rural landscape with a mosaic of modern, enhanced traditional, and traditional varieties and technologies that will conserve and increase biodiversity through assisted and natural introgression of exotic genes into sorghum landrace populations. Enhanced maicillos have produced up to 58% more grain yield than their maicillo parent in test plots and are resistant to sorghum downy mildew. Five improved maicillos are currently undergoing extensive on-farm testing, one of which is in Guatemala. A release is expected soon in Honduras.

In keeping with the midterm aim, over 240 landrace accessions have been collected, 149 of which have been classified to race. Most accessions are caudatum-kafir or caudatum-durra integrated races. Forty-four maicillos have been found to possess useful genes and have been placed in the TAMU/USDA sorghum conversion program as an additional conservation measure. Once converted, these materials will contribute genes for disease and insect resistance, drought tolerance, and cereal

quality to breeders located in United States and other temperate zones. Partially converted line SC1207-2, has excellent food quality (TAM-126), is resistance to anthracnose in Brazil along with 23 other maicillos (TAM-124), and has shown superior combining ability with U.S. lines. The hybrid A155*SC1207-2, has produced test plots yields as high as 13.4 t/ha in Mexico (TAM-121). Four maicillos have been identified to suppress population density increase of *Spodoptera frugiperda* through antibiosis (MSU-105).

Long term goals call for the extension of enhanced maicillo to "hybrid maicillo" for the purpose of maximizing small farmer benefit and shifting subsistence agriculture to production agriculture. This task builds on the elite germ plasm and extension framework put in place with previous goals. Although male parents are available, maicillo female lines will not be ready until 1990. Experimental hybrids with 25% maicillo under drought stress were observed to be superior in 1987. Yield testing initiated in 1988 showed the top of the test in the 1988 International Improved Maicillo Yield Trial was a hybrid with 25% maicillo germplasm. Currently, ten hybrid maicillos ranging from 25 to 75% maicillo germplasm are being tested along side their maicillo relatives in El Salvador, Guatemala and Honduras for adaptation, yield potential, and yield stability.

Host Country Collaboration and Work Sites

Project TAM-131 operates under a memorandum of understanding with the Honduran Ministry of Natural Resources (1981) and with the Panamerican Agricultural School (1988). Government of Honduras and AID/H provide significant local currency support (PL480) for project activities. Regional networking is conducted via information, germplasm, and scientist exchange, and collaborative research with the Ministries of Agriculture in El Salvador and Guatemala, and ICRISAT international center. Nine INTSORMIL projects representing four universities also collaborate and provide backstopping. Project TAM-131 serves as a base for conducting graduate student research in-country; four advanced degrees have been completed and five are in process.

Seven locations have been established for screening early generation material for adaptation, resistance to multiple diseases, drought tolerance and other stress. Because TAM-131's germplasm is not restricted, these sites serve as the introduction point for enhanced maicillo into the surrounding area. After preliminary evaluation, collaborators can include superior performers into their program. Eventually, some ME will find their way into farmer's hands via the local on-farm testing program. Summary of sites follows:

Institution/Location	Resistance/Tolerance Evaluated
Ministry of Natural Resources, Honduras	
La Lujosa, Choluteca	Gray Leaf Spot, Acremonium Wilt, Zonate Leaf Spot, Oval Leaf Spot, Ladder Spot, and high temperature
Las Playitas, Comayagua	SDM (pathotype P5), Gray leaf Spot, Ladder Spot.
Escuela Agricola Panamericana, Honduras	
El Zamorano, Fco, Morazan	Rust, Gray Leaf Spot, SDM (pathotype P1).
RAPACO, El Paraiso	Late season drought, "simultaneo" intercropping, adaptation to low input/marginal land.
Centro de Tecnologia Agricola, El Salvador	
Santa Cruz Porillos	Low input, "aporque" intercropping, Gray Leaf Spot.
San Andres	Fertile soil, Gray Leaf Spot.
Instituto de Ciencia y Tecnologia Agricolas, Guatemala	
Jutiapa	Gray Leaf Spot, Rust, Zonate Leaf Spot, "relevo" intercropping.

The purpose of this elaborate network is to develop widely adapted, high yielding cultivars with resistance to multiple diseases and tolerance of an array of abiotic stresses. This network not only provides a mechanism for germplasm distribution to national programs but more importantly creates a multiplier effect when national programs cross their elite materials into honduran ME and return these derivatives to the network for regional testing.

Research Procedures

Germplasm enhancement will be based on introduction, collection, and hybridization of exotic lines and maicillo. Work will concentrate on the improvement of local photoperiod sensitive varieties called maicillo criollo. Broad crosses between elite introduced germplasm and superior maicillo landraces will be made to increase genetic variability within the maicillo population. Progeny will be selected for intermediate plant height (2-dwarf), higher yield potential, longer head length, and host plant resistance to local disease. Plant maturity and cereal quality for tortilla utilization will be maintain comparable to maicillo. Early generation material will be evaluated in single row plots at 3 to 7 locations to select for combined resistance to diseases (see above list), broad adaptation, and heat and drought tolerance. Superior advanced varieties (F4 or greater) and experimental maicillo hybrids will be evaluated for yield and stability in Honduras, El Salvador and Guatemala in the replicated performance tests. Development of hybrid maicillo is a high

priority and an off season nursery will be used to advance male-sterilization of MC and ME lines. A paired progeny backcross method is used for male-sterilization and the first maicillo A-lines will complete five backcrosses December 1989. Also, enhanced maicillo males with superior combining ability will be identified. Superior ME lines will be placed in the DMV germ plasm bank and maicillo landraces will be collected for the MC germplasm bank. Crosses between MC, ME, and exotic germplasm will continue as the primary means of increasing genetic variability. Notes will be taken on F2 population to identify maicillo genotypes for seed color, plant height and other simply inherited traits.

On-farm Research demonstration plots with graduating levels of technology will be continued to introduce farmers to new cultivars and production technology. Currently, local varieties and technology are compared to: 1) improved cultivars, 2) improved cultivars plus seed treatment, and 3) improved cultivars, seed treatment, plus nitrogen fertilizer. However, these levels may be adjusted as needed. The number of demonstrations will range from 50 to 100 sites depending on what the SRN extension service can bear. Enhanced maicillo will be intercropped with indigenous maize populations in the spring while improved varieties and hybrids will be planted in relay with maize in the fall.

Special Studies will be conducted by graduate students to obtain critical information for the overall success of the INTSORMIL effort. Completed studies have elucidated the predominant sorghum diseases in Honduras and strategies for their control, fall armyworm and neotropical stemborer population dynamics, identification of soil inhabiting phytophagous arthropod pests, impact of new sorghum biotechnologies in southern Honduras, and nutrition status of preschool rural children in areas where sorghum is grown. Other areas that have been identified for investigation include MC host plant resistance (antibiosis) to fall armyworm, comparative growth analysis of MC, ME, and conventional sorghum in maize intercropping, nitrogen efficiency of MC and ME, determination of the yield advantage of hybrid maicillo and ME combining ability.

Measures of Success

Collaborative research will be evaluated by on-site review; i.e., EEP review, PI visits, and field days for farmers and extension personnel. Research results will be published and distributed. Quantitative measures of success include; 1) number of varieties and hybrids released, the acreage on which they are grown and yield compared to national average, 2) number of on farm demonstrations and percentage of farmers that adopt disseminated technology, 3) number of elite lines distributed, 4) number of graduate students that complete their research in Honduras, 5) placement of INTSORMIL trained personnel in research positions in the region.

Anticipated Reports and Articles

- Forage hybrid ATx623*Tx2784 bulletin.
- Proceedings of the maicillos criollos and other sorghums in middle America workshop.
- Catracho Bulletin
- Sureño Bulletin
- Sorghum Production guide
- PCCMCA (2 to 4 each year)
- CLAIS (1 to 2 per year)

General Comments

Project TAM-131 provides logistical support for INTSORMIL graduate students conducting research in Honduras. It also assists PI's in distribution of germplasm and growing special nurseries. The establishment of a forth year at the EAP has created the opportunity to direct research for the "Ingeniero Agronomo" degree at the EAP. This opportunity will provide an excellent means for identify candidates for graduate study. As the project moves closer towards achieving midterm and long range goals, expansion into El Salvador and Guatemala with additional collaborative research will be attempted.

Progress (last two years)

Sorghum breeding project TAM-131, "Tropical Sorghum Conservation and Enhancement in Honduras and Central America," has operated in Honduras since 1981. Its overall objective is to increase the quality of life of rural people in Honduras through genetic conservation and enhancement of sorghum to reduce yield loss and increase productivity and utilization. The project operates under a memorandum of understanding with the Honduran Ministry of Natural Resources (1981) and with the Panamerican Agricultural School (1988). Government of Honduras and AID/H provide significant local currency support for project activities through PL480. Regional networking is conducted via information, germ plasm, and scientist exchange, and collaborative research with the Ministries of Agriculture in El Salvador and Guatemala, and ICRISAT international center. Nine INTSORMIL projects representing four universities also collaborate and provide backstopping. Project TAM-131 serves as a base for conducting graduate student research

in-country; four advanced degrees have been completed and five are in process.

Near term goals focus on enhancement of improved varieties and hybrids which makeup roughly 10% of the sorghum acreage in Honduras. These have been met with the introduction and joint release of Tortillero (1983), hybrid Catracho (1984), and Sureño (1985). The next planned release is a forage sorghum hybrid with resistance to sorghum downy mildew.

Follow-up studies of released cultivars are underway to demonstrate their efficiency and to determine their level of acceptance and impact. Forty-seven on farm demonstrations in pure stand were completed in 1988 and these indicate that Sureño and Catracho increase grain yield over traditional cultivars 23% and 38%, respectively. These results strike a blow against the belief that improved germplasm does not perform as well as the varieties they replace when grown under traditional agricultural management. The magnitude of their yield advantage increases considerably when seed is treated with a systemic insecticide and 60 kg/ha nitrogen is applied at floral differential. Utilization of these additional inputs boost yield 68 and 113%, respectively. These results demonstrate the superiority of improved germplasm at both high and low input levels. Catracho also exhibits the quantum jump in productivity that can be achieved with hybrids. Honduran farmers look upon Sureño and Catracho with admiration and speak highly of these cultivars. Family income increases on average from $1.60 per day ha-1 to $2.70 with Sureño and $4.40 with Catracho. Both Sureño and Catracho were developed under a multi-location testing program and are widely adapted. In Mexico, they have produced test plot yields as high as 10.1 and 11.4 t/ha, respectively (TAM-121). In Ghana, Sureño is used extensively by Global 2000 and has produced spectacular results.

Midterm goals focus on conservation and enhancement of tropical sorghum landrace populations in Central America called "*maicillo criollo*," which have diverged into a unique group of sorghum adapted to intercropping with maize. Maicillo comprises about 90% of the sorghum acreage in Honduras and is preferred by resource poor farmers who traditionally intercrop sorghum with maize on marginal land, maicillo serves as "drought crop insurance". The midterm goal calls for the release of enhanced traditional varieties designated "*maicillo mejorado*." This task builds on the collection and evaluation of landrace populations, and their transformation via hybridization with exotic germplasm. Enhanced maicillos will upgrade small farmer food production for self-sufficiency and sustain the conservation of local germplasm *in-situ* via an informal network of village level landrace custodians. The perceived *in-situ* conservation will forge a rural landscape with a mosaic of modern, enhanced traditional, and traditional varieties and technologies that will conserve and increase biodiversity through assisted and natural introgression of exotic genes into sorghum landrace populations. Enhanced maicillos have produced up to 58% more grain yield than their maicillo parent and are resistant to sorghum downy mildew. Five improved maicillos are currently undergoing extensive on-farm testing, one in Guatemala. A release is expected soon in Honduras.

