

# **INTSORMIL**

## **1980 ANNUAL REPORT**

**July 1979 - March 1980**

### **SORGHUM - MILLET COORDINATED RESEARCH SUPPORT PROGRAM**

**Grant: AID/DSAN/XII-G-0149  
from the Agency for International Development,  
and the INTSORMIL Institutions:**

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

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ANNUAL REPORT  
COLLABORATIVE RESEARCH SUPPORT PROGRAM

in

SORGHUM AND MILLET

Period July 1, 1979-March 31, 1980

Funded by Grant AID/DSAN/XII-G-0149  
from the Agency for International Development,  
Washington, D.C.

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

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## I. SUMMARY.

Sorghum and millets are major food crops of the least-developed and most marginal world agricultural areas. Grain sorghum and pearl millet are especially significant sources of human food in South Asia, much of sub-Saharan Africa, and certain regions of Latin America and the Caribbean. These two crops logically were chosen as the highest priority food grains requiring research in the "Title XII" Coordinated Research Support Program (CRSP) framework.

The Sorghum/Millet CRSP was activated July 1, 1979 after almost two years of planning and preparatory activity. Eight U.S. Land Grant institutions were selected as active members of the CRSP grouping, which is organized as an informal consortium designated "INTSORMIL." Program management is conducted by a headquarters and administrative staff located at the University of Nebraska-Lincoln. This report summarizes the first 9 months' activities of the program and highlights significant research results which are emerging from the CRSP projects.

The most significant overseas activity of the program is expected to be its support role for national and regional improvement effort in the two crops concerned. Discussions were begun with USAID country missions and AID/W Regional Bureaus to focus on countries where the two crops are highly important and where there is a basis for programmatic involvement with host-country research agencies. India, Yemen, Egypt, Mali, Sudan, Haiti, Guatemala and Honduras were chosen for early program wide linkages. Subsequently, contacts with Tanzania, Brazil and Mexico were made which give promise of additional successful cooperation. INTSORMIL staff have visited most of these countries in recent months. Two of the visits - to Mali/Upper Volta and Tanzania - were in response to USAID country mission requests for technical assistance.

Breeding and genetics studies in the program build largely on work begun in earlier A.I.D.-funded projects. A significant development occurred during the year when tropical-temperate sorghum "conversion" strains from the Texas A&M program produced outstanding yields of good quality grain in winter trials in Guatemala. Nebraska studies on yield stability in sorghum and pearl millet showed promising results for widely adapted strains in both species.

Kansas State continued the development of new pearl millet types which out-yielded highly-selected sorghum hybrids under difficult growing conditions. Cooperation between breeders and entomologists produced new midge-resistant strains which were distributed to several developing countries.

Studies in plant physiology, nutrition and stress resistance, while fundamental in approach, are essential to development of germ plasm and cultural practices which will produce better yields in marginal environments. Early results from trials in Arizona, Kansas and Nebraska show that resistance to drought and heat stress varies genetically even in these two "drought resistant" crop species. Even under extreme stress conditions, some sorghum and millet strains were found to be able to develop and produce some grain.

Plant pathologists and entomologists made progress in developing methods and plant materials for effective control of major plant diseases and insect pests. Materials resistant to sorghum downy mildew and sorghum midge have been found and distributed to plant scientists in developing countries.

Utilization research in the CRSP concentrated on improving use and nutritional value of sorghum and millet in areas where these are major food grains. Recent findings show that traditional West African methods of preparing sorghum and millet for food include techniques likely to be effective in eliminating anti-nutritional factors in these grains. A disturbing finding from other A.I.D.-funded nutritional work had indicated that at least some sorghum types were poorly digested by children and likely to cause serious nutritional problems if

used as the major food source. Our scientists expect to adapt the traditional West African techniques to broad-scale utility, and hope to reduce unfavorable nutritional effects accordingly.

Planned research in the coming months may conveniently be summarized under six topics, as follows.

Breeding, genetics and varietal improvement.

These projects have the major objective of developing improved varieties and germ plasm of sorghum and pearl millet, suited for practical use by sorghum and millet growers in developing countries. Emphasis will be placed on germ plasm having good agronomic performance, a high degree of yield stability, and acceptable food quality and grain characteristics. Nine projects at 5 institutions have major direction in this area.

Physiology, plant nutrition, cultural practices and cropping systems.

Research in these topics concentrates on plant growth, behavior and response, with particular emphasis on stress response under conditions comparable to those of developing countries. From this basic information, field studies will extend the knowledge to methods and systems for growing the crop to produce superior and more stable performance. Thirteen projects at 5 participating institutions give major emphasis in this field.

Plant Pathology.

Integration of plant disease research with the plant breeding programs is central to the breeding efforts in this CRSP. The severity of plant disease losses is so great and their effect on food supplies so serious that special efforts are required on the identification and control of the most damaging plant diseases. In all, 9 research projects at 4 institutions give primary emphasis to plant pathology research and plant disease control.

Entomology and pest control.

Production losses from insects and vertebrate pests are extremely serious, particularly in the more hazardous or marginal areas of crop adaptation. Pest

management research, as with plant pathology, is integrated into all the major plant breeding projects. In addition, special emphasis is being placed on control of the major insect pests by feasible, integrated means requiring specialist treatment of the research problems. Six research projects at 2 institutions are specially concentrated on insects and pest management.

#### Storage, utilization and nutrition.

Post-harvest storage losses in quantity and quality, and problems with palatability, acceptability and nutritional value of food products prepared from sorghum and millet are serious difficulties. Prevailing practices have provided solutions to some of these problems, but major impediments still remain. Projects organized under the CRSP deal with the difficult task of focusing modern scientific knowledge and tools on the food utilization problems of less-developed societies. Six projects at 5 institutions are focused on various aspects of utilizing the grain for food.

#### Socio-economic considerations.

Constraints in social and economic conditions obviously affect the end-use of improved food crop production -- that is, the improvement of human nutritional standards and quality of life. This CRSP integrates socio-economic research into the generalized, commodity-oriented development program. Three major projects, at 3 of the eight participating institutions, address socio-economic problems in their relation to improved production and utilization.

During the coming year, major efforts will concentrate on securing and improving linkage relationships in the selected developing countries. Close cooperation with ICRISAT, particularly in a Latin American regional program, and with SAFGRAD in sub-Saharan Africa, will be specially emphasized.

Since the domestic organization and management structure are fully in place, no problems or special requirements are expected with U.S.-based activities.

## II. BACKGROUND OF THE PROGRAM

The Sorghum/Millet Coordinated Research Support Program (CRSP) was organized and funded in mid-1979 as one of the first two CRSP activities developed as part of the "Title XII" initiatives of the Agency for International Development (A.I.D.) and the Board for International Food and Agricultural Development (BIFAD).

Planning for the Sorghum/Millet CRSP was carried out by the University of Missouri, under an A.I.D. contract, with the policy supervision of the Joint Research Committee (JRC) of BIFAD. The five-year authorization, with two years of forward-funding obligation, was issued by A.I.D. with effect from July 1, 1979. The University of Nebraska-Lincoln was chosen by the participating U.S. Land-Grant institutions to be the Management Entity for the grant, and accepted the grant during July 1979 on behalf of the participating institutions.

The CRSP program as presently structured is managed administratively by the University of Nebraska-Lincoln (UN-L). Policy and technical guidance are exercised by a grouping called "INTSORMIL" ("International Sorghum and Millet Research") created by a Joint Memorandum of Understanding signed by all participating institutions.

Day-to-day affairs of the program are centrally coordinated by a Program Director and small staff at UN-L. Business management and accounting are handled by the Grants and Contracts Office of UN-L. Policy guidance is provided by a 5-person Board of Directors, chosen from the member institutions. Technical oversight and recommendations to the Board are accomplished by a 6-person Technical Committee.

Specific objectives of the CRSP, as delineated in the Grant document, are:

Link institutions having common interests in organized programs or research on this CRSP.

Mobilize and coordinate the research talent from the participating institutions to ameliorate world food, nutrition, and poverty problems specifically in the research priority area of this CRSP.

Be responsible for the program and fiscal management of this CRSP in accordance with the management plan set forth.

Achieve optimum collaboration and information exchange on this CRSP with AID Missions, International Research Centers, U.S. and LDC Institutions.

The CRSP participants and Management Entity, in close collaboration with AID Bureaus and Missions, are working to organize close linkages and collaboration with appropriate research institutions and agencies in developing countries. These include national research institutes, state or provincial universities and institutes and international research centers. A major purpose of these linkages will be to maximize scientist-to-scientist cooperation in the solution of pressing developmental problems.