In keeping with the midterm aim, over 240 landrace accessions have been collected, 149 of which have been classified to race. Most accessions are caudatum-kafir or caudatum-durra integrated races. Forty-four maicillos have been found to possess useful genes and have been placed in the TAMU/USDA sorghum conversion program as another conservation measure. Once converted, these materials will contribute genes for disease and insect resistance, drought tolerance, and cereal quality to breeders located in the United States and other temperate zones. Partially converted line SC1207-2, has excellent food quality (TAM-126), is resistance to anthracnose in Brazil (TAM-124), and has shown superior combining ability with U.S. lines. The hybrid A155*SC1207-2, has produced test plot yields as high as 13.4 t/ha in Mexico (TAM-121). Four maicillos have been shown to suppress population density increase of *spodoptera frugiperda* (MSU-105).

Long term goals call for the extension of enhanced maicillo to "hybrid maicillo" for the purpose of maximizing small farmer benefit and shifting subsistence agriculture to production agriculture. This task builds on the elite germ plasm and extension framework put in place with previous goals. Although male parents are available, maicillo female lines will not be ready until 1990. Experimental hybrids with 25% maicillo under drought stress were observed to be superior in 1987. Yield testing was initiated in 1988 and the top of the test in the 1988 International Improved Maicillo Yield Trial was a hybrid maicillo. Currently, ten hybrid maicillos ranging from 25 to 75% maicillo germplasm are being tested along side their maicillo relatives in El Salvador, Guatemala and Honduras for adaptation, yield potential, and yield stability.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: Tropical Sorghum Conservation and Enhancement in Honduras and Central America

Project Leader: Dan Meckenstock/Darrell Rosenow **Project Number:** TAM-131

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=TAM131	--	----------				
Staff Salaries & Benefits	35.64	40.39	42.37	44.15	46.33	208.88
Post Doctorates	13.68	15.50	16.26	16.95	17.78	80.17
Graduate Students	14.00	16.00	16.00	17.00	18.00	81.00
Other Salaries	17.82	20.20	21.19	22.08	23.17	104.46
Supplies	15.48	17.54	18.40	19.18	20.12	90.72
Equipment	5.58	6.32	6.63	6.91	7.25	32.69
Travel	20.16	22.85	23.97	24.98	26.21	118.17
Other Direct Costs	13.86	15.71	16.48	17.17	18.02	81.24
Overhead	43.92	49.78	52.22	54.41	57.10	257.43
	======	======	======	======	======	=======
	180.14	204.29	213.52	222.83	233.98	1054.76

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=TAM131	--	----------				
University Staff	59.84	62.83	65.98	69.28	72.74	330.67
Staff Benefits	15.56	16.34	17.15	18.01	18.91	85.97
Supplies	2.03	2.13	2.24	2.35	2.47	11.23
Equipment	6.30	6.62	6.95	7.29	7.66	34.81
Travel	5.04	5.29	5.56	5.83	6.13	27.85
Other Direct Costs	17.69	18.58	19.51	20.48	21.51	97.76
Overhead	19.53	20.51	21.54	22.61	23.74	107.93
	======	======	======	======	======	=======
	126.00	132.30	138.92	145.86	153.15	696.23

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=TAM131	--	----------				
University Staff	56.99	56.99	56.99	56.99	56.99	284.97
Staff Benefits	14.82	14.82	14.82	14.82	14.82	74.09
Supplies	1.94	1.94	1.94	1.94	1.94	9.68
Equipment	6.00	6.00	6.00	6.00	6.00	30.00
Travel	4.80	4.80	4.80	4.80	4.80	24.00
Other Direct Costs	16.85	16.85	16.85	16.85	16.85	84.25
Overhead	18.60	18.60	18.60	18.60	18.60	93.02
	======	======	======	======	======	=======
	120.00	120.00	120.00	120.00	120.00	600.00

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Sustainable Production, Processing and Marketing Systems for Local Cereals in Mali.

Dr. Lloyd Rooney
Texas A&M University

Collaborating Institutions

Host Country

Dr. Moussa Traore, Institut Economie Rurale, Bamako, Mali
Dr. Oumar Niangado, Institut Economie Rurale, Cinzana, Mali
Md. Mariane Haidara, Institut Economie Rurale, Bamako, Mali
Md Salimata Coulibaly, Institut Economie Rurale, Bamako, Mali
Mr. Abdoulaye Traore, Institut Economie Rurale, Bamako, Mali
Mr. Mamourou Djourte, Institut Economie Rurale, Bamako, Mali
Mr. Amadou Sy, Institut Economie Rurale, Bamako, Mali
Dr. Yacouba Doumbia, Entomology, IER, Bamako, Mali
Dr. N. Beninati, Plant Breeder, ICRISAT, IER, Bamako, Mali
Dr. S.V.C. Shetty, Agronomist, ICRISAT, IER, Bamako, Mali

U.S.

Dr. D.T. Rosenow, Texas A&M Agr.icultural Experiment Station, Lubbock, Texas.
Dr. C.Y. Sullivan, Dept. of Agronomy, University of Nebraska, Lincoln, Nebraska
Dr. David Andrews, Dept. of Agronomy, University of Nebraska, Lincoln, Nebraska
Dr. J. Maranville, Dept. of Agronomy, University of Nebraska, Lincoln, Nebraska
Dr. A.B. Onken, Texas A&M Agricultural Experiment Station, Lubbock, Texas
Dr. R.A. Frederiksen, Texas A&M University, College Station, Texas.
Dr. George Teetes, Texas A&M University, College Station, Texas

Introduction

The research program in Mali will continue to be conducted with stronger interactions between IER, ICRISAT, INTSORMIL and TROPSOILS. In addition, the Peanut, Bean and Cowpea CRSP's will be integrated into the research program especially in the areas of cropping systems and utilization.

Project Objectives

The objectives of the Collaborative Sorghum/Millet Research Program in Mali will be aimed at developing systems to produce sustainable yields of sorghum and millet for food, under the marginal cropping conditions of the Sahelian Region. Drought, poor soil fertility, soil toxicity, insects and diseases are major constraints. Productivity of local varieties is very low, but they have a high degree of adaptation with very good food quality.

We will develop new cultivars with improved yields of good quality grain. The new cultivars will have built in resistance to major biological stresses with drought and heat resistance added.

Millet and Sorghum utilization is a major constraint because traditional processing requires daily expenditure of time and energy to dehull, mill and prepare traditional foods. Attractive, desirable shelf stable foods from sorghum and millet produced at the local level using simple technologies are required. The substitution of sorghum flours for wheat and rice products can be potentially useful in many areas of Africa, Asia and Latin America. Sorghum with improved processing properties accompanied by improved technology could alleviate this major constraint to use of sorghum in urban areas. Parboiling of millet and sorghum is promising as a village level technique to produce rice sustitutes i.e. MIL RI & SORI. Value added processing could enhance income generation and produce more stable markets for Sorghum & Millet above its traditional use. Thus, surplus grain would be converted into marketable products while generating income on the the farm.

The major objectives with examples are discussed. These plans will be updated each year contingent with progress and available opportunities. Each P.I. in IN-

TSORMIL is paired with an IER P.I. and is responsible for conducting research in their area.

Genetic Enhancement

Breeding for improved yield and adaptation, disease resistance, grain quality, drought, insect resistance, and improved nutrient efficiency.

Objectives

To identify introduced germplasm and elite local cultivars or breeding lines with high levels of the above traits.

To develop improved cultivars adapted to Malian conditions with high yield potential, good levels of disease, insect and drought resistance and acceptable food quality.

Bio interactive Stresses

Entomology Objectives:

To evaluate practical techniques for screening sorghums for resistance to panicle feeding bugs, to relate resistance to kernel characteristics and to cooperate with breeders in the development of sorghum with resistance to head bugs.

To relate panicle feeding bug abundance with kernel damage, pathogen infection and determine its affects on food quality.

To determine methods of controlling the head girdler and other major pests of millets.

Pathology Objectives

Develop an integrated approach to solving the major disease problems of Mali through interaction of pathology and breeding.

Long smut anthracnose and sooty stripe are major diseases in Mali that will be managed.

Sustainable Production Systems

Soil Fertility and Water use Efficiency and Soil Toxicity Problems Objectives

Determine the effects of soil fertility on water use and grain production.

Investigate the factors affecting soil toxicity problems in Malian soils.

Stress Physiology

The objective is to identify breeding lines for various types of drought and other stress resistance and to study the underlying physiological mechanisms through which such resistance is obtained.

Utilization, Quality and Marketing of Local Cereals

Objectives

To define grain characteristics related to desirable food quality in sorghum and millets and work with breeders to evaluate new lines and cultivars for food quality.

To investigate factors affecting grain characteristics and subsequent effects on grain quality. The effect of head bugs and grain moulds on grain quality is of special significance.

To develop new food products from sorghum, and millet with increased utilization and marketing potential.

Collaborate with peanuts, beans and cowpea CRSP's to develop new food products from combinations of these major commodities.

Coordinate marketing and economic studies with product development activities to achieve profitable systems of production and processing.

Networking & Training

Student Training: Ten Malian graduate students are currently in INTSORMIL institutions for MSC and PhD training. Additional students are in the pipeline for training which will be expanded within constraints.

Malian scientists interact with West African scientists thru regional meetings and Dr. Da Sansan, Head, Burkinan Cereals program has visited Mali to exchange ideas and breeding materials. These efforts will be expanded.

Malian Food Technology laboratory personnel have visited ITA in Dakar and more interactions are planned between Mali, Niger, Senegal and Burkina.

Budget

Current annual budget of $60,000 is inadequate. Budget must be increased to 120K to provide for new thrust areas ie.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: INTSORMIL Mali Project

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=MALI	--	----------				
Staff Salaries & Benefits	35.64	40.39	42.37	44.15	46.33	208.88
Post Doctorates	13.68	15.50	16.26	16.95	17.78	80.17
Graduate Students	14.00	16.00	16.00	17.00	18.00	81.00
Other Salaries	17.82	20.20	21.19	22.08	23.17	104.46
Supplies	15.48	17.54	18.40	19.18	20.12	90.72
Equipment	5.58	6.32	6.63	6.91	7.25	32.69
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Other Direct Costs	13.86	15.71	16.48	17.17	18.02	81.24
Overhead	43.92	49.78	52.22	54.41	57.10	257.43
	======	======	======	======	======	=======
	180.14	204.29	213.52	222.83	233.98	1054.76

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=MALI	--	----------				
University Staff	13.13	13.78	14.47	15.19	15.95	72.52
Other Salaries	4.20	4.41	4.63	4.86	5.11	23.21
Supplies	12.60	13.23	13.89	14.59	15.32	69.62
Equipment	27.30	28.67	30.10	31.60	33.18	150.85
Travel	5.78	6.06	6.37	6.69	7.02	31.91
	======	======	======	======	======	======
	63.00	66.15	69.46	72.93	76.58	348.11

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=MALI	--	----------				
University Staff	12.50	12.50	12.50	12.50	12.50	62.50
Other Salaries	4.00	4.00	4.00	4.00	4.00	20.00
Supplies	12.00	12.00	12.00	12.00	12.00	60.00
Equipment	26.00	26.00	26.00	26.00	26.00	130.00
Travel	5.50	5.50	5.50	5.50	5.50	27.50
	======	======	======	======	======	======
	60.00	60.00	60.00	60.00	60.00	300.00

Sustainable Production, Processing and Marketing Systems for Local Cereals in Niger

Project PRF-109
John Axtell
Purdue University

INTSORMIL/INRAN Cooperators

Agronomy Program

Issoufou Kapran, Ibrahim Mohamadou, Maman Nouri, INRAN; John Clark, NAAR/Niger; Chandra Reddy, NAAR; Steve Mason, Minamba Bagayoko, and Helen Kasalu, Nebraska; Gebesa Ejeta, Purdue; and Richard Vanderlip, Kansas State

Breeding Program

Moussa Adamou, Issoufou Kapran and Charif Ari, INRAN; John Clark, NAAR/Niger; Lynn Gourley, Mississippi State; John Axtell and Gebisa Ejeta, Purdue University

Economic Program

Maliki Kadi, DECOR/INRAN; Mahaman Issa and O. Zarifa, INRAN; Barry Shapiro and John Sanders, Purdue University

Food Quality Program

M. Oumarou and Issoufou Kapran, INRAN; John Clark, NAAR; and Allen Kirleis, Purdue University

Millet Program

Ouendeba Bottorou, INRAN; Wayne Hanna, Georgia and Gebisa Ejeta, Purdue University

Pathology Program

Issoufou Kolo, INRAN; Omer El Hilu, ARC/Sudan; and Richard Frederiksen, Texas A&M University

Physiology

Charif Ari, Goube Gaoh and Abdourahmane Alou, INRAN; Jerry Maranville, Paresh Verma and Jerry Eastin, Nebraska

Agronomy Program

Agronomy and Cropping Systems: Stand Establishment of Grain Sorghum Lines

Principal Investigators: Host Country Scientists: Dr. John Clark, Dr. Issoufou Kapran. U.S. Collaborating Scientist: Dr. Stephen C. Mason, Dr. Gebisa Ejeta, Dr. Richard Vanderlip, Ms. Helen Kasalu (Graduate student from Zambia)

Research Objectives

Evaluate emergence and seedling survival of grain sorghum lines under Nigerien conditions.

Introduction

This research will be built on preliminary studies conducted in Niger in 1987 and Nebraska in 1988.

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Research Procedures

Collect emergence and seedling survival of grain sorghum lines to correlate to laboratory tests being conducted at Nebraska.

Agronomy and cropping systems: N contribution of intercropped cowpeas to pearl millet.

Principal Investigators: Host Country Scientists: Mr. Ibrahim Mahamadou, Mr. Maman Nouri, Dr. Chandra Reddy. U.S. Collaborating Scientists: Dr. Stephen C. Mason, Mr. Minamba Bagayoko (Graduate student from Mali)

Research Objectives

Complete three-year field study of immediate and residual nitrogen contribution of intercropped cowpea to pearl millet.

Introduction

Two-years of this research are completed, but the year 2 data has not been transmitted to me from Niger.

Research Procedures

Plant pearl millet sole crop on field plots established in 1988. Data to be collected includes grain yield, N concentration of millet glag leaves, and N removal in grain in stover.

Key Accomplishments to Date

Data from 1987 indicate that little immediate transfer of N from intercropped cowpea to pearl millet occurred

Breeding Program

Combining ability of aluminum tolerant sorghum hybrids in Niger.

Principal Investigators - Host Country Scientists: Moussa Adamou/John Clark. U.S. Collaborating Scientist: Drs. Lynn Courley and John Axtell

Research Objectives

The main purpose of this project is to evaluate different hybrids and lines of sorghum for tolerance to the acid soil conditions in Niger.The specific objectives are:

Evaluate known acid soil tolerant lines and varieties under Nigerien conditions.

Evaluate general and specific combining ability of these genotypes by evaluation of the performance of their hybrids in Niger.

Compare the performance of those lines and hybrids to some of the local Nigerien varieties grown on sandy soils.

Determine the level of tolerance to Al of these selected Nigerien local varieties in nutrient culture.

Introduction

Sorghum is considered to be among the five most important cereal crops in the world. It is grown on over 46 million hectares in both the temperate and tropical regions (FAO, 1983). It is one of the main sources of food calories in the semi-arid tropics.

In Niger, sorghum is considered as one of the major sources of food for the human population. In fact, it is the second major cereal crop after pearl millet. The cultivated area planted to sorghum is around 800,000 hectares for a total production of about 400,000 tons per year. Statistics for the recent African hunger crises have not yet been published and may be more alarming.

Despite its importance, sorghum yields in Niger have been declining over the past few years. This decline, in general, can be attributed to the decrease of annual rainfall as well as to the acidity of tropical soils. This is true especially for the sandy soils which constitute 3/4 of the total cultivated area in Niger. For these sandy soils, a long term solution has to be found in breeding sorghum for resistance to acid soil toxicities.

Soil acidity is considered a major growth-limiting factor for a number of crops in many areas of the world (Clark, 1982; Foy, 1984). Poor plant growth on acid soils varies in degree with soil pH, amount and type of clay mineral, level and kind of organic matter, level of salts, and plant species or genotype (Clark, 1982). The growth limiting factors of acid soils include: aluminum and manganese toxicities, and also deficiencies of some essential elements. Soil acidity develops from the weathering of acidic parent materials that were initially low in basic cations (Ca, Mg, K, and Na).

Plant species and cultivars within species differ widely in their tolerance to Al toxicity (Clark, 1982; Flores et al, 1988b; Gourley, 1987; and Kamprath and Foy, 1972). Al tolerance has been associated with pH increases in the root zone for some cultivars of wheat, barley, rice and maize. Al tolerance has also been found to be related to nitrogen, calcium, and phosphorus nutrition. Certain Al-tolerance wheat cultivars are characterized by the ability to use NO-3 effectively in the presence of NH+4. In

certain cultivars of wheat, barley, and soybeans, Al tolerance was associated with the plants' ability to resist Al-induced Ca deficiency.

There is a growing interest in Niger to consider an effective use of these sandy soils for some economically important cereals other than millet. Yet only a few of the local sorghum varieties are grown on these soils. No improved or exotic (introduced) sorghum variety has been reported to grow successfully over a period of years on these soils.

Genetic manipulation of crops to tolerate mineral stress is a practical approach to improve productivity on acid soils. Considerable research is being devoted to locate and identify crops and/or specific genotypes that can tolerate acid soil conditions (Flores et al., 1988b; Gourley, 1987). To achieve this, a basic understanding of crop responses to acid soil conditions is necessary.

Research Procedures

Samples of sandy soils from different regions in Niger will be analyzed for pH, aluminum content, and levels of basic cations and other essential elements. Some of these analyses will be carried out at the INRAN Soil Laboratory in Niamey and also at Mississippi State University.

Development of sorghum varieties and hybrids for use in Niger.

Principal Investigators: Host Country Scientists: Issoufou Kapran, Charif Ari, INRAN. U.S. Collaborating Scientist: Gebisa Ejeta, Purdue University

Research Objectives

To assemble useful sorghum germplasm for the development of high yielding and stable sorghum varieties and hybrids with adaptation to growing conditions in Niger.

To evaluate and identify sorghum lines and hybrids with resistance to Striga hermonthica.

To evaluate and identify sorghum lines and hybrids with increased resistance to early and late season drought stress.

Introduction

This project is a continuation of an ongoing collaborative activity earlier initiated with Dr. John Clark. With the return of Mr. Issoufou Kapran from training the collaboration is now directly with him, with Dr. Clark providing overall guidance.

Continued effort will be in the direction of selected sampling of germplasm for introduction, with close monitoring of germplasm pools particularly suitable for direct and indirect use in INRAN's breeding program. Efforts will also be directed to standardizing procedures in screening for resistance to Striga hermonthica and drought stress.

Research Procedures:

Intercrosses of germplasm assembled at Purdue for potential use in Niger will be sampled and sent for evaluation at Kollo and Tarna during the next five crop seasons. The collaborators will evaluate the different populations and early generation progenies for adaptation to Niger.

Using sorghum lines with proven resistance to Striga in Niger, hybrid combinations will be made during Winter 1988/89 in Puerto Rico. These hybrids will be evaluated under Striga infected fields for increased levels of resistance.

A random mating population of sorghum has been developed at Purdue using sorghum lines known to have varying levels of Striga resistance. Plans have been made for continued mass selection of this population under Striga infestation. This program will begin during the 1989 crop season and continue for the next five years.

Various sorghum lines known for their drought resistance have been intercrossed and selection for yield has been made at West Lafayette. These parental lines and their resultant progenies will be evaluated for drought resistance under sandy soil at Tarna and N'-Douga. Selected progenies will be advanced for multi-location testing in Niger.

Economic Program

Economic evaluation of new technologies in sorghum and millet production in Niger.

Principal Investigators: Host Country Scientists: Maliki Kadi, Head of DECOR, INRAN, Mahaman Issa, O. Zarifa. U..S. Collaborating Scientists: Akin Adesina, Barry I. Shapiro, John H. Sanders

Research Objectives

To evaluate the profitability, riskiness, and fit of various new technologies into the farmers' production systems. These technologies were defined in the INRAN farm-testing program. At the same time, farmers' methods of making decisions will be evaluated.

Introduction

Akin Adesina has finished his Ph.D. thesis on the impact of new technologies in Southern Niger, and Maradi region. This thesis is presently being distributed to the Nigeriens and others working on Niger problems and a journal article will be written based upon these results.

Barry Shapiro is completing his thesis on the small farmer settlements which include some small irrigated areas north of Niamey. He will be considering both dryland and irrigated technologies.

Research Procedures

Field-interviewing and data-collection are then combined with programming models to analyze the farm-level effects and constraints to the introduction of various new technologies.

Food Quality Program

Evaluation of sorghum/millet food quality.

Principal Investigators: Host Country Scientists: Moussa Oumarou, INRAN, Issoufou Kapran, INRAN; John Clark, NAAR. U.S. Collaborating Scientist:Allen Kirleis, Purdue University

Research Objectives

Determine the relationship between micro food quality testing procedures (grain hardness, gel consistency, gel stickiness, etc.) and consumer acceptance of tuwo in Niger.

Develop a program for evaluating millet quality in Niger. Surveys will be done in Niger to determine preferred grain types for traditional foods. Evaluation procedures will then be established and tested based on survey findings.

Introduction

In the 1986 crop year, 16 sorghum hybrids were subjected to sensory evaluation of tuwo quality in Niger. Grain from these hybrids was tested for gel consistency, grain hardness, and amylograph peak viscosity (all measures of porridge quality) at Purdue. The sensory test results showed that there were no significant differences among the hybrids for tuwo consumer acceptance. However, the micro quality tests indicated that significant quality differences existed among hybrids. A better understanding of the relationship between micro quality test results and consumer acceptance is needed.

Research Procedures

In 1987, a set of 12 sorghum hybrids were grown in Niger. These hybrids are currently being evaluated, using micro food quality testing methods at Purdue. Based on these laboratory test results, consumer acceptance sensory evaluation tests will be conducted in Niger in 1989. A new design was used for the 1989 sensory tests in order to establish the relationships between laboratory quality testing methods and consumer preference.

Surveys are currently underway in Niger to collect data on the type of grain preferred for traditional millet foods. Representative grain from the millet varieties, identified as having good food quality from the survey, will be physically and chemically characterized. Based on these findings, micro testing procedures will be established for evaluating milling and food making quality of Nigerien millets.

Millet Program

Genetic studies on pearl millet varieties from Niger and other African countries.

Principal Investigators: Host Country Scientists: Ouendeba Bottorou, INRAN. U.S. Collaborating Scientist: Dr. Wayne Hanna, Georgia and Dr. Gebisa Ejeta, Purdue

Introduction

Pearl millet (*Pennisetum americanum*) is a cereal crop widely grown in Africa and Asia; it is used for both human and animal consumption. It is grown annually on an area of 11.5 million hectars in India and more than 15 million hectars in Africa.