The CRSP grant contains funds for direct "pass-through" to developing country research agencies, and for technical assistance on specific problems. In addition, each sub-grant to U.S.-based institutions contains funds for support of overseas operations. The "pass-through" and technical assistance funds are presently held in the budget of the central Management Entity.

The planning process for the CRSP identified a number of major constraints presently limiting production and utilization of sorghum and millet in developing countries where these crops are of major importance to the food supply. The research projects comprising the CRSP activities all are designed to develop solutions to one or more of these constraints. As the program develops progressively more of the actual research activities are expected to be conducted in developing countries, or with the closest possible association between the U.S. participating institutions and appropriate developing-country research agencies.

Sub-allocation of grant funds was made to participating U.S. institutions during the latter months of 1979, and the domestic-based structure of the program essentially was fully in place by early January 1980. A major planning meeting of research scientists in the program was held January 14-15,

1980, with over 60 investigators, representing all eight participating institutions, in attendance. In all, 41 individual research projects have been activated and funded in the CRSP structure. This report, which covers the period July 1, 1979 to March 31, 1980, will include relatively little discussion of research accomplishments, since the research work has only recently gotten underway. It will, however, provide baseline information on the structure of the program and on the researcher's plans for solving the identified major constraints.

### III. IDENTIFIED CONSTRAINTS, RESEARCH NEEDS, AND PROJECT STRUCTURE.

#### A. Identified Constraints.

The planning process for the Sorghum/Millet CRSP thoroughly reviewed the status of production and consumption on a worldwide basis, and determined that a number of major constraints existed in the production, marketing and utilization of both crops. In its report, the planning group specified 24 "principal" constraints, classified under 9 topical headings, and used these as a basis for indicating 15 major research needs. These in turn provided the rationale for the plan of work set forth in the CRSP grant document.

Following is a listing of the principal constraints as identified in the planning group's report, issued in December 1977: (see Appendix 3 for reference)

1. Low soil fertility
2. Water-related problems
3. Difficulty of establishing seedling stands
4. Pest damage
5. Weed competition
6. Risk and lack of production stability
7. Lack of proper machinery for tillage
8. Inadequate farm and commercial storage
9. Unstable varietal performance
10. Lack of basic plant science information
11. Lack of effective seed production and distribution
12. Insect damage
13. Plant disease hazards
14. Limited germ plasma collection and maintenance
15. Anti-nutritional and unpleasant taste factors
16. Poor information and communication systems
17. Lack of risk-taking ability
18. Inferior status of sorghum and millet as foods
19. Deficient knowledge of production and utilization statistics
20. Probable social constraints on adoption of new technologies
21. Inadequate price and marketing policies
22. Poor market information
23. Inadequate market organization and performance
24. Shortage of trained technical personnel

#### B. Research Needs.

The planning process focused on research needs in sorghum and millet with

special application to problems of small-scale subsistence farmers in the poorer developing countries. The most urgent research needs were identified from the listing of principal constraints and the planners' best judgement as to possible means of alleviating them. Fifteen major needs were delineated:

1. Expanded work in plant breeding and genetics, integrated with research in all other pertinent areas of study.
2. Research on cultural practices and technologies appropriate to non-monetized or low-capital economies.
3. Integrated plant disease control studies, emphasizing comprehensive programs suited to the needs and conditions of developing countries.
4. Integrated, biologically-sound insect and pest control work.
5. Research to improve acceptability and quality of high-yielding varieties of grain sorghum and millet.
6. Development of appropriate storage systems to reduce post-harvest losses.
7. Development of improved means for technology communication.
8. Improving the supply of trained personnel.
9. Development of improved marketing structures, organization, performance and information.
10. Collaborative research leading to more effective pricing and other governmental policies.
11. Research on the socio-cultural complex involved in the use and acceptance of the crops as human food.
12. Studies leading to the reduction of risk in production and marketing.
13. Special studies on nutritional problems directly related to food use of sorghum and millet.
14. Development of farming cropping systems and management which will maximize effective returns to sorghum and millet growers.
15. Creation of an international data base to make sorghum/millet research data easily available on a worldwide basis.

### C. Project Structure.

Eight U.S. Land-Grant institutions were finally selected as initial participants in the Sorghum/Millet CRSP activity. It is intended that a number of developing-country research agencies will join the organized structure as participants, when individual agreements are worked out with the governments and institutions concerned.

The research projects, as organized, are designed to address the identified constraints and to meet the indicated research needs. More than 60 senior staff members at the 8 member institutions are involved in 41 defined projects. A complete listing of projects, by title, institution, and CRSP project number, is set forth in Appendix 1 to this report.

For internal coordination, six informal subject-matter groupings of research projects and workers have been formed. These groupings were utilized at the first Investigators Workshop (Lincoln, NE, January 14-15, 1980) to focus discussion and planning of the program's research activities. Having proved effective, these groupings will be continued in subsequent workshop and coordination activities. Discussion of research plans and progress in this report will follow this grouping, as indicated below. It should be noted that five of the organized projects are included in two groupings each.

#### 1. Breeding genetics and varietal improvement.

The major thrust of these projects is to develop improved varieties of germ plasm of sorghum and pearl millet, suited for practical use in improving the materials available to sorghum and millet growers in developing countries. Emphasis is placed on germ plasm having good agronomic performance, a higher degree of yield stability, and acceptable food quality and grain characteristics. Nine projects at 5 institutions have major direction toward this phase of research.

#### 2. Physiology, plant nutrition, cultural practices and cropping systems.

Research in these topics is intended to provide needed basic information on plant growth, behavior and response, with particular emphasis on stress response under conditions comparable to those of developing countries. From this basic information, field studies will extend the knowledge to develop practical methods and systems for growing

the crop to produce superior and more stable performance. Thirteen projects at 5 participating institutions give major emphasis to this field of study.

### 3. Plant Pathology.

Integration of plant disease research with the plant breeding programs is integral to all the major breeding efforts in this CRSP. In addition, the severity of plant disease losses is so great and their effect on food supplies so serious that special efforts are required as a direct focus on the identification and control of the most damaging plant diseases. In all, 9 research projects at 4 institutions give primary emphasis to plant pathology research and plant disease control.

### 4. Entomology and pest control.

Production losses from insects and vertebrate pests are extremely serious, particularly in the more hazardous or marginal areas of crop adaptation. Sorghum and pearl millet, as the principal cereal grains in some of the environmentally most marginal crop production regions, are especially subject to devastating damage by these pests. Integration of pest management research, as with plant pathology, is a feature of all the major plant breeding projects in this CRSP. In addition, special emphasis is being placed on control of the major insect pests by feasible, integrated means requiring specialist treatment of the research problems. Six projects at 2 institutions are specifically concentrated on insect and pest management research.

### 5. Storage, utilization and nutrition.

Post-harvest storage losses in quantity and quality, and problems with palatability, acceptability and nutritional value of food products prepared from sorghum and millet are serious difficulties even if and when major production constraints can be overcome. Folk-wisdom and prevailing practices have provided empirical solutions to some of these problems, but major impediments still remain. The institutions involved in the Sorghum/Millet CRSP have outstanding research capabilities in all the needed fields; projects organized under the CRSP deal with the difficult task of focusing modern scientific knowledge and tools on the food utilization problems of less-developed societies. Six projects at 5 institutions are focused on various aspects of the utilization field.

### 6. Socio-Economic Considerations.

The listings of constraints and research needs focused intensively on social and economic considerations which are likely to affect the end-use of improved food crop production -- that is, the improvement of human nutritional standards and quality of life. A special strength of the CRSP concept and of the Sorghum/Millet CRSP in particular is the integration of socio-economic research into the fabric of a generalized, commodity-oriented development program. Three major projects, at 3 of the eight participating institutions, specifically address socio-economic problems in their relation to improved production and utilization of the relevant major crop commodities.

#### IV. ACTIVE RESEARCH WORK

In this section of the report, research projects which have been activated will be outlined and, where possible, early research findings will be discussed. The overall coordinated program has been underway such a short time that there has been limited opportunity for any major research accomplishments. However, a number of the projects are based on contract research previously conducted with A.I.D. financial support, and it is appropriate to regard progress in such projects as part of the overall program effort.

The following discussion follows the 6 topical groupings of research activities, delineated in III.C. above, for convenience in assessing activities and progress of the research.

##### n. Breeding, Genetics and Varietal Improvement.

Nine projects at 5 institutions currently have major focus on this phase of research. In each case, the essential goal is to produce germ plasm stocks, varieties, lines or hybrids which have superior genetic qualities suited for use under conditions to be found in developing countries. Reduction of risk, particularly in marginal environments and low-input farming, is an especially significant goal of these efforts.