In Niger, of the 6 million hectars under rainfed cultivation, more than 3 million ha are sown each year with pearl millet. It is understandable, therefore, why the National Agricultural Research Institute (INRAN) has put more emphasis on this crop. Most of the pearl millet improvement work in Niger has been done on local landraces from which several varieties adapted to different growing areas, have been developed. One constraint faced by millet breeders in Niger has been the lack of significant differences in yield between released and newly developed varieties. To date most of the pearl millet improvement work has been within local populations and very little effort put on intercrosses among populations. Significant heterosis may exist in intercrosses among these populations, and the potential for hybrid and synthetic varieties may be great. Niger being one of the centers of diversity for millet, the local cultivars present a large amount of variability providing increased potential for genetic exploitation.

This study is formulated to provide genetic information with potential use in millet breeding programs in Africa. The specific objectives are:

To study the heterotic patterns among Niger millets and among other African millets.

To characterize the diversity among Niger pearl millet varieties.

To assess the general and specific combining ability of African millets with U.S. seed parents and their interactions with locations.

Justifications

Pearl millet will continue to be a major staple food crop in the Sahel zone because of its ability to withstand the adverse agro-climatic conditions prevalent during the growing season. The main constraints to the production of this cereal crop are inadequate and poorly distributed rainfall and the poor soils. The local millet populations are quite adapted to those environments but have limited yield potential. For a long time, research in Niger has dealt mostly with selection within populations (intra population improvement) and a few varieties have been developed for the different millet growing regions in the country. In many of these regions, no significant difference in grain yield was found between improved varieties and existing local varieties. A new breeding approach is therefore needed to increase the yield potential of millet varieties for Niger. An inter population improvement approach using Nigerien and other African millet varieties could provide the necessary germplasm pool to effect a more productive selection program. The chance to breed for a high yielding variety will likely be enhanced.

The present project will provide information on the heterotic patterns among various pearl millet populations. This will be useful for breeders in the Sahel and other African countries where millet is an important crop. The information on the relative magnitude of general and specific combining ability is very important in making decisions concerning the type of breeding procedure to use and in selecting germplasm material that is relevant for success. The germplasm resulting from intercrosses for this study could also provide a new gene pool that is currently unavailable.

Furthermore, African pearl millet germplasm have not been fully exploited for forages per se. In Niger there is increasing interest in initiating a breeding program for forage type millets. Dual purpose millet varieties or synthetics with good grain and forage yields will be of immediate benefits. African pearl millet germplasm may contribute important attributes for use as forage hybrids in the USA as well. The purpose of the combining ability study on forages is to investigate genetic variation for forage yield and quality among African millets and to test their heterotic relationship when used in combination with female parents developed in the temperate zone.

Materials

The materials will consist of five Niger millet varieties, five African varieties and three U.S. (male sterile) seed parents.

Niger Varieties

- CIVT
  P_3 Kolo
  ZOK
  HKP
  ZA

African Millets

- Souna 3 - Senega
  INIARI - Togo
  Mansori - Sudan
  Ex Bornu - Nigeria
  Ugandi - Sudan

U.S. Seed Parents

- Tift 85 DA
  Tift H23Da$_1$E
  Tift 23DA$_m$E

Methodology

1. Seed increase from the different varieties under quarantine at Tifton, Georgia.

2. Characterization of the populations under study.

3. Crossing Block

a. Grow 500 plants of each population

b. Take pollen from each, bulk, and put back on each plant to maintain populations.

c. Bulk pollen from 200 plants in each population and use to pollinate 200 plants in another populations. All population will be intercrossed in this manner; use stored pollen technique to accomplish.

d. Use bulked pollen from 200 plants in each population to pollinate.

- Tift 85 DA
  Tift $H23DA_1E$
  Tift $H23DA_mE$

Evaluation

Interpopulation crosses: The F1's and their parents were evaluated for 2 seasons at Tifton (1 location) and in Niger (2 locations). After each season, the grain quality analysis was done at Purdue. The characters to be recorded were: grain yield, days to 50% flowering, plant height, ear length, downy mildew incidence and grain protein.

Combining ability study: The F1 hybrids and parental lines were evaluated at Tifton, Georgia and West Lafayette, Indiana for two years (1988 and 1989 crop seasons). Data on forage yield and quality; grain yield and quality; as well as other agronomic characters as listed above will be collected over the next five crop seasons.

Pathology Program

Sorghum and Millet Pathology

Principal Investigators: Host Country Scientists: Issoufou Kollo. U.S. Collaborating Scientist: Richard A. Frederiksen

Research Objectives:

Evaluate sorghum for resistance to long smut under natural epidemics.

Establish and collaborate in the AALSN (All Grain Long Smut Nursery).

Investigate the interactions of *Striga* in pearl millet.

Determine the actual field effects of downy mildew on pearl millet.

Introduction

Since there are very limited laboratory facilities, plans have been made to develop in field oriented research projects and to work in collaboration with other African and INTSORMIL workers. The work takes advantage of the location, significant problems and local opportunities. Much more work is necessary and could be done with more adequate levels of support.

Research Procedures

Long smut proposed collaboration projects with Mr. I. Kollo.

Repeat the date of planting experiments with both local and IDIN entries. Rely on natural infection except for early planted "spreader" rows of BTx623.

Make a replicated date of planting experiment, starting at least 1 week preceeding the normal date of planting of BTx623 and the local cultivar A4D4, and continuing for at least 4 weeks. Date of booting and head exertion flowering will be recorded for plants, at each date of planting. This experiment without inoculation will provide information on the time of natural infection and rate of disease development.

Grow and evaluate the All African Long Smut Nursery (AALSN) at 2 dates of planting and at Bengou, Maradi, and Kollo.

Travel to Mali to confer with M. Diourte on long smut epidemiology studies.

Store smut spores under several conditions. a.) Cold storage in sori (closed containers) b) Cold storage as spore balls (closed containers) c) Open ventilated bags or ambient, as sori, d) In closed containers at ambient

Evaluate growth of sori as a function of sink size.

Evaluate F_3 rows from F_2 plant for gene action. (Continuation of work started in 1988).

Make additional crosses between R x S and R x R lines for additional genetic information.

Determine yield losses caused by long smut.

Evaluate systemic fungicides for control of long smut.

Striga (Sorghum and pearl millet)

Select a site for control of Striga using rotation and inter-cropping. This work should be cooperative with agronomists and should be done for both sorghum and pearl millet. Components of the rotation and intercropping may include Dolchis bean and cowpea.

Make a collection of Striga resistance sorghums and evaluate their response in pot culture to known levels of Striga seed infestation. Make collections of plant roots for histological analysis in USA.

Quantity inoculum in pot culture and obtain estimates of inoculum by cultivar interaction.

Define or describe the nature of the host parasite interaction of several different resistant sorghums.

Evaluate host range, particularly the role of wild grasses.

Pearl Millet Downy Mildew

Determine the extent of losses caused by PM downy mildew in farmers' fields. the approach will be to score disease severity of plant hills and handle disease severity by hill for yield.

Establish a pot culture technique for evaluation of INRAN breeding lines for reaction to PM downy mildew.

Score selective land race cultivars and advanced breeding lines for vulnerability to PM downy mildew.

Physiology Program

Influence of nitrogen and/or phosphorus on total water use and water use efficiency of pearl millet.

Principal Investigators: Host Country Scientists: Idrissa Soumana, INRAN, Charif Ari, INRAN, Goube Gaoh, INRAN, Seyni Sefifi, INRAN, Abdel Berrada, NAAR . U.S. Collaborating Scientist: Jerry Maranville, Nebraska, Jerry Eastin, Nebraska, Paresh Verma, Nebraska, Steve Mason, Nebraska

Research Objectives

Administrative

Reactivate to it's full potential, the weather station at Maradi Research Station to gather full climatic data for modeling purposes.

Establish a method of transferring money to Niger from NE-114 project so that it is used for these project objectives and support of NE-114 research.

Prepare the groundwork to bring Mr. Cherif Oumarou to the University of Nebraska for short-term training pertinent to UNL-114 objectives.

Research

Characterize adapted pearl millet genotypes for morphological growth habit emphasizing leaf area development.

Measure environmental parameters influencing evapotranspiration such as wind speed, intercepted radiation, precipitation amount and frequency, and soil characteristics.

Characterize pearl millet genotypes for physiological parameters relative to water conservation mechanisms such as stomatal conductance control and how this is influenced with improved fertility.

Calculate water budgets for specific regions from data over a range of soil fertility and management schemes such as residue alternatives.

Eventually, test management and fertility/genotype alternatives based on predicted moisture use matched to expected water availability.

Introduction

Total water use from a unit of land area of growing crop is a function of soil and leaf evaporation and transpiration. This is termed evapotranspiration (ET) and can be calculated empirically by various equations. Transpiration is the largest component of ET when the soil is dry to a depth of at least 2 cm on the surface. This being the case, leaf area index (LAI) is a critical component of a production system, particularly in dry areas, since the higher the value, the more total water will be transpired raising the ET value to where it may exceed total water availability. LAI is determined by genotype, fertility, and water supply for the most part. Little is known about the magnitude of the influence fertility such as N and P has on leaf area of a given genotype, and consequently the fertility influence on its total seasonal water use. Moreover, a genotype may become more water-use efficient if nutrient supply is adequate, but no measure of this is usually available for a given genotype nor is it taken into account in water budget calculations. It is important to know these factors in order to determine best management of the crop regarding how much leaf area should be targeted (plant spacing/population/genotype/fertility) for the amount of water available for production (water holding capacity/total precipitation). It is also important in developing improved genotypes of pearl millet for the specific region.

Research Procedures

Adapted genotypes in Niger will be characterized for morphological growth habit by sampling two or three representative plants from two or three treatment (N level/water level) and determining leaf area, height and biomass production over the growing seaso· Samples should be taken every week at a minimum and more often if possible. Leaf area will be measured by the LI 3000 A. Biomass is the fresh weight of above ground portions. Height is important for characterizing leaf distribution of given genotypes. The measures described will also be important in models employed later.

Weather station data will be gathered and processed from the weather measuring instruments on station. A

light sensing rod will be used to measure percent of incoming radiation that is intercepted over the season.

Characterization of genotypes will be made under controlled conditions at Nebraska using adapted and introduced types. Photosynthesis and stomatal conductance is measured with the LICor 6200 Photosynthesis system and leaf water potentials over a range of fertility levels with the thermocouple psychrometer. Limited measurements can be made in the field in Niger (once or twice during the season) with the LI-6200 to substantiate data from Nebraska

Water budget models are available and need some modification to suit Niger conditions and genotype characteristics. This will be accomplished at Nebraska using the larger mainframe computer if needed.

Management alternatives such as fertility, row spacing, population, residues and genotypes will be tested based on matching the expected water use to expected water availability in field trials.

Building upon the results from physiology research conducted in Niger during 1987 and 1988, and based on the national research goals identified by INRAN, the following projects need to be conducted in cooperation with Mr. Mamane Nouri and Mr. Issoufou Kapran and are being proposed for the next five years.

Millet-cowpea intercropping systems

Water-use efficiency research conducted in 1987 and 1988 indicated that to maximize the efficiency of water used cowpea requires a light level higher than what is available to it in the recommended intensive millet-cowpea intercropping system. Alternate millet and cowpea rows as opposed to two rows of cowpea between millet rows appeared promising enough to merit further research probably because it allowed a better light distribution for the cowpea canopy between the millet rows.

We propose to confirm the water-use efficiency of millet and cowpea results from the intercropping systems with the same population densities but different spatial arrangements. Seasonal and instantaneous water-use efficiency of millet and cowpea would be measured in the following millet-cowpea intercropping systems (N'-Dounga): a) Millet - 150 cm x 75 cm. Cowpea - 75 cm x 75 cm . b) Millet - 150 cm x 75 cm. Cowpea - 150 cm x 37.5 cm

Several alternative arrangements for both low and high input situations would be compared again in 1988 with the traditional and intensive systems for yield estimates. The following intercropping systems would be compared for final yield (N'Dounga, Benjou): a) Traditional system used by farmers (no P or N): Millet - approximately 5000 hills/ha; Cowpea - approximately 3500 hills/ha . b) Recommended intensive system (check): Millet - 150 cm x 75 cm; Cowpea - 75 cm x 75 cm. c) Same population density as in I.B. (b), but a different cowpea spacing (alternate millet-cowpea rows) to allow more light on cowpea canopy: Millet - 150 cm x 75 cm; Cowpea - 150 cm x 37.5 cm d) Same as I.B. (c) but cowpea rows alternate for grain and forage types. e)Millet: 1.5 m x 75 m; Cowpea: 1.5 m x .50 m. f) Same as in I.B. (e) but cowpea rows alternate for grain and forage types. g) Millet: 1.5 m x .75 m; Cowpea: 1.5 m x .75 m No P or N h) Millet: 1.25 m (avg) x 1 m; Cowpea: 2.5 m x .5 m No P or N

Crop residue trial (Ouallam)

The experiment initiated at Ouallam in 1987 will be continued to confirm results obtained over the next five crop seasons. Soil temperature and soil moisture profiles will be characterized during the seedling stage in the different residue treatments imposed and related to the visual seedling survival score. Residue results were very positive in 1988. We should do some joint planning with Mr. Mamane Nouri and Dr. Reddy on expansion of those experiments in locations other than Ouallum.

Seedling stress (N'Dounga)

Gas exchange and water vapor exchange of the seedling as affected by environmental stress would be studied in 4-6 selected millet genotypes with contrasting establishment capabilities. Effect of sand blasting on these physiological parameters would also be studied. These parameters would be related to the visual seedling survival score. Similar research could be considered on sorghum.

Phosporous trial

Effects of phosphorous fertilizer should be studied on legume production in the intercropping system and experiment continued over years to see the carryover effects on millet due to better legume growth. The following treatments will be compared in the I.B. (h) intercropping system: a)No Phosphorous b)100 kg SSP applied basally c)50 kg SSP side dressed on cowpea d)100 kg SSP side dressed on cowpea Direct cowpea yield increases from P fertilizer may provide the money resources or cash flow necessary for purchase of P fertilizer. This probably will result in higher millet yields over time because of increased cowpea N fixation. A small fertilizer investment should contribute substantially to sustainable agriculture.

Sorghum stress screening (Maradi)

With the return of Mr. Issoufou Kapran we should explore setting up a sorghum stress screening program at Maradi where irrigation facilities are available. Using irrigation and early planting one can fairly closely simulate water and high temperature stress during the seedling stage which could be contrasted with the irrigated control to screen germplasm for better establishment under field stress conditions.

Physiology Program

Principal Investigators: Host Country Scientists:Abdourahmane Nouri, INRAN. U.S. Collaboration Scientist: Paresh Verma, Nebraska and Jerry Eastin, Nebraska

Work Plans

Building upon the results from physiology research conducted in Niger since 1987, the following projects will be conducted:

Millet-Cowpea intercropping systems

Photosynthesis-transpiration in cowpeas

Crop Residue Trials

Seedling Stress

INTSORMIL/Niger Summary

There are several interdisciplinary activities involved in the INTSORMIL/INRAN/Niger Collaborative Research Program. In the past, the program had involved participation by senior graduate students and post doctorates from INTSORMIL projects working in Niger during the crop season. A shift is now in progress to support INRAN collaborative research projects by returning newly trained INRAN staff similar to the model that INTSORMIL has developed in Sudan. The INRAN Director General and INRAN scientists are in agreement that more of the collaborative research support will go directly to INRAN scientists with collaborative ties to U.S. based INTSORMIL principal investigators.

The following collaborative research projects will be continued for the next five years.

Agronomy and Cropping Systems: Stand Establishment of Grain Sorghum Lines. Issoufou Kapran, INRAN; John Clark, NAAR/Niger; Steve Mason, Nebraska; Gebisa Ejeta, Purdue; Richard Vanderlip, Kansas State; and Helen Kasalu, Nebraska.

Agronomy and Cropping Systems: Contribution of Intercropped Cowpeas to Pearl Millet. Ibrahim Mohamadou, INRAN; Maman Nouri, INRAN; Chandra Reddy, NAAR; Steve Mason, Nebraska; and Minamba Bagayoko, Nebraska.

Combining Ability of Aluminum Tolerant Sorghum Hybrids in Niger. Moussa Adamou, INRAN; John Clark, NAAR/Niger; Lynn Gourley, Mississippi State; and John Axtell, Purdue.

Development of Sorghum Varieties and Hybrids for Use in Niger. Issoufou Kapran, INRAN; Charif Ari, INRAN; and Gebisa Ejeta, Purdue.

Economic Evaluation of New Technologies in Sorghum and Millet Production in Niger. Maliki Kadi, DECOR/INRAN; Mahaman Issa, INRAN; O. Zarifa, INRAN; Barry Shapiro, Purdue; and John Sanders, Purdue.

Evaluation of Sorghum/Millet Food Quality. Moussa Oumarou, INRAN; Issoufou Kapran, INRAN; John Clark, NAAR; and Allen Kirleis, Purdue.

Genetic Studies on Pearl Millet Varieties from Niger and Other Countries. Ouendeba Botorou, INRAN; Wayne Hanna, Georgia; and Gebisa Ejeta, Purdue.

Sorghum and Millet Pathology Program. Idrissa Soumana, INRAN; Issoufou Kolo, INRAN; Omer El Hilu, ARC/Sudan; and Richard A. Frederiksen, Texas A&M.

Influence of Nitrogen and/or Phosphorus on total Water Use and Water Use Efficiency of Pearl Millet. Charif Ari, INRAN; Jerry Maranville, Nebraska; and Goube Gaoh, INRAN.

Physiology Program. Abdourahmane Alou, INRAN; Paresh Verma, Nebraska; and Jerry Eastin, Nebraska.

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 Sahelian trials for the past 10 years, but is not accepted by farmers because of poor food grain quality.

A number of useful collaborative research activities have been developed in Niger between INTSORMIL principal investigators and INRAN scientists. Because of time constraints only four of these research projects can be mentioned in this presentation. They are intended to be illustrative of the ongoing collaborative research. Detailed comments by each of the following can be found in the 1988 INTSORMIL Annual Report.

Moussa Adamou, INRAN, Mississippi State; Issoufou Kapran, INRAN, Purdue; Ouendeba Botorou, INRAN, Purdue, Georgia, ICRISAT; and Frank Gilstrap, INRAN, Texas A&M.

The major activity for disseminating research results within Niger has been the INTSORMIL/INRAN/NCRP Sorghum and Millet Workshop, which was implemented during Year 7. The workshop proceedings were distributed throughout the U.S. and LDCs. Additional research information exchanges have tal. n place through INTSORMIL scientist visits to Niger.

Continual dialogue between INTSORMIL and INRAN scientists much 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.

Two principal problems will face INTSORMIL during 1989 and they both involve funding levels. When the INTSORMIL/Niger budget was first established the exchange rate was 400 cfa/$1.00 and it has since declined to 300 cfa/1 dollar. This has significantly reduced our purchasing power of those dollars spent in-country for such items as gasoline, housing, labor costs and other expenses. The Purdue contract for Niger has been renewed for four years and INTSORMIL/NAAR cooperation will continue as in the past. We are hopeful INRAN will appoint an INRAN scientist to serve as host country coordinator which will significantly improve research coordination.

Dr. Omer El Hilu (ARC/Sudan) working with Richard Frederiksen (Texas A&M) and John Clark (Purdue/INRAN NAAR Project) will initiate an All Africa Long Smut Disease Nursery (AALSN). Different research organizations in East and West Africa, for the last few seasons, have supported a disease screening program. Hence, it is essential at this stage to combine promising lines coming out of the different programs and INTSORMIL IDIN in one nursery to be tested in various countries affected by the disease. The suggested nursery can be tested using artificial inoculation and, in those endemic areas, may also be left for natural infection. The result of this test will serve the objectives of: 1) detecting heterogeneity within the population of T. ehrenbergii in the African continent; and 2) selecting the most suited cultivars for the breeder.

Significant advances have been made in the breeding program at INRAN, primarily on sorghum, as a result of collaboration with INTSORMIL. A functional sorghum breeding program with an array of activities including varietal and hybrid development with carefully monitored screening and selection of genotypes, nursery management, and regional evaluation has been installed in place of a varietal testing routine that was practiced earlier. Intercrossing of adapted germplasm with local Nigerien varieties has yielded useful selections that are currently under regional evaluation. One entry from a selection made by Dr. John Clark from the cross P967083 by SEPON 46 yielded 2,098 kg/ha in comparison with the check variety L-30 which yielded 802 kg/ha. Other entries selected by INRAN breeders from progeny of crosses between Tanzania rice type sorghums and SEPON selections also look promising.

A hybrid sorghum breeding program initiated at INRAN in collaboration with INTSORMIL has also made useful contributions. A wide array of parental germplasm pool (which is essential in developing a functional breeding program) has been accumulated and made available to INRAN sorghum breeders. Two excellent M.S. thesis projects, supervised by INTSORMIL principal investigators, have been completed on evaluating potential of sorghum hybrids in Niger. Issoufou Kapran, working with Gebisa Ejeta, evaluated 90 hybrids under contrasting environment over two seasons and identified five experimental sorghum hybrids with excellent adaptation and yield potential in Niger. Kapran found that sorghum hybrids yielded much higher than local varieties both under rainfed (149%) and irrigated (161%) locations in Niger; and that heterosis (the superiority of hybrids over parents) of experimental sorghum hybrids was higher under rainfed (166%) than under irrigated (145%) conditions.