Work begun under earlier A.I.D. contracts and continued as part of the present CRSP program shows promise of quick pay-off with relatively limited additional effort. Two outstanding examples of this are the Texas A&M "tropical adaptation conversion" work with sorghum and the Kansas State efforts in the improvement of pearl millet. These projects and their promising results will be discussed in appropriate sections below.

##### 1. Texas A&M

Four major improvement projects are active at Texas A&M and its co-operators. Two of these involve major cooperation with other

disciplines -- namely, plant pathology and entomology. One is concerned with rather basic research designed to make production of improved varieties more simple.

The major breeding projects are primarily concerned with developing sorghum types with wide adaptation and stable yields. Material developed under previous A.I.D.-funded research was continued under selection in a wide range of environments across Texas, and in Puerto Rico, Mexico and Guatemala. Selection in South Texas has proved to be effective for developing types with suitable agronomic adaptation and high yield potential in tropical LDC's. A particularly significant finding is that "converted" types with tropical adaptation and high-yield factors thus derived from a basis of temperate-zone material produced very high yields (above 7000 lbs/acre) in Guatemala during the past "winter" season. Some of these strains have very desirable grain quality and plant characteristics. It is intended to expand their testing quickly, and if they live up to their early promise, some of these strains can soon be made available to LDC farmers, at least in Latin America.

Sorghum germ plasm stocks with high levels of resistance to disease such as maize dwarf mosaic (MDM), bacterial stripe, bacterial streak, and grain molds have been identified and were increased in Puerto Rico during the 1979-80 winter season. Significant progress has been made in developing agronomically-desirable lines with high resistance to sorghum midge, a world-wide serious pest of grain sorghum. Midge-resistant material was distributed during 1979 to a number of developing countries, including Columbia, Ethiopia, Ghana, Kenya, The Phillipines, Tanzania and Thailand.

Fundamental research on sorghum reproductive systems is directed specially toward discovery of effective apomictic (non-sexual) and new male sterile/restorer systems. Progress was made toward both objectives.

The ultimate objective is to develop types from which hybrid seed can be easily and conveniently produced, even under conditions of poorly-developed seed industries.

## 2. Purdue.

The plant breeding project at Purdue has developed from a previous long-term A.I.D.-supported project for developing high-yielding types with high nutritional quality of the grain. This project is very closely integrated with food utilization studies (E. below) at Purdue and four other INTSORMIL institutions.

An International Food Grain Sorghum Yield Trial has been organized and coordinated as part of this project effort. Several selected varieties have shown superior yields, good agronomic acceptability, and good food grain quality, when tested in developing countries and evaluated in the preparation of local traditional food products.

A somewhat disturbing finding was that high-protein, high-lysine sorghums tested in child-feeding experiments in Peru were only 60% as digestible as wheat. These findings were not in accord with expectations and warrant careful review. Possibly anti-nutritional factors are involved.

A field visit to Mali and Upper Volta by one of the investigators (and one from Texas A&M) was especially useful in that local procedures were observed which would be likely to modify or eliminate certain anti-nutritional factors. Field observations made on this visit will be extremely useful in establishing realistic criteria for evaluating food quality of sorghum and millet grain.

## 3. Arizona.

The Arizona project is a combination of breeding and physiological

studies, designed to develop drought-tolerant and water use-efficient sorghum and millet strains under extremely rigorous environmental conditions. Preliminary screening during 1979, using a sprinkler irrigation gradient system on sandy soil, with near-zero rainfall and extremely high temperatures, indicated marked variations in stress response of various sorghum and millet genotypes. A refined, collaborative trial, involving some 300 entries from four of the INTSORMIL institutions, was planted March 19-20, 1980.

#### 4. Nebraska.

Plant breeding projects at Nebraska are specially concerned with the development of new, broadly-adapted breeding populations and with the development of lines and hybrids with stable yield performance over a wide range of environments. Standard sets of material have been grown at a number of locations in Nebraska and Kansas, representing wide differences in average temperature, rainfall, photoperiod and length of growing season. Additional environmental variation has been introduced by differences in plant population density, planting dates, irrigation treatments and type of soil preparation. Findings have shown that inherent variations in maturity patterns are highly significant in conditioning environmental response. This fact must be closely considered in evaluating trial results and in planning future experiments.

The project "recurrent selection in sorghum" differs from other breeding projects in the program in that its chief focus is on development of broadly-adapted, random-mating populations which retain high degrees of genetic variability for major agronomic characters. Several such populations are under development, and some of these show early promise for use in certain developing countries. A collaborative selection phase, using the same base populations, is comparing selection in the relatively mild

climate of Nebraska with selection under extreme stress conditions in Arizona.

#### 5. Kansas State.

The major pearl millet breeding and selection efforts in the CRSP are being conducted by Kansas State, with the majority of the actual field selection at the Fort Hays station in west-central Kansas. This project has been supported under an A.I.D. research contract (AID/ta-C-1458) but is being integrated into the overall Sorghum/Millet CRSP effort.

Millet types produced in this program show excellent promise in yield and grain quality. Yields of the best hybrids thus far developed in this project ranged from 3610 to 5920 kg/ha, which is directly comparable to the yields of well-adapted grain sorghum commercial hybrids. This finding is especially promising in view of the fact that the pearl millet breeding work has been underway for only a few years.

#### B. Physiology, Plant Nutrition, Cultural Practices and Cropping Systems.

Thirteen projects at 5 institutions have principal emphasis on these fields of research. Broadly speaking, the major objectives are to develop basic information on plant responses and to learn how these responses can be modified or utilized to maximize and stabilize agronomic performance. As in the plant breeding projects, the practical goal is to minimize farmer risk and maximize practical, economical yields.

##### 1. Nebraska.

Studies on physiology and closely associated topics were undertaken at Nebraska with A.I.D. contract support, and have been continued and expanded under the CRSP. Six projects, ranging from basic physiological investigations to field cropping systems, are active at Nebraska.

Drought stress tolerance is a particular objective of one project. Genetically-controlled responses have been observed, and the fundamental

biologic control underlying favorable stress reaction is being sought. It has been found that severe early drought stress reduced photosynthetic capability, and it appears that tolerance to early drought is closely related to stability of photosynthetic capacity. This characteristic can be studied effectively in greenhouse or growth chamber conditions.

Efforts are continuing to select types whose root characteristics lead to maximum water uptake and water use efficiency.

Response to temperature stress is being studied in both grain sorghum and pearl millet. Early findings of studies comparing responses in the field to those in growth chambers showed that above-normal night temperatures reduced yield of test strains almost identically in the two study methods. This confirmed that research in the growth chambers can be expected to produce results directly applicable to field conditions.

The period between flowering and maturity (grain fill period) is a time in which major changes in final yield can occur. Based on work in other crops (corn, particularly), it appears that problems encountered during this period may be responsible for much of the low yield often encountered in tropical growing conditions. No definitive data are yet available, but a growth chamber study with pearl millet during the 1979-80 winter has shown interesting preliminary results.

Mineral element use efficiencies and tolerances are being studied under rather unique circumstances both in the field and growth chambers. Some genotypes have shown good resistance to high levels of aluminum (Al); this is significant because Al toxicity is common in many highly-acid soils in the tropics and subtropics.

Nitrogen uptake in both sorghum and pearl millet is being studied with the particular goal of searching for types which have the most efficient conversion of soil nitrogen to grain yield. Early trials have

shown wide variation among sorghum genotypes for such efficiency.

Climatological studies are underway with the principal goals of defining the climatological conditions which influence sorghum development and yield, and of being able to use analog techniques to forecast performance in areas other than those in which field experiments have been conducted.

## 2. Arizona.

Physiological studies in the combined breeding-physiology project are concentrating on relations between seedling vigor and drought resistance, and on the physical mechanisms of drought tolerance in sorghum and pearl millet. Special attention is being paid to the ability of resistant genotypes to flower and set seed at low moisture levels and high temperature stress.

## 3. Mississippi State.

The special capabilities of Mississippi State for seed and seedling studies are being utilized to determine the significance of seed quality in overall sorghum and millet performance, and effective means of improving seed quality or overcoming detrimental quality effects, under conditions applicable to LDC's.

Preliminary results indicated that equipment and techniques being used for controlled-condition studies accurately reflect actual field conditions. Evidence from early tests indicated that major genetic differences exist in resistance to seed weathering and quality loss under high-humidity conditions of seed maturation.