Experiments are in progress by Dr. Paresh Verma and Dr. Jerry Eastin which will provide information needed to optimize water-use efficiency of the cereal/legume (millet/cowpea) intercropping system. Studies are being conducted to determine seasonal and instantaneous water-use efficiencies of both millet and cowpea. Once the water extraction patterns of the two crops and the optimum shade level needed to maximize photosynthesis but minimize transpiration for maximum water-use efficiency in cowpea are know, we will be able to alter the time of cowpea are known, we will be able to alter the time of cowpea planting and hence shading level, to increase overall production of the intercropping system.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: Sustainable Production, Processing and Marketing Systems for Local Cereals in Niger

Project Leader: John Axtell **Project Number:** PRF-109

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=PRF109	--	----------				
Staff Salaries & Benefits	38.61	40.59	42.57	44.35	46.53	212.65
Post Doctorates	14.82	15.58	16.34	17.02	17.86	81.62
Graduate Students	15.00	16.00	16.00	17.00	18.00	82.00
Other Salaries	19.31	20.30	21.29	22.18	23.27	106.35
Supplies	16.77	17.63	18.49	19.26	20.21	92.36
Equipment	6.05	6.36	6.67	6.94	7.29	33.31
Travel	21.84	22.96	24.08	25.09	26.32	120.29
Other Direct Costs	15.02	15.79	16.56	17.25	18.10	82.72
Overhead	47.58	50.02	52.46	54.66	57.34	262.06
	======	======	======	======	======	=======
	195.00	205.23	214.46	223.75	234.92	1073.36

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=PRF109	--	----------				
Post Doctorates	5.72	6.01	6.31	6.63	6.96	31.63
Fringe Benefits	1.92	2.01	2.11	2.22	2.33	10.59
Supplies	53.31	55.98	58.77	61.71	64.80	294.57
Equipment	10.50	11.03	11.58	12.16	12.76	58.02
Travel	33.12	34.78	36.52	38.34	40.26	183.02
Other Direct Costs	30.38	31.90	33.50	35.17	36.93	167.90
Overhead	27.79	29.18	30.64	32.17	33.78	153.57
	======	======	======	======	======	=======
	162.75	170.89	179.43	188.40	197.82	899.30

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=PRF109	--	----------				
Post Doctorates	5.45	5.45	5.45	5.45	5.45	27.26
Fringe Benefits	1.83	1.83	1.83	1.83	1.83	9.13
Supplies	50.77	50.77	50.77	50.77	50.77	253.86
Equipment	10.00	10.00	10.00	10.00	10.00	50.00
Travel	31.55	31.55	31.55	31.55	31.55	157.73
Other Direct Costs	28.94	28.94	28.94	28.94	28.94	144.69
Overhead	26.47	26.47	26.47	26.47	26.47	132.35
	======	======	======	======	======	=======
	155.00	155.00	155.00	155.00	155.00	775.00

FIVE YEAR WORKPLAN

A. **PROJECT TITLE :** Sudan Country Program - Purdue University

B. **INSTITUTIONS COLLABORATING :**

1. HOST COUNTRY
   - Agricultural Research Corporation
   - Gezira Research Station
   - Kadugli Research Station
   - El Obeid Research Station
   - Food Research Centre, Shambat

2. U.S.
   - Purdue University
   - University of Nebraska-Lincoln
   - Texas A&M University
   - Mississippi State University

C. PRINCIPAL INVESTIGATORS:

1. HOST COUNTRY RESEARCHERS
   - El Hilu Omer, ARC/INTSORMIL Coordinator
   - Osman El Obeid Ibrahim
   - El Hag H. Abuelgasim
   - S.M. Farah
   - H.M. Hamdoun
   - A.G.T. Babiker
   - N. Sharaf Eldin
   - S.M. Badi
   - Hamid Faki
   - Abdel Latif Nour

2. U.S. RESEARCHERS
   - D. Rosenow, Texas A&M University
   - R. Frederiksen, Texas A&M Universiy
   - D. Andrews, University of Nebraska
   - J. Eastin, University of Nebraska
   - H. Pitre, Mississippi State University
   - G. Ejeta, Purdue University
   - L. Butler, Purdue University
   - J. Sanders, Purdue University
   - A. Kirleis, Sudan Country Coordinator, Purdue University

D. **RESEARCH OBJECTIVES:**

The INTSORMIL/ARC Sudan cooperative program has the overall objective to cooperate with and assist in strengthening the national research efforts in the development and utilization of improved cultivars of sorghum and millets.

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E. FIVE YEAR WORKPLAN

1. The major constraints of sorghum and millet production in the Sudan are as follows:
   - Lack of good drought tolerant sorgum and millet cultivars to meet the need in low rainfall areas of Sudan.
   - Lack of available sorghum and millet cultivars tolerant to striga, diseases, insects, and bird pests.
   - Benefits of row planting compared to broadcasting not known.
   - Optimum plant population for different rainfall areas.
   - Limited use of fertilizers for soil fertility maintenance and obtaining high yields of sorghum and millet.
   - Farms are under-utilized for cropping purposes and no soil conservation measures are adopted to prevent soil erosion.
   - Lack of cooperatives and credit facilities to small sorghum and millet growers.
   - Lack of combinable high yielding sorghum cultivars with excellent food qualities.

2. Objectives you plan to work on as related to sorghu/millet constraints

   a. **Sorghum Breeding**

   - Develop high yielding, sorghum varieties and hybrids with good grain quality for both irrigated and rain-fed production sectors.
   - Develop sorghum cultivars with high levels of resistance to the major pests (stem borers, shoot flies, head bugs) and diseases (long smut, charcoal rot).
   - to develop cultivars with high levels of drought tolerance and higher grain yield.
   - Develop striga resistant cultivars and participate in an integrated approach to Striga control
   - Undertake current selection using random-maturing populations (Striga resistant, drought resistant, etc.) with broad genetic base to be used as a source of new inbred lines for release as varieties, pollen parents for synthesis of new experimental hybrids or as breeding material.

   - Cooperating Scientists:
     Abdel Latif M. Nour (ARC)
     Osman EL Obeid Ibrahim (ARC)
     Darrell T. Rosenow (INTSORMIL)

Gebisa Ejeta (INTSORMIL)
Allen Kirleis (INTSORMIL)

b. **Millet Breeding**

- Development of pearl millet varieties adapted to nutrient and moisture stress conditions
- Evaluation of local and introduced varieties and populations for resistance to pest and disease
- Determination of the genetic variability for for response to moderate nutrient supply and/or soil moisture conservation

- Cooperating Scientists:
  El Hag Abu Elgasim (ARC)
  David Andrews (INTSORMIL)

c. **Agronomy and Water Management**

- Effects of plant spacing and arrangement on grain yield and water use efficiency of sorghum under rain-fed conditions
- Develop more detailed information on the reactions of available genotypes to post anthesis imposed water stress
- Determine the effects of nitrogen and phosphorus levels on sorghum grain yields
- Determine the effects of rotation of crops with sorghum on grain yield, and nitrogen and water use efficiency under rain-fed conditions.

- Cooperating Scientist:
  S. M. Farah (ARC)
  Jerry Eastin (INTSORMIL)

d. **Plant Pathology**

- Screening sorghum cultivars for charcoal rot tolerance under imposed stress and in drought areas.
- Screening cultivars for anthrocnose resistance and differences in virulence among isolates.
- Screening of sorghum cultivars for long smut resistance
- Study the epidemiology of the long smut pathogen
- Survival of long smut, factors affecting germination of chlamydospores and screening of new cultivars.
- Cooperating Scientists:
  Hilu Omer (ARC)
  Richard Frederiksen (INTSORMIL)
  Darrell Rosenow (INTSORMIL)

e. **Striga**

- Determine the effects of soil and environmental conditions on Striga seeds biology
- Determine the effects of striga seeds population on tolerance limits and/or resistance of some selected sorghum varieties
- Determine the optimum application time of nitrogenous fertilizers, and herbicides for controling striga on sorghum.
- Cooperating Scientists:
  A.G.T. Babiker (ARC)
  H.M. Hamdoun (ARC)
  Gebisa Ejeta (INTSORMIL)
  Larry Butler (INTSORMIL)

f. **Entomology**

- Identify chemical insecticids with outstanding performances to alternate with Sevin, the only chemical currently recommended against sorghum stem borers
- Identiy sorghum lines with resistance to stem borers.
- Cooperating Scientists:
  N. Sharaf Eldin (ARC)
  Henry Pitre (INTSORMIL)

g. **Sorghum Food Quality**

- Develop laboratory procedures for evaluating new sorghum varieties and hybrids for Kisra quality
- Develop new food uses for sorghum and millet
- Evaluate the nutritional quality of traditional and introduced sorghum and millet foods.
- Cooperating Scientists:
  Sitt M. Badi (ARC)
  Allen W. Kirleis (INTSORMIL)

h. **Economics**

- Evaluate the impact of new technologies at the farm level and identify the farm-level constraints to new technology introduction.
- Evaluate the farm-level impact of alternative agricultural policies for their efects on technology introduction.
- Collaborate with other agricultural scientists in evaluating characteristics of new cultivars and in identifying other constraints relevant to the technology development process.
- Estimate the economic impact of new INTSORMIL Techonologies in various regions.

- Collaborating Scientists:
  Hamid Faki (ARC)
  John Sanders (INTSORMIL)

i. **Library Improvement**

- Provide ARC libraries with current sorghum and millet reference material.
- Cooperating Scientists:
  El Hilu Omer (ARC)
  El Hag (ARC)
  Allen Kirleis (INTSORMIL)

3. **Research Sites** - The major sites for the collaborative research between the Agricultural Research Corporation and the INTSORMIL are located at Gezira and El Obeid Research Stations, and the Food Research Center, Khartoum North.

4. **Workshop** - A joint INTSORMIL/ARC workshop on Sorghum and Millet improvement for the Sudan is being planned for October 29 to November 3, 1989. This workshop will review the progress of sorghum and millet development and will focus on establishing research priorities for allocation of scarce resources to critical constraints of improved production and utilization of these two crops in the Sudan.

The ARC has submitted a proposed agenda and request for partial funding support for this workshop through the USAID Mission in Khartoum.

5. **Measures of Success, How Measured** -Technical reports are submitted every year by the individual ARC scientist from each discipline. It is also anticipated that reports will be presented during the proposed workshop which will then be integrated and published in a joint INTSORMIL/ARC proceedings.

6. **General Comments** -INTSORMIL must continue to develop an integrated, multidisciplinary research program to address sorghum improvement and utilization in the areas of breeding, pathology, entomology, agronomy, striga, food quality, and economics.

As there is considerable potential for increasing millet production in Western Sudan, there should be an increased effort on the part of ARC and INTSORMIL to accelerate millet breeding research in the areas of entomology, agronomy, striga and food quality.

Since 1984, funding to support this collaborative research has remained the same. It is imperative that substantial funding increases be considered to support not only the

present level of on-going research but also to expand future INTSORMIL activities in the Sudan. This is necessary as in-country research costs have doubled due to inflation and wage increases. This has sharply diminished the available funds to expand the program or support purchase of equipment and supplies for ARC.

There is also a need for INTSORMIL Management Entity to further negotiate with the USAID Mission for securing additional funds through their buy-in program.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: INTSORMIL Sudan Project

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=SUDAN	--	----------				
Staff Salaries & Benefits	25.74	40.00	41.98	43.56	45.74	197.02
Post Doctorates	9.88	15.35	16.11	16.72	17.56	75.62
Graduate Students	10.00	15.00	16.00	17.00	18.00	76.00
Other Salaries	12.87	20.00	20.99	21.78	22.87	98.51
Supplies	11.18	17.37	18.23	18.92	19.87	85.57
Equipment	4.03	6.26	6.57	6.82	7.16	30.84
Travel	14.56	22.62	23.74	24.64	25.87	111.43
Other Direct Costs	10.01	15.55	16.32	16.94	17.79	76.61
Overhead	31.72	49.29	51.73	53.68	56.36	242.78
	======	======	======	======	======	=======
	129.99	201.44	211.67	220.06	231.22	994.38

Base Budget + 5% Inflation (Compounded Yearly)

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=SUDAN	--	----------				
Post Doctorates	25.78	27.07	28.43	29.85	31.34	142.47
Fringe Benefits	1.95	2.05	2.15	2.26	2.37	10.79
Supplies	30.21	31.72	33.31	34.97	36.72	166.93
Travel	12.60	13.23	13.89	14.59	15.32	69.62
Other Direct Costs	13.65	14.33	15.05	15.80	16.59	75.42
Overhead	5.05	5.31	5.57	5.85	6.14	27.92
	======	======	======	======	======	=======
	89.25	93.71	98.40	103.32	108.48	493.16

Base Program Budget $2,700,000 Per Year

Expense	Year12	Year13	Year14	Year15	Year16	Total
---------- proj=SUDAN	--	----------				
Post Doctorates	24.56	24.56	24.56	24.56	24.56	122.78
Fringe Benefits	1.86	1.86	1.86	1.86	1.86	9.30
Supplies	28.77	28.77	28.77	28.77	28.77	143.86
Travel	12.00	12.00	12.00	12.00	12.00	60.00
Other Direct Costs	13.00	13.00	13.00	13.00	13.00	65.00
Overhead	4.81	4.81	4.81	4.81	4.81	24.07
	======	======	======	======	======	=======
	85.00	85.00	85.00	85.00	85.00	425.00

Proposed New Initiatives and Budgets

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Justification for Increased Funding for New Iniatives

Millet Research

Nutrient and soil moisture deficits are acknowledged as the primary constraints to pearl millet grain production in Africa. New varieties and pest management technologies become doubly effective when these primary productivity constraints are alleviated. Research on improvement of the soil resource (particularly the organic matter status) is, therefore, central to any comprehensive research program aimed at improving sustainable pearl millet production at the farmer level in Africa.

Improvement of the soil moisture and nutrient holding capacity should be research through:

- Effect of millet legume rotations (or intercrops) on soil status over several seasons.
- Management of pearl millet residues with and without added N + P fertilizers superimposed on (1) above.
- Interaction of improved millet genotypes with management systems.
- Participation of agricultural economics in both planning and analyses of experiments.

The pearl millet head girdler [*Raghuva* = (*Heiliochielus*) *albipunctella*] is a serious insect in the major pearl millet production area across west Africa from Senegal to the Sudan.

The existing landrace varieties usually escape by reason of late maturity since insect attack peaks just before the main crop flowers. Even so, losses can be heavy--up to 40% have been reported from Mali. Varieties flowering earlier than normal can be devastated. Despite prolonged testing, no useful host plant resistance has been detected. Strategies for increased pearl millet production in this important area which involve using or breeding higher yielding short season varieties (for instance, to reduce drought risks) cannot be used until the head girdler can be controlled. There is a general lack of knowledge about this pest, but the following are critical areas needing research:

- Life cycle studies-- possibilities of breaking diapause, determining egg laying preferences.
- Cultural control of diapause larvae.
- Biological control--parasites (a wasp, *Brecon hebetor* occurs naturally), viruses?
- Host plant resistance-- a critical review is needed.

Improving grain pearl millet through transfer of valuable traits from related species is a potentially valuable tool in the improvement of this crop. Research has shown that it is possible, using the latest technology, to discover, transfer and utilize valuable traits (e.g. new disease resistances, higher growth rate, new and different seed parents --Tift 85 was released with resistance to blast, rust, and leaf spot) into cultivated pearl millet from relatives in the primary and secondary *pennisetum* gene pools. The transfer of apomixis from the tertiary gene pool (which enables hybrids to be 'fixed' and reproduced by simple seed increase) is at an advanced stage. Cytoplasms in related species have been shown to be different and potentially useful.

This research has reached a the stage where it can have a direct impact on crop production both in the U.S. and developing countries and could make a valuable contribution to INTSORMIL's productivity and effectiveness.

Research needed to utilize the material emerging from the transfer work done so far includes:

- Evaluate progeny from pearl millet (PM) x elephant grass (EG) crosses for disease resistance, particularly downy mildew.
- Develop stocks from PM x EG crosses with higher grain yields derived from higher growth rates.
- Develop pearl millet lines carrying different cytoplasms.
- Support research on completing transfer or apomixis and evaluating material for accompanying traits.

Biotechnology for Sorghum/Millet Improvement

During the past decade, several new techniques have been developed using biotechnology for crop improvement and identification of pests. In some instances these techniques may be the most appropriate means to limit some of the most serious constraints to the attainment of sustainable yields in sorghum and millet. Research would be focused in three areas. These are:

- Restriction of fragment length polymorphisms (RFLP) mapping,
- Tissue culture of sorghum and pearl millet and
- Development of specific DNA probes for identification of pathogens and arthropods of sorghum and millet.

Selected aspects of biotechnology can be transferred and utilized collaboratively with scientists in developing countries. Those approaches as related to needs of sorghum and millet improvement are discussed below.

Approaches

A first step will be the development of an RFLP map of the sorghum genome. Aspects of mapping of the sorghum genes have been initiated at several of the INTSORMIL participating Universities and the opportunity exists for INTSORMIL scientists to collaborate with these laboratories to expedite mapping. The current excitement in this field derives from the utility of the RFLP map, especially when integrated with traditional crop breeding approaches. This technique facilitates the movement of desirable genes among varieties, aids in the transfer of novel genes from related wild species, and makes analysis of complex polygenic traits possible with high density RFLP maps to clone unknown genes which contribute to particular traits of interest. Access to such genes would allow their expression to be optimized with respect to crop performance in specific environments.

INTSORMIL will have an interest in genes which map for resistance to specific pathogens. This is particularly true for *Striga* since it is not a parasite in the U.S. DNA sequences closely linked with a particular RFLP will be especially useful in identifying plants with genetic resistance to disease in the absence of this parasitic plant. There is no known resistance to *Striga* in pearl millet but there is resistance in sorghum. Consequently the isolation of genes from sorghum and the development of vectors for the transfer of these genes could revolutionize the approach to protecting pearl millet from the *Striga* parasite.

Mapping of the pearl millet genome should also be undertaken at the earliest possible opportunity for the same reasons as the mapping of sorghum.

The development of RFLP maps of pathogens, pests and parasites of sorghum and millet has been initiated and may be one of the most valuable tools for the identification of selected species of the agent and their taxonomic relations. There is an urgent need to clarify the taxonomic confusion among pathogens and the use of DNA can be an invaluable approach. Using specific DNA probes, individual seeds infected with virulent pathogens can be detected. Virtually identical procedures are possible for nematodes and insect pests of sorghum and millet.

Current technology makes it possible to establish a molecular basis for differentiating viral strains (using strain-specific DNA probes) and for understanding virus-vector-plant interactions. This can be done by physically and functionally mapping the RNA genome of the more important plant viruses by using established biotechnology and genetic engineering protocols. Strain identification base on genomic characters will help clarify the existing confusion of identification of viruses and virus complexes and benefit plant breeders and epidemiologists around the world.

Tissue culture of sorghum and millet remains the major vehicle for the application of biotechnology to improvement of sorghum and millet. Current work has demonstrated that tissue culture techniques can aid in the improvement of sorghum for drought stress, these techniques have been most useful when they have been conducted in concert with conventional programs.

Expansion of INTSORMIL Economics and Social Sciences Efforts

Various internal and external reviews of INTSORMIL have supported the economics program and also have argued for expanding back into the social sciences. There is presently ongoing economic field work in three INTSORMIL collaborating countries and one collaborating program in Burkina Faso. This field work evaluates the farm-level impact or potential impact of the new technologies being developed by collaborative efforts between INTSORMIL and national research scientists. This research gives feed back to research scientists and policy makers on research activities, technology performance, farmer constraints, and agricultural policy alternatives to facilitate technological change. It evaluates technologies for profitability, riskiness, and fit into farmers' production systems. Now long run sustainability concerns are also being incorporated into the analysis. Training of national researchers in technology evaluation is also an important project activity.

The latest EEP report recommended the addition of another economist to study domestic and international marketing issues for sorghum and millet. Issues of taste and acceptability of new cultivars, new products, and alternative uses of these two traditional cereals are becoming increasingly important to slow the displacement of these cereals in urban areas by rice, wheat and maize. Developing countries need to avoid the foreign exchange costs and political instability of being highly dependent on cereal imports. Domestic cereal production needs not only new technologies to facilitate production but also on the consumer side to facilitate processing and preparation. INTSORMIL breeders are producing new cultivars with different characteristics than traditional cultivars. New products, such as parboiled (rice-like) sorghum, is also available experimentally and needs to be field tested. Moreover, the major structural shift of these traditional cereals from foods to feed grains will gradually occur over the next two decades and this process needs to be evaluated and facilitated. Finally, this marketing project would also study international sorghum/millet marketing.

The optimal budget also plans for the reintroduction of sociology/anthropology activities. The field work in Sudan, Honduras, and Mexico was a strong component

of the early description of farming systems of millet and sorghum in these countries. Now the reintegration of this research is important to evaluate acceptability of new products and sociological effects of new technology introduction. This research needs to be closely integrated with the agricultural scientists in INTSORMIL and the national agricultural research centers.

Communications

The technology dissemination component of the INTSORMIL program has been seriously under funded. As the program has developed technologies which need to be communicated to a larger audience worldwide in the developing world, INTSORMIL has found that its resources for providing these materials has been very limited.

At the present time budgets only allow publication of grant mandated materials (Annual Reports, trip reports, and other related materials). As the program has become more active in co-sponsoring workshops in collaborating countries and with ICRISAT there has been a greater and greater burden placed on the program to finance the publication of proceedings and related materials.

INTSORMIL recently has introduced a Technical series, from which four publications have been published to date. The recent *Striga* bulletin is a state of the art statement regarding recent break throughs on understanding the relationship and control of this serious parasitic pest of sorghum. There are other technological areas which need to be publicized in much the same way. Other topic areas include the story on sorghum head bug in West Africa, the genetics of seed and plant color in sorghum and its relationship to food quality, and the most recent research output from cropping systems and intercropping studies.

A communications project will allow the program to create a greater interface with other developing countries where sorghum and millet are produced but who are not a active collaborating INTSORMIL country or a INTSORMIL collaborating program site.

Strengthening Of Collaborating Host Country Programs

The EZC recommended that under an optimal program that each of the INTSORMIL collaborating country budgets be increased up to $195,000 each. This increase funding will provide for greater collaboration and strengthening of the multidisciplinary collaborative research to take place in those national programs. The specific areas to augmented in each program are as follows:

- Niger: Millet breeding, millet agronomy, sorghum and millet utilization, sorghum pathology, cooperation with TROPSOILs and ICRISAT Sahelian Center.
- Mali:Millet agronomy, millet and sorghum breeding, sorghum and millet pathology, sorghum and millet insect pests (panicle bugs and millet head girdler), sorghum and millet utilization (new or alternative uses), and cooperation with TROPSOILS.
- Sudan: *Striga*, drought resistance, millet breeding, hybrid sorghum breeding, entomology, composite flours and other grain quality aspects for food utilization, and sorghum and millet agronomy.
- Honduras:Sorghum agronomy, pathology, entomology, graduate student research and strengthening of on farm technology adaptation and adoption trials.
- Colombia:Drought tolerance and sorghum pathology.
- Botswana:SADCC area networking, termination of buyin from AID Bilateral ATIP project, sorghum and millet agronomy, sorghum and millet breeding.
- Senegal:Sorghum and millet quality, millet breeding, millet agronomy, sorghum breeding, millet economics, leveraging of funds from AID Mission Bilateral Agricultural Research Phase Two Project through the University of Arizona.
- Kenya:Sorghum breeding, drought tolerance, utilization and sorghum pathology. Leveraging of funds from AID Mission Bilateral Agricultural Research Project with MIAC/University of Missouri. INTSORMIL is providing a breeder to that activity through a buyin.

Linkages with the following three countries would reestablish collaborative research activities after the budget cuts of 1986. These linkages would provide connections with AID graduate country research programs which in turn would contribute to quick payoffs due to the strength of these national research programs on sorghum and millet. The research in these programs is relevant to INTSORMIL collaborating countries and collaborating programs as well as the U.S.

- India:Millet *Striga*, millet economics, millet pathology, millet drought physiology, and millet breeding.
- Mexico: Sorghum/millet quality, drought tolerance, cold tolerance, disease and insect pest research. Research in Mexico is relevant to much of Central and South America.
- Brazil:Acid soil research, low soil fertility and soil management, pathology, and bird feeding resistance. Research in Brazil is relevant to other countries in South America and Africa.