## 4. Texas A&M.

A project on efficient nutrient use in sorghum is similar to, and closely coordinated with, two related projects at Nebraska. Response to nitrogen (N), phosphorous (P) and iron (Fe) will be the special

objectives of study. Soil and growing conditions in Texas are so different from those of Nebraska that it is considered desirable to conduct these experiments in general parallel in the two states.

Another Texas A&M project, on temperature and moisture stresses, also parallels similar work at Arizona and Nebraska. Here again, growing seasons, soil conditions and moisture supply patterns in Texas differ both within the state and from those at the Arizona and Nebraska locations.

Another project links the breeding programs with studies on performance under suboptimal soil moisture conditions. These tests are being conducted on a wide range of soil textures, and in rainfall regimes quite different from other of related work in Nebraska and Arizona.

#### 5. Kansas State.

The Kansas State projects deal principally with pearl millet, but to some extent with sorghums also. Physiological and developmental processes related to stress tolerance are being studied in both crops, in Kansas and cooperatively at Hissar and Hyderabad, India. A special study is underway comparing the effects of plant height and plant architecture on stress tolerance. Early findings in the Kansas study indicate that short dwarf types (as compared with medium height and tall types) resisted stress better and yielded the most grain.

Studies on pearl millet stand establishment and plant growth currently are being conducted under the contract project AID/ta-C-1458. These studies will be incorporated into the CRSP framework during 1980 and 1981. Special emphasis is being placed on the reaction of pearl millet genotypes to various stress conditions.

### C. Plant Pathology.

Nine research projects at 4 participating institutions are specially concerned with plant diseases and their control. The major emphasis of all studies ultimately is to find effective, economical means, suited to LDC conditions, for reducing losses caused by plant diseases of sorghum and millet.

#### 1. Texas A&M.

Growing directly out of previous A.I.D. contract research support, 6 projects at Texas A&M have major emphasis on plant diseases and their control. Much of the activity underway is collaborative with ICRISAT and with research agencies in a number of developing countries.

The Texas research group is recognized as the outstanding world authorities on downy mildew, a world-wide major pathogen of sorghum, pearl millet and other cereal crops. Screening for resistance to this disease, using techniques developed at Texas A&M, is a major effort of the disease identification project. Results thus far have shown that inheritance of resistance is complex and that expression of resistance is subject to strong environmental modification. Worldwide testing to find resistant types and to evaluate new material is being coordinated in this project.

Two other major, world-wide diseases being investigated in detail are head smut and anthracnose. Previous laboratory techniques for studying head smut susceptibility/resistance have been relatively ineffective; techniques based on tissue cultures are being explored to improve selection efficiency. Anthracnose, a disease that can spread very rapidly in grain sorghums, has been shown to be relatively easy to control by simple chemical seed treatments or by use of non-infected seed.

A project with special implications for the conditions of the least-developed countries is exploring the use of cultural and biological measures

for controlling certain plant diseases. Charcoal rot, downy mildew, stalk rots and certain seedling diseases appear to be likely targets for these control methods. An added feature of this research is its attempt to determine interrelations and interactions among casual agents in disease complexes.

Virus diseases of sorghum and pearl millet are important, but relatively poorly understood. A project in virus identification and the diagnosis of virus-caused diseases is underway, and among its findings, has ascertained that an apparently new virus disease occurs in Venezuela. Studies are underway to identify the new virus and to locate sources of resistance to it.

Fundamental studies on the nature and mode of inheritance of resistance are underway with sorghum downy mildew, head smut and grain molds. During the course of these studies, a new race of the fungus causing sorghum downy mildew (Peronosclerospora sorghi) was discovered in Texas. Tests are being conducted to find sorghum types resistant to this new race as well as to those previously known.

Many insects infecting sorghum and millets are vectors (carriers) of important plant diseases. Joint work of plant pathologists, entomologists and breeders is underway to identify the interrelations involved and to develop effective control means. The relation between winged aphids and the spread of certain virus diseases is a special target of these studies.

Development of sorghum genotypes with multiple resistance to diseases is a major goal of plant breeding/pathology cooperative projects. During the 1979-80 winter season, new types combining resistance to bacterial stripe, bacterial streak, zonate leaf spot and grain mold were increased and advanced in a Puerto Rico winter nursery.

Several major international disease nursery programs are coordinated by Texas A&M in a world-wide cooperative program to improve disease resistance. These include the:

All-Disease and Insect Nursery (ADIN)

International Disease and Insect Nursery (IDIN)

Uniform Head Smut Nursery (UHSN)

International Sorghum Anthracnose Virulence Nursery (ISAVN)

Results from these nurseries for 1979 were summarized in the final report of research contract AID/ta-C-1384. Subsequent summary results will be disseminated as part of the INTSORMIL reporting system.

## 2. Purdue.

Advanced techniques are being used to screen sorghum genotypes for resistance to major diseases, especially "milo disease" (Periconia circinata) and anthracnose. The special techniques being used in this project are based on the fact that these (and some other) diseases do much of their damage to the host plant through the action of toxins. The research is concerned with isolating the toxins and using purified toxins to select for resistant types and to study the basic mechanisms of host plant resistance.

## 3. Mississippi State.

The humid growing weather normal to Mississippi provides environmental conditions for sorghum and millet quite different from those found in most of the other participating domestic locations. The usual growing conditions in Mississippi are, however, basically similar to the conditions found in many tropical or sub-tropical LDC's with monsoon-type climates. Therefore, Mississippi State is concentrating its sorghum improvement studies on problems particularly important to similar environments.

Early findings from these studies have shown that a number of pathogenic fungi, particularly Fusarium species can attack sorghum heads soon after pollination and result in severe damage to developing grain. Such damage is important both to the use of the grain for food and to its value for seed. A special search is being made for genotypes resistant to the more common fungi which cause damage to developing heads.

#### 4. Nebraska.

Plant pathology work at Nebraska in this program concentrates on the screening of tissue cultures of grain sorghum for resistance to fungus metabolic products. This relatively fundamental work, coordinated with a related project at Purdue, is aimed at the development of highly efficient, large-scale screening of sorghum genotypes for resistance to major diseases.

#### D. Entomology.

Six projects at two institutions concentrate on insect and pest management research as related to sorghum and pearl millet production and improvement. Insect and pest damage are particularly significant in marginal production areas of these crops, where devastating losses from these causes frequently occur. In particular, the INTSORMIL projects hope to develop effective non-chemical means of control, to combine loss reduction with the best possible degree of environmental protection.

##### 1. Texas A&M.

Breeding for insect resistance is a major project effort, involving close cooperation between entomologists, geneticists and breeders. In the central breeding project at Texas A&M, resistance to sorghum midge, greenbugs, corn leaf aphids and the Banks grass mite is being sought for incorporation into desirable agronomic strains.

The Corpus Christi, Texas location provides severe natural infestation of several major insect pests, including the sorghum midge. Field evaluations

there in 1979 showed that 7 agronomically improved lines had good levels of midge resistance, and that 9 selections derived from advanced crossing programs had significantly less midge damage than a major group of fairly resistant material. A number of these selections already have been made available to plant breeders in developing countries.

Essential to progress in control of insects, particularly in developing countries, is the evaluation of feasible systems for integrated control. Research on such systems, involving resistant varieties, cultural manipulation, and biological control, is being conducted as a major Texas A&M project. One of the significant findings to date is that sorghum midge resistance has been found to be related to rate of flower and seed development; the more rapidly developing types usually have less midge damage. There also is evidence that some resistant strains are antibiotic to the midge. Summarized data of previous midge screening trials have been compiled and are available to LDC scientists.

Another project is evaluating indigenous and exotic natural enemies of greenbugs, the Banks mite, and parasitic caterpillars. Equipment and methodologies are on hand to culture parasites of these harmful species, and to determine if such parasites can be successfully spread into natural insect populations. Early results with one exotic parasite of aphids is promising.

Because of the world-wide importance of the sorghum midge as a pest, a special project has been developed for its biological control. Adult emergence of the midge in the spring has been found to depend on temperature, moisture and the availability of hosts. Four species of insects have been found to be parasitic on the midge; only one of these is abundant in midsummer when midge populations are the most damaging. The other three species are more prevalent in late summer, after the time of maximum midge damage to sorghum in Texas.

Another project at Texas A&M is concentrating on insect-pathogen-host interactions in both insect and disease damage caused by aphids, leafhoppers and other sucking insects. Such species frequently transmit plant diseases, especially viruses, which cause damage additional to that resulting directly from insect feeding. Early activities in this project have been chiefly concerned with techniques for observing feeding behavior and insect-plant interactions for the species under study.

## 2. Mississippi State.

The insect complex attacking sorghum in Mississippi tends to be different from that in Texas. As is true for the disease complex, the Mississippi conditions are particularly analogous to those of monsoon-climate subtropical and tropical areas. Sorghum midge is a serious pest in Mississippi as in Texas, but attacks on a somewhat different seasonal cycle. The fall armyworm and related leaf-feeding caterpillars are particularly important major pests being studied at Mississippi. As in the Texas projects, development of resistant varieties is being studied as a key control tool.

## E. Storage, Utilization and Human Nutrition.

Six projects at 5 INTSORMIL institutions are concerned with various aspects of utilization, human nutrition and post-harvest handling of sorghum and millet grain. The use of these crops as significant food sources in marginal crop production environments makes them particularly important objects for needed improvements. The INTSORMIL grouping of research in this field is strong and encompasses a wide variety of experience in the staff of the various projects. A particular strength is the close institutional and programmatic coordination among production, utilization and socio-economic components of the research program.

### 1. Purdue.

The major role of Purdue in A.I.D.-funded research on food grain quality improvement has been well established over the last 15 years. Purdue's

sorghum improvement project, discussed in A.2. above, has a strong focus on enhanced nutritional quality and effective food utilization of the grain. Major scope and findings of this project have already been presented.

Another project at Purdue is focused directly on the improvement of nutritional value of high-tannin sorghums. Bird and other pest resistance of sorghum grain is known to be highest when the tannin content of the grain is high. Since tannins bind to both proteins and starches in non-ruminant digestion, the likelihood of anti-nutritional effects in humans is very high.

Early findings have shown that most high-tannin forms reach a peak before the grain is mature and then declines. Chemical studies have shown that the "immature" tannin form is fully as toxic as that in the mature grain, and therefore that the reduction during maturation leads to a real decrease in anti-nutritional effects. Growing out of this, the Purdue researchers have sought and found types which may be termed "safe tannin" strains. Such types are high in tannins when the grain is immature and most in need of bird protection, and low in tannin at full maturity. One such strain, IS-2830, is very promising in early trials and will be further studied in detail.

Another significant laboratory finding serves to explain certain traditional food preparation practices in major sorghum-consuming areas. Preparation of batter and cooking, each individually and more in combination, were found to decrease the detectable levels of tannins. When dilute alkali was added, tannins were decreased even more. This may explain the practice, common in West Africa, of adding ash or other alkali to sorghum flour before cooking. In other African areas, vegetable acids are added, and in yet other areas, the batter is fermented before cooking. Further laboratory studies are needed to elucidate the chemical and nutritional implications of these various practices.

A number of fundamental studies are being conducted on the chemical interactions between proteins and tannin, and on their nutritional effects. An interesting finding of this work is that, while the free amino acids proline and glycine do not bind strongly to tannins, the affinity of complete proteins for tannins is directly related to their proline and glycine content. The nutritional implications of these findings are not yet clear, but they do suggest a possibly useful line of further research.

## 2. Kansas State.

Two major areas of post-harvest significance are involved in the Kansas State research. In one project, storage and preservation of pearl millet is under intensive study. This is especially important, because pearl millet grain and particularly its milled products are notorious for difficulties in keeping quality. Early findings indicate that millet and its products are highly susceptible to a variety of stored-grain insect pests. A number of these are found more or less world-wide and can be studied by normal techniques at Kansas State. One major potential pest, the Khapra beetle, is not found in the U.S. and is therefore strictly quarantined. Research with this insect must be conducted by cooperative efforts at overseas locations.

Utilization and nutritional quality of pearl millet are under intensive study in another Kansas State project. Milling studies in this project have shown that "good" and "poor" quality millets grown in Africa have different milling properties from those of Kansas-grown material. Grain hardness appeared to be a related factor.

Chemical and nutritional studies have shown that, in general, lysine and methionine are the limiting amino acids in pearl millet as in most other cereal grains. Some variability in lysine content, attributable to genetic differences, has been found. The leucine:isoleucine ratio, considered to be

of considerable nutritional significance, is fairly constant in different pearl millet types but much lower than that usual in grain sorghums.

### 3. Texas A&M.

Food quality studied at Texas A&M are chiefly focused on sorghums, and emphasize the evaluation of traditional food products, prepared in forms acceptable for consumption by local populations.

A field visit to Upper Volta and Mali late in 1979 enabled elucidation of detailed traditional food preparation methods, and revealed interesting differences. A thick porridge, "To", is common to both countries, but is prepared by adding alkali in Mali and acid (usually tamarind juice) in Upper Volta. Apparent grain quality was found to vary with methods of preparation; for example, the exotic sorghum variety E-35-1 was regarded in Mali as making poor To and was found to have poor keeping quality there. However, To made from the same type in Upper Volta, in the acidic preparation form, had excellent keeping quality. Thus, it is apparent that selection of "high quality" varieties will have to take methods of food preparation into consideration.

Sorghum quality for tortilla making, using traditional Central American techniques, also is being evaluated. White sorghums are preferred in those areas for tortillas, but even some white types produce undesirable colors in the cooked tortillas. Several "native" sorghums from Central America and some types from the world collections and the Texas A&M sorghum breeding programs were found to have highly satisfactory tortilla quality.

Collaborative grain quality trials are being conducted with ICRI SAT, using grain grown in India and in the United States. These samples are being evaluated for food quality in a wide range of traditional food products, including To and related thick porridges, tortillas and chappaties (unleavened

bread) and kiswa or injera (fermented flat breads).

#### 4. Florida A&M.

No previous project on these crops was underway at Florida A&M; thus, initial activities under the CRSP were concerned with the research operations. Studies will concern food products and recipes suitable for sorghum and millet consumption in human diets, with emphasis on Caribbean countries. This work is closely coordinated with studies at Mississippi State (see 5. below)

#### 5. Mississippi State.

The major thrust of the Mississippi State project is the integration of social sciences, nutritional science and agronomic studies in developing more effective use of sorghum and millets where they are staple food grains. This work will be closely integrated with that of Florida A&M.

Preliminary studies in Haiti and Honduras have shown that grain sorghum is presently an important food grain in the less-productive regions of both countries. Early trials have indicated that mixtures of corn and sorghum flours can be used to produce tortillas of highly acceptable flavor and texture. Preliminary studies indicate that child weaning foods based on sorghum-beans mixture may be useful.

#### F. Socio-economic Considerations.

Three major projects at three institutions focus on socio-economic considerations. Methods to be followed in these studies have some general similarities but there also are significant differences in research approaches. Moreover, each institution has chosen a different geographical area for primary consideration; thus, there is an effective basis for interaction but little if any duplication in the research underway.

##### 1. Kentucky.

Actual field work has not yet begun because overseas arrangements are

still in process. The Sudan is targeted as the principal initial area for field operation. All studies are to be conducted in close cooperation with the economic research group at ICRISAT.

Planned work is in three areas. One set of studies will use a cultural-economic approach to identify farming strategies and the patterns of production, distribution and consumption of sorghum and millet. Special attention will be paid to the relationships between culture, behavior patterns and the technologies utilized.

A second phase of study is the identification and analysis of communication among scientists and between scientists and others, as these relate to the development of appropriate, practical technologies for sorghum and millet. ICRISAT, the LDC research institutions and the U.S. research structure all will be considered in these studies.

In a third area, models of the information diffusion and technology adoption processes will be used to assess the effectiveness of technology diffusion and the patterns of change in sorghum/millet technology.

## 2. Purdue.

Purdue's studies are aimed at broad-scale interpretation of the socio-economic considerations involved in crop production and utilization in this area. The early efforts in this project will be to gather and synthesize information on production, risk, marketing and utilization of the two crops. Studies will be conducted in Senegal, Mali and Upper Volta. Field work in the area is necessary, and will be initiated as soon as the necessary official clearances can be obtained.

This project has a special focus on the role of women in the production marketing and utilization systems. In another project, funded by SAFGRAD, local data are being collected from several locations. The INTSORMIL project

will then synthesize available information and conduct a comparative analysis across the region.

### 3. Kansas State.

This project will focus on a socio-anthropological approach to farming systems analysis, in significant sorghum-millet growing areas in India. No field work has yet been done because arrangements and clearances for in-country activities have yet to be completed.

These studies will combine analysis of the traditional farming systems in Rajasthan, India, with evaluation of new technologies in village trials. The work will be conducted in close cooperation with ICRISAT, the University of Udaipur, and other research agencies in India.

Within the INTSORMIL program, coordination will be maintained with the Kentucky studies in the Sudan and the Purdue studies in West Africa. Coordination with ICRISAT also is of extreme importance, especially since that Institute has branch activities in both the Sudan and West Africa.

## V. PLANS FOR THE NEAR TERM

Work plans for the remainder of 1979-80 and for the 1980-81 operating year have been submitted by project leaders for all 41 of the component projects of the CRSP. Since the summer of 1980 will be the first field season for the majority of the projects, the chief emphasis of most plans is to begin full-scale research operations during the upcoming season. Overseas activities are mainly dependent on administrative arrangements which have not yet been completed.

Below is given a summary, by topical groupings, of the most significant near-term plans of the present INTSORMIL participating institutions. Proposed activities in developing countries are not treated in any detail in this section of the report; these activities are outlined on a country-by-country basis in VI below.

### A. Breeding, Genetics and Varietal Improvement.

1. Arizona will concentrate on identification of drought- and high temperature-resistant sorghum and millet lines, testing about 300 germ plasma collections.
2. Kansas State will continue development of improved pearl millet materials; some 2,000 lines will be under selection and several hundred new hybrids will be tested.
3. Nebraska will continue trials of standardized varietal sets at three locations, and will concentrate on selection for drought and low temperature resistance in new materials. The recurrent selection and mass selection programs in sorghum will be continued.
4. Purdue will place special emphasis on selection of sorghums for high quality in the preparation of traditional West African foods, and will conduct cooperative trials with workers in Mali and Upper Volta.

5. Texas A&M will continue development of converted types with tropical adaptation. Evaluation for disease resistance will be emphasized, particularly under natural infestations in South Texas. Several disease resistant source lines will be finally evaluated and released, as will two selected populations. A major coordinated trial of insect resistant lines and hybrids will be distributed to interested sorghum workers in other areas, and tested in several environments in Texas. Lines, populations and hybrids showing promise for stress tolerance will be tested at two major locations. New sterility-restorer systems will be tested and more strongly apomictic lines will be sought in new breeding material.

B. Physiology, Plant Nutrition, Cultural Practices and Cropping Systems.

1. Arizona will study morphological and physiological reactions of a wide range of material being tested under extreme conditions of heat and drought stress
2. Kansas State will study temperature and water stress effects on a set of different sorghum genotypes at two locations in Kansas and one in India. Seedling emergence and vigor tests will be conducted on pearl millet, at several planting dates and differing soil conditions. Relation of seedling vigor to mature grain yield will be studied. Herbicides commonly used for grain sorghum will be tested for their effects on pearl millet.
3. Mississippi State will begin characterization of sorghum and millet seed quality and seedling emergence with a seedbed simulator which permits close control of varying environmental factors. Cooperative studies will be established in Honduras and possibly in India to study seedling problems under these widely different conditions.

4. Nebraska will continue its physiological studies on a wide range of topics. Instrumentation and facilities will be completed and tested for accurate measuring and control of stress factors and their effects on plant responses. Water temperature interaction studies at Garden City, Kansas, will be begun. Selected materials for the grain fill study will be tested at two widely different environments in Nebraska. Screening for differential response to mineral nutrients will be continued, and a special study will be made on low-nitrogen soil. Cooperative studies on acid, high aluminum soils in Brazil will be conducted. Nitrogen efficiency of a wide range of sorghum and millet types will be studied. Phenological time scale characterization of sorghum genotypes will be continued and refined.
  5. Texas A&M will continue studies of efficient nutrient use, with special emphasis on nitrogen and iron. Studies of heat tolerance, desiccation tolerance and wax load will be conducted on a wide range of sorghum types. Early and late plantings at Chillicothe will provide comparison of low versus high temperature effects on early development. Drought tolerance will be studied in sorghum by using a "rainout" shelter to enhance drought conditions.
- C. Plant Pathology.
1. Mississippi State will field-increase seed of a number of imported lines grown in greenhouse quarantine, and make seed available for the first time to INTSORMIL breeders. They will also continue grain mold and seedborne pathogen studies and selection for resistance.
  2. Nebraska will establish cell cultures and whole plant regeneration, and use the resulting material in toxin screening to find disease resistance at the tissue level.

3. Purdue will analyze major pathogens of sorghum for production of toxic metabolites, and will carry out special studies on resistance to Colletotrichum graminicola.
  4. Texas A&M will continue major efforts to breed sorghum carrying multiple disease resistance. The international nursery system will be utilized to continue broad-scale evaluation of disease response and agronomic performance under a variety of growing conditions. LDC participation in this testing network will serve as a direct channel both for research information and for seed stocks.
- D. Entomology.
1. Mississippi State will evaluate midge-resistant types in a three-state cooperative trial, and will continue intensive search for resistance to the fall armyworm. Cooperation with Brazil in midge studies will be initiated.
  2. Texas A&M will strengthen its programs for incorporating high levels of insect resistance into agronomically desirable sorghum lines and hybrids. Emphasis will continue to be placed on resistance to the midge, greenbugs, leaf aphids and the Banks grass mite. Development and evaluation of integrated insect management and control systems will continue, with special emphasis on feasible biological methods of control.
- E. Storage, Utilization and Human Nutrition.
1. Florida A&M in close collaboration with Mississippi State, will review food habit surveys for Haiti, visit that country for selection of specific work sites, and begin development of sorghum-based foods and recipes suited to the local habits and situation.
  2. Kansas State will assess the actual storage and post-harvest loss problems with pearl millet, in selected LDC countries, and orient

its research on stored-grain pest damage to fit appropriate conditions as found in developing countries. Evaluation of nutritional quality in pearl millet will continue, emphasizing changes induced by various milling and processing techniques. Intensive surveys will be made in selected LDC's to determine local methods and quality standards involved in food use of grain sorghum and pearl millet.

3. Mississippi State plans to establish direct linkages in Honduras and, with Florida A&M, in Haiti. Special emphasis will be placed on development and nutritional evaluation of sorghum-based child weaning foods. Sociological aspects of sorghum consumption will be evaluated simultaneously.
4. Purdue will continue its major emphasis on development of sorghums with enhanced nutritional value, and on the nutritional improvement of high-tannin sorghum tates. In the latter field, evaluation of traditional food preparation practices in terms of laboratory findings on tannin effects will be a special area of concentration.
5. Texas A&M will study relationships between grain chemical composition and food quality of sorghum-based products such as To, tortillas and chappaties. Also emphasized will be development of laboratory methods for preparing realistic equivalents of traditional foods from small, experimental samples of various sorghum strains.

F. Socio-economic Considerations.

1. Kentucky plans to establish a field base in the Sudan, and proceed with data collection in three research topics related to its major objectives.
2. Kansas State plans to establish field data collection on farming systems in India, in collaboration with ICRISAT and the University of Udaipur.

3. Purdue will continue and expand its field studies in West Africa, and will develop data correlations from information collected in Senegal, Mali and Upper Volta. It will also organize workshops and joint discussions to bring together related investigations in the INTSORMIL system.

## VI. DEVELOPING-COUNTRY ACTIVITIES

### A. Introduction.

The stated major goal of this CRSP is to increase production and food availability of sorghum and millet in developing countries where these are major crops. Thus, it is obvious that activities within developing countries (DC's) themselves and cooperative research involving DC research agencies are essential to achievement of this major goal.

The grant document requires the CRSP Management Entity to proceed at an early stage with development of a consolidated program plan for work in and with developing countries. Information to be set forth in this section of the report and in Appendix 2 will summarize activities to date and the present status of this consolidated planning effort.

### B. Selection of Developing Countries for Cooperative Efforts.

#### 1. The Planning Activity.

In early stages of the planning process, the University of Missouri planning team made extensive site visits to developing countries where sorghum and millet are important crops. From these visits and from expressions of interest by various LDC agencies, general recommendations were made that the LDC institutions be included as working partners in CRSP research operations, and that the Management Entity of the CRSP activity take leadership in establishing the needed linkages with LDC institutions and the appropriate international research institutes and agencies. No specific selections or priority recommendations were made as to countries where work was to be conducted, or as to the nature of cooperative arrangement to be made.

#### 2. Early Screening by A.I.D.

Even before the CRSP was actually funded, the Food Crops Division of A.I.D. (AID/DS/AGR/FCP) sent a circular telegram to all A.I.D. field Missions and

offices, outlining the proposed activity and requesting a statement of local interest in participation. A similar message was sent to U.S. embassies in selected "A.I.D. graduate" countries.

The responses to this airgram were reviewed and appraised by the INTSORMIL Administrative Council in July 1979 and the Technical Committee in August. One of the first activities of the Program Director, who assumed his duties August 1, 1979, was to work with Dr. Jackson of DS/AGR/FCP and other A.I.D. officials to make a preliminary selection of countries to be visited and plan trips for on-site discussions. This selection was based on the analyses made by the Administrative Council and Technical Committee, and took into consideration the expressed interest of the U.S. participating institutions.

### 3. Site Visits.

In September and October, 1979, the Program Director and the A.I.D. Program Manager visited ICRISAT (Hyderabad, India) and New Delhi, India for preliminary discussions on coordination. Dr. Jackson subsequently visited Yemen, the Sudan, Tanzania, Mali, Upper Volta and Ghana. Dr. Leng discussed the program with USAID/Egypt and with senior officials of FAO, Rome.

Later, a two-man team visited Mali and Upper Volta, and one representative each has visited Guatemala and Honduras. In all cases, discussions were of a preliminary nature, chiefly being a mutual exchange of specific information and expressions of interest in cooperative research.

### 4. Present Status of Selection and Plans.

The Program Director and Technical Committee have recommended, and the Board of Directors has approved, selection of several countries for initial direct involvement in the program. In addition, close coordination is considered essential with several international or regional research centers of programs. These cooperative efforts are classified under

three headings, and each selected country or agency will be discussed below under this classification.

a. Principal "program-level" countries.

The Technical Committee recommended, and the Board approved, a list of "program level" countries. In such countries, more than one INTSORMIL institution and all appropriate scientific disciplines are expected to be involved.

(1). India.

Visited September 1979. There is considerable interest by Government of India and cooperation from USAID/Delhi. A descriptive packet and letters were sent via A.I.D. pouch in mid-January, as soon as individual project descriptions were ready. The Indian Council of Agricultural Research (ICAR) responded February 28, expressing further interest.

INTSORMIL institutions interested in collaboration include Kansas State, Nebraska, Texas A&M and Mississippi State. When the ICAR proposal for specific cooperation is received, INTSORMIL will develop a response and take a technical team (3 persons) to India to finalize an agreement.

(2). Yemen.

Visited October 1979. Arizona has an on-going sorghum/millet research project (country-mission funded) there and will be the executing agent for CID on a major research project when finally put in place. We have sent a descriptive packet to Yemen through Arizona and will pursue discussions as appropriate.

(3). Egypt.

Visited briefly in October 1979; at that time, USAID/Cairo discouraged further contact on behalf of CRSP. However, a "Major Cereals Research Project" has been contracted to CID by the Mission, and the project leader-designate has requested assistance and technical back-up from INTSORMIL. We have agreed

in principle to provide this. The present plan is for the CID project leader to develop contacts and lay groundwork with USAID/Cairo and Egyptian officials. INTSORMIL staff will then visit Egypt to develop details of cooperation.

(4). Sudan.

Visited in October 1979. INTSORMIL has agreed with USAID/Khartoum and Africa Bureau to work in part through CID-contracted Western Sudan Agricultural Research Project (WSARP). The African Bureau expressed a wish for us to discuss possible cooperation with the new Food and Agricultural Officer. This was done February 21, and informational packets were sent to him for carrying to Sudan. INTSORMIL is awaiting a response, and then will visit Khartoum with a technical team as soon as the time is appropriate. We are anxious for timely contact since Kentucky field work cannot begin until Mission and Government of Sudan approve.

(5). Mali.

Visited in November 1979 and a technical assistance visit was made by Rooney (Texas A&M) and Kirleis (Purdue) late-November-December 1979. Apparently ready for collaboration, especially on food utilization. There has been a cable request from USAID/Bamako asking when a team and project information are coming. The project information was sent early February.

We plan for a visit by the Program Director and a technical team to finalize agreement for cooperation. The exact time will depend on reply from Mali.

(6). Haiti.

This country chosen as a major contact because two institutions (Mississippi State and Florida A&M) have special contacts and competence there. A liaison visit was requested in February; the Mission responded requesting delay of visit until reorganization of local program completed. Planned work in Haiti will be specially concerned with food utilization of sorghum.

(7). Guatemala.

Texas A&M has a sorghum specialist, Dr. Plant, on duty in Guatemala with ICTA (National Agricultural Research Institute). This should provide a base for developing work in Guatemala. Latin America Bureau has concurred, and USAID/Guatemala apparently is interested.

A direct contact was made on the occasion of a Latin America sorghum meeting in Guatemala City in late March. INTSORMIL was represented at this meeting and the occasion was used to develop plans for cooperative work with ICTA.

(8). Honduras.

An informal visit was made in January, and we subsequently had a formal inquiry from the National Agricultural Research Institute about coordination. Informational material has been sent to the USAID Mission and the Government. When a response has been received, a prompt visit should be made to work out details of coordination.

(9). Brazil.

Not initially given high priority because message from Brazilia did not indicate interest. Latin America Bureau (A.I.D.) indicated strong interest and support, especially for "biomass/energy" work with Brazilian National Sorghum program headquartered at Sete Lagoas. This did not meet with JRC approval, but several INTSORMIL projects are interested in coordination with Brazil. We are attempting to learn the specific interests of Brazilian research agencies.

C. International Centers and Organizations, and Regional Agencies.

The CRSP grant document emphasizes the critical importance of developing collaborative research relations with appropriate international research organizations and centers, and with major regional research networks, especially those in which

A.I.D. is a major sponsor. To date, the major linkages being developed are with ICRISAT (international center), FAO (worldwide, United Nations grouping) and SAFGRAD (African regional research network).

(1). ICRISAT.

In the international agricultural research center system, ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) has been assigned principal research responsibility for sorghum and the millets. It is therefore vital that INTSORMIL establish and maintain the closest possible coordination with ICRISAT in development and execution of its overseas activities.

Drs. Jackson and Leng visited ICRISAT headquarters at Hyderabad, India, for discussions with Director Swindale and his senior staff on various aspects of cooperation. It was mutually agreed that the maximum level of cooperative effort would be of high benefit to both programs and to the overall interests of international development.

The specific items of cooperation are so numerous that it would be almost impossible to list them all. Some of the more significant activities already underway or planned include:

- a. Joint research in food quality of sorghum and millet selections, including a joint utilization workshop at ICRISAT, mid-1980.
- b. Cooperative investigations on major plant diseases, especially downy mildew and ergot.
- c. Joint preparation and revision of plant disease identification handbooks.
- d. Collaborative research on pearl millet development as related to temperature regimes (with Nebraska).
- e. Advanced training and professional development of ICRISAT staff at INTSORMIL institutions.

- f. Collaboration in field socio-economic studies in India, Sudan and West Africa.
- g. Exchange of germ plasm and breeding stocks on a regular basis.
- h. Joint operations in collection, evaluation and maintenance of major world germ plasm collections.
- i. Joint planning of major symposium, "Sorghum in the 80's" to be held at ICRISAT early in 1981.

(2). Food and Agriculture Organization, United Nations (FAO).

The Program Director visited FAO headquarters in Rome in October 1979, and discussed possible cooperative activities with senior FAO officials. Subsequently, correspondence was exchanged to explore further some specific areas needing coordination. Among items discussed, where cooperation may be useful, are:

- a. Food utilization of sorghum and pearl millet.
- b. Joint activities in semi-arid regions of Africa, particularly Kenya and selected West African countries.
- c. Possible cooperation with sorghum/millet research in Somalia.
- d. Cooperation with FAO interests in world germ plasm collection.

(3) Semi-Arid Food Grains Research and Development Program (SAFGRAD).

This major program is supported by A.I.D. and several other major international development agencies. Its objective is the development of a coordinated research and testing program for cereals and grain legumes, related farming systems, and training of a cadre of African scientists, in semi-arid African areas. A.I.D. support is in the form of a major project grant to the Scientific and Technical Research Commission (STRC) of the Organization of African Unity (OAU).

The mutual interests and basic need for cooperative efforts of SAFGRAD and the INTSORMIL program are obvious. The two crops concerned in this CRSP,

sorghum and millet, are two of the five crops receiving priority attention from SAFGRAD. All African countries which are likely sites for INTSORMIL cooperation are SAFGRAD participants. Virtually all the U.S. academic expertise in the two crops is involved in the INTSORMIL program. Accordingly, it is essential for INTSORMIL and SAFGRAD to develop appropriate and productive mechanisms for coordination.

Efforts have been made to develop cooperation, but these have been hampered by uncertainties and complexities in making the appropriate contacts. Recently, AID/W appointed a new SAFGRAD project officer in its Africa Bureau, and contact has been established with him. It is hoped that this soon will result in better delineation of programmatic coordination.

In the meantime, the Purdue work in West Africa on socio-economic considerations is closely related to a similar Purdue project being conducted as a SAFGRAD effort. Some linkages in Mali, Upper Volta and Senegal thus are available and these will be utilized to develop further specific ties.

#### C. Other Contacts.

Several INTSORMIL institutions and research staff have developed or are interested in more individualized contacts with research institutions and staff in developing countries. Most of the major programs have a number of such contacts; a few are listed here for illustrative purposes:

##### (1). Tanzania.

The national sorghum research coordinator has established contact with Purdue and Texas A&M. Breeding materials and data are being exchanged, and several Tanzanian students are to come to INTSORMIL institutions for training.

##### (2). Botswana.

Nebraska has established contacts with Ministry of Agriculture sorghum research workers, and is interested in establishing cooperative

field studies in Botswana, particularly in the area of stress tolerance.

(3). Cameroon.

The USAID Mission in Cameroon has informed AID/W and INTSORMIL of its interest in joint activities between the Sorghum/Millet CRSP and an AID-funded Grain Crops Research project soon to be activated in the Cameroons. INTSORMIL staff have expressed interest in such contacts, but we are awaiting contracting and activation of the country Mission project before attempting further planning.

(4). Mexico.

Several of the INTSORMIL institutions, particularly Texas A&M, Arizona and Nebraska, have long histories of contact with sorghum research in Mexico. Under the INTSORMIL program, activities have thus far been principally confined to joint germ plasma and strain evaluation, cooperatively with ICRISAT, CIMMYT and the Mexican national sorghum program. There are overriding reasons for developing much closer cooperation in the future, which might lead to programmatic coordination with Mexico as a major collaborator. Details of such coordination need to be carefully reviewed and planned; in the meantime, significant individual cooperation will continue.

DOMESTIC INSTITUTIONAL, PROJECT AND MANAGEMENT STRUCTURE,  
SORGHUM/MILLET CRSP

University of Arizona, Tucson, AZ

Administrative Representative - Dr. L. W. Dewhirst  
Principal Investigator - Dr. Victoria Marcarian  
Project: Sorghum Selection for Arid Conditions - XII UA 1

Florida A & M University, Tallahassee, FL

Administrative Representative - Dr. Charles C. Kidd  
Principal Investigator - Dr. Hetty Banatte  
Project: Food Uses for Grain Sorghum and Pearl Millet - XII FAM 1

Kansas State University, Manhattan, KS

Administrative Representative - Dr. Floyd Smith  
Principal Investigator - Dr. Richard Vanderlip  
Projects: Pearl Millet Breeding - XII KSU 1  
Physiological and Developmental Processes - XII KSU 2  
Farming Systems Studies - XII KSU 3  
Storage and Preservation of Pearl Millet - XII KSU 4  
Nutritional Quality of Pearl Millet - XII KSU 5  
Seedling Vigor and Stand of Millet - XII KSU 6

University of Kentucky, Lexington, KY

Administrative Representative - Dr. Herbert Massey  
Principal Investigator - Dr. Milton Coughenour  
Project: Sociological Constraints in Sorghum and Millet Culture - XII UK 1

Mississippi State University, Mississippi State, MS

Administrative Representative - Dr. R. Rodney Foil  
Principal Investigator - Dr. Mary Futrell  
Projects: Seed Factors, Stands and Emergence - XII MSU 1  
Sorghum Crop Protection and Pest Management - XII MSU 2  
Human Nutritional Improvement - XII MSU 3

University of Nebraska, Lincoln, NE

Administrative Representative - Dr. R. W. Kleis  
Principal Investigator - Dr. Jerry Eastin  
Projects: Sorghum Drought Resistance - XII UN 1  
Temperature Stress in Sorghum and Millet - XII UN 2  
Sorghum Grain Fill Period - XII UN 3  
Adaptation and Yield Stability - XII UN 4  
Sorghum/Millet Mineral Efficiency - XII UN 5  
Nitrogen Uptake in Sorghum and Millet - XII UN 6  
Sorghum Recurrent Selection - XII UN 7  
Climatology of Grain Sorghum - XII UN 8  
Toxins in Resistance Screening - XII UN 9

Purdue Research Foundation, West Lafayette, IN

Administrative Representative - Dr. T. Kelley White

Principal Investigator - Dr. John Axtell

Projects: Socio-Economic Constraints - XII PRF 1  
 Mechanisms of Sorghum Disease Resistance - XII PRF 2  
 Development of Superior Grain Sorghums - XII PRF 3  
 Enhancement of High Tannin Utilization - XII PRF 4

Texas A & M University, College Station, TX

Administrative Representative - Dr. Dudley T. Smith

Principal Investigator - Dr. Richard Frederiksen, (College Station)  
 Dr. Darrell T. Rosenow (Lubbock)

Projects: Sorghum Breeding for Productivity - XII TAM 1  
 Sorghum Breeding for Disease Resistance - XII TAM 2  
 Sorghum Breeding for Insect Resistance - XII TAM 3  
 Efficient Plant Nutrient Use - XII TAM 4  
 Resistance to Environmental Stresses - XII TAM 5  
 Improvement of Reproductive Systems - XII TAM 6  
 Host Plant Disease Resistance - XII TAM 7  
 Cultural Control of Plant Diseases - XII TAM 8  
 Diagnostic Systems for Plant Diseases - XII TAM 9  
 Nature of Resistance to Diseases - XII TAM 10  
 Insect Resistance by Host Plants - XII TAM 11  
 Biological Control of Insect Pests - XII TAM 12  
 Integrated Insect Control Systems - XII TAM 13  
 Insect Vectors of Virus Diseases - XII TAM 14  
 Food and Nutritional Quality - XII TAM 15  
 Adaptation to Suboptimal Conditions - XII TAM 16

INTSORMIL Headquarters, Lincoln, NE

Program Director - Dr. Earl R. Leng  
Administrative Technician - Mrs. Janet Deshayes

Board of Directors

Dr. D. T. Smith, Chairman  
Dr. R. R. Foil  
Dr. R. W. Kleis  
Dr. Floyd Smith  
Dr. D. Woods Thomas

Technical Committee

Dr. Jerry Eastin, Chairman  
Dr. John Axtell  
Dr. Larry Busch  
Dr. Mary Futrell  
Dr. D. T. Rosenow  
Dr. Richard Vanderlip

AID/W Project Offices

Contact/Grants Officer - Mr. Morton Darvin, CM/COD  
Program Manager - Dr. R. I. Jackson, DS/AG/FCP

PLANNING MATRIX FOR DEVELOPING-COUNTRY  
INVOLVEMENT, SORGHUM/MILLET CRSP

| Region/Country | Topical Groupings* |          |          |          |          |          |
|----------------|--------------------|----------|----------|----------|----------|----------|
|                | <u>1</u>           | <u>2</u> | <u>3</u> | <u>4</u> | <u>5</u> | <u>6</u> |
| Asia           |                    |          |          |          |          |          |
| India          | X                  | X        | X        | X        | X        | X        |
| Near East      |                    |          |          |          |          |          |
| Yemen          | X                  | X        |          |          | X        |          |
| Egypt          | X                  | X        | X        | X        |          |          |
| Africa         |                    |          |          |          |          |          |
| Sudan          | X                  | X        |          |          | X        | X        |
| Mali           | X                  |          | X        | X        | X        | X        |
| Latin America  |                    |          |          |          |          |          |
| Guatemala      | X                  | X        | X        | X        | X        | X        |
| Honduras       | X                  | X        | X        | X        | X        | X        |
| Haiti          |                    |          |          |          | X        | X        |
| ICRISAT        | X                  | X        | X        | X        | X        | X        |

\* 1 - Breeding, genetics and varietal improvement

2 - Physiology, plant nutrition, cultural practices and cropping systems

3 - Plant pathology

4 - Entomology

5 - Storage, utilization and human nutrition

6 - Socio-economic considerations

Statements of Interest by U.S. Institutions

| <u>U.S. Institution</u> | <u>Region of Interest</u> |             |                  |                  |
|-------------------------|---------------------------|-------------|------------------|------------------|
|                         | <u>Africa</u>             | <u>Asia</u> | <u>Latin Am.</u> | <u>Near East</u> |
| Arizona                 |                           |             | X                | X                |
| Florida A&M             |                           |             | X                |                  |
| Kansas State            | X                         | X           |                  |                  |
| Kentucky                | X                         |             |                  |                  |
| Mississippi State       | X                         |             | X                |                  |
| Nebraska                | X                         | X           | X                | X                |
| Purdue                  | X                         |             | X                |                  |
| Texas A&M               | X                         | X           | X                | X                |

The combined expressions of topical and regional interest will involve program-wide coverage in each of the four A.I.D. regions.

## REFERENCES TO KEY DOCUMENTS

The following documents contain key information concerning the planning, organization and inception of the Sorghum