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: International Sociology/Anthropology Research

Project Leader: **Project Number:**

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=KY101	--	----------				
Staff Salaries & Benefits	39.60	41.58	43.76	45.54	47.92	218.40
Post Doctorates	15.20	15.96	16.80	17.48	18.39	83.83
Graduate Students	15.00	16.00	17.00	17.00	18.00	83.00
Other Salaries	19.80	20.79	21.88	22.77	23.96	109.20
Supplies	17.20	18.06	19.01	19.78	20.81	94.86
Equipment	6.20	6.51	6.85	7.13	7.50	34.19
Travel	22.40	23.52	24.75	25.76	27.10	123.53
Other Direct Costs	15.40	16.17	17.02	17.71	18.63	84.93
Overhead	48.80	51.24	53.92	56.12	59.05	269.13
	======	======	======	======	======	=======
	199.60	209.83	220.99	229.29	241.36	1101.07

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: INTSORMIL Biotechnology Project

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=BIOTECH --	----------					
Staff Salaries & Benefits	0.00	16.83	30.49	51.48	54.05	152.85
Post Doctorates	0.00	6.46	11.70	19.76	20.75	58.67
Graduate Students	0.00	6.00	12.00	20.00	21.00	59.00
Other Salaries	0.00	8.42	15.25	25.74	27.03	76.44
Supplies	0.00	7.31	13.24	22.36	23.48	66.39
Equipment	0.00	2.64	4.77	8.06	8.46	23.93
Travel	0.00	9.52	17.25	29.12	30.58	86.47
Other Direct Costs	0.00	6.55	11.86	20.02	21.02	59.45
Overhead	0.00	20.74	37.58	63.44	66.61	188.37
	====	=====	======	======	======	======
	0.00	84.47	154.14	259.98	272.98	771.57

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: INTSORMIL Cross CRSP Activities

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=CROSSCRSP	--	----------				
Staff Salaries & Benefits	5.94	6.34	6.73	10.89	11.48	41.38
Post Doctorates	2.28	2.43	2.58	4.18	4.41	15.88
Graduate Students	2.00	2.00	3.00	4.00	4.00	15.00
Other Salaries	2.97	3.17	3.37	5.45	5.74	20.70
Supplies	2.58	2.75	2.92	4.73	4.99	17.97
Equipment	0.93	0.99	1.05	1.71	1.80	6.48
Travel	3.36	3.58	3.81	6.16	6.50	23.41
Other Direct Costs	2.31	2.46	2.62	4.24	4.47	16.10
Overhead	7.32	7.81	8.30	13.42	14.15	51.00
	=====	======	======	======	======	======
	29.69	31.53	34.38	54.78	57.54	207.92

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: INTSORMIL Millet Head Girdler Project

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=GIRDLER	--	----------				
Staff Salaries & Benefits	14.85	15.64	16.43	17.03	17.82	81.77
Post Doctorates	5.70	6.00	6.31	6.54	6.84	31.39
Graduate Students	6.00	6.00	6.00	7.00	7.00	32.00
Other Salaries	7.43	7.82	8.22	8.51	8.91	40.89
Supplies	6.45	6.79	7.14	7.40	7.74	35.52
Equipment	2.33	2.45	2.57	2.67	2.79	12.81
Travel	8.40	8.85	9.30	9.63	10.08	46.26
Other Direct Costs	5.78	6.08	6.39	6.62	6.93	31.80
Overhead	18.30	19.28	20.25	20.98	21.96	100.77
	=====	======	======	======	======	======
	75.24	78.91	82.61	86.38	90.07	413.21

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: INTSORMIL Millet Genetic Project

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=HANNA	--	----------				
Staff Salaries & Benefits	14.85	15.64	16.43	26.93	28.31	102.16
Post Doctorates	5.70	6.00	6.31	10.34	10.87	39.22
Graduate Students	6.00	6.00	6.00	10.00	11.00	39.00
Other Salaries	7.43	7.82	8.22	13.46	14.16	51.09
Supplies	6.45	6.79	7.14	11.70	12.30	44.38
Equipment	2.33	2.45	2.57	4.22	4.43	16.00
Travel	8.40	8.85	9.30	15.23	16.02	57.80
Other Direct Costs	5.78	6.08	6.39	10.47	11.01	39.73
Overhead	18.30	19.28	20.25	33.18	34.89	125.90
	=====	======	======	======	======	======
	75.24	78.91	82.61	135.53	142.99	515.28

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: INTSORMIL Sorghum/Millet Marketing Studies

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=NEWECON	--	----------				
Staff Salaries & Benefits	9.90	20.39	31.28	32.47	34.06	128.10
Post Doctorates	3.80	7.83	12.01	12.46	13.07	49.17
Graduate Students	4.00	8.00	12.00	12.00	13.00	49.00
Other Salaries	4.95	10.20	15.64	16.24	17.03	64.06
Supplies	4.30	8.86	13.59	14.10	14.79	55.64
Equipment	1.55	3.19	4.90	5.08	5.33	20.05
Travel	5.60	11.54	17.70	18.37	19.26	72.47
Other Direct Costs	3.85	7.93	12.17	12.63	13.24	49.82
Overhead	12.20	25.13	38.55	40.02	41.97	157.87
	======	======	======	======	======	=======
	50.15	103.07	157.84	163.37	171.75	646.18

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: INTSORMIL Communications Project

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=COMMUNICAT -- ----------						
Staff Salaries & Benefits	17.82	23.76	31.88	33.07	34.65	141.18
Post Doctorates	6.84	9.12	12.24	12.69	13.30	54.19
Graduate Students	7.00	9.00	12.00	13.00	13.00	54.00
Other Salaries	8.91	11.88	15.94	16.53	17.33	70.59
Supplies	7.74	10.32	13.85	14.36	15.05	61.32
Equipment	2.79	3.72	4.99	5.18	5.43	22.11
Travel	10.08	13.44	18.03	18.70	19.60	79.85
Other Direct Costs	6.93	9.24	12.40	12.86	13.48	54.91
Overhead	21.96	29.28	39.28	40.75	42.70	173.97
	=====	======	======	======	======	======
	90.07	119.76	160.61	167.14	174.54	712.12

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: INTSORMIL Brazil Project

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=BRAZIL -- ----------						
Staff Salaries & Benefits	6.93	7.33	15.64	21.19	22.18	73.27
Post Doctorates	2.66	2.81	6.00	8.13	8.51	28.11
Graduate Students	3.00	3.00	6.00	8.00	9.00	29.00
Other Salaries	3.47	3.66	7.82	10.59	11.09	36.63
Supplies	3.01	3.18	6.79	9.20	9.63	31.81
Equipment	1.09	1.15	2.45	3.32	3.47	11.48
Travel	3.92	4.14	8.85	11.98	12.54	41.43
Other Direct Costs	2.70	2.85	6.08	8.24	8.62	28.49
Overhead	8.54	9.03	19.28	26.11	27.33	90.29
	=====	=====	======	======	======	======
	35.32	37.15	78.91	106.76	112.37	370.51

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: INTSORMIL Cameroon Project

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=CAMROON --	----------					
Staff Salaries & Benefits	6.93	7.33	7.72	11.09	11.68	44.75
Post Doctorates	2.66	2.81	2.96	4.26	4.48	17.17
Graduate Students	3.00	3.00	3.00	4.00	4.00	17.00
Other Salaries	3.47	3.66	3.86	5.54	5.84	22.37
Supplies	3.01	3.18	3.35	4.82	5.07	19.43
Equipment	1.09	1.15	1.21	1.74	1.83	7.02
Travel	3.92	4.14	4.37	6.27	6.61	25.31
Other Direct Costs	2.70	2.85	3.00	4.31	4.54	17.40
Overhead	8.54	9.03	9.52	13.66	14.40	55.15
	=====	=====	======	======	======	======
	35.32	37.15	38.99	55.69	58.45	225.60

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: INTSORMIL India Project

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=INDIA	--	----------				
Staff Salaries & Benefits	9.90	10.49	16.04	21.58	22.57	80.58
Post Doctorates	3.80	4.03	6.16	8.28	8.66	30.93
Graduate Students	4.00	4.00	6.00	8.00	9.00	31.00
Other Salaries	4.95	5.25	8.02	10.79	11.29	40.30
Supplies	4.30	4.56	6.97	9.37	9.80	35.00
Equipment	1.55	1.64	2.51	3.38	3.53	12.61
Travel	5.60	5.94	9.07	12.21	12.77	45.59
Other Direct Costs	3.85	4.08	6.24	8.39	8.78	31.34
Overhead	12.20	12.93	19.76	26.60	27.82	99.31
	=====	======	======	======	======	======
	50.15	52.92	80.77	108.60	114.22	406.66

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: INTSORMIL Kenya Project

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=KENYA	--	----------				
Staff Salaries & Benefits	9.90	10.49	11.09	11.48	12.08	55.04
Post Doctorates	3.80	4.03	4.26	4.41	4.64	21.14
Graduate Students	4.00	4.00	4.00	4.00	5.00	21.00
Other Salaries	4.95	5.25	5.54	5.74	6.04	27.52
Supplies	4.30	4.56	4.82	4.99	5.25	23.92
Equipment	1.55	1.64	1.74	1.80	1.89	8.62
Travel	5.60	5.94	6.27	6.50	6.83	31.14
Other Direct Costs	3.85	4.08	4.31	4.47	4.70	21.41
Overhead	12.20	12.93	13.66	14.15	14.88	67.82
	=====	======	======	======	======	======
	50.15	52.92	55.69	57.54	61.31	277.61

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: INTSORMIL Mexico Project

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=MEXICO	--	----------				
Staff Salaries & Benefits	6.93	7.33	15.64	21.19	22.18	73.27
Post Doctorates	2.66	2.81	6.00	8.13	8.51	28.11
Graduate Students	3.00	3.00	6.00	8.00	9.00	29.00
Other Salaries	3.47	3.66	7.82	10.59	11.09	36.63
Supplies	3.01	3.18	6.79	9.20	9.63	31.81
Equipment	1.09	1.15	2.45	3.32	3.47	11.48
Travel	3.92	4.14	8.85	11.98	12.54	41.43
Other Direct Costs	2.70	2.85	6.08	8.24	8.62	28.49
Overhead	8.54	9.03	19.28	26.11	27.33	90.29
	======	======	======	======	======	=======
	35.32	37.15	78.91	106.76	112.37	370.51

INTSORMIL Proposed Research Project
July 1, 1990 - June 30, 1995

Project Title: INTSORMIL Senegal Project

Optimum Budget + 5% Inflation (Compounded Yearly)

Budget Line Item	Year 12	Year 13	Year 14	Year 15	Year 16	Total
---------- proj=SENEGAL	--	----------				
Staff Salaries & Benefits	9.90	10.49	11.09	11.48	12.08	55.04
Post Doctorates	3.80	4.03	4.26	4.41	4.64	21.14
Graduate Students	4.00	4.00	4.00	4.00	5.00	21.00
Other Salaries	4.95	5.25	5.54	5.74	6.04	27.52
Supplies	4.30	4.56	4.82	4.99	5.25	23.92
Equipment	1.55	1.64	1.74	1.80	1.89	8.62
Travel	5.60	5.94	6.27	6.50	6.83	31.14
Other Direct Costs	3.85	4.08	4.31	4.47	4.70	21.41
Overhead	12.20	12.93	13.66	14.15	14.88	67.82
	======	======	======	======	======	=======
	50.15	52.92	55.69	57.54	61.31	277.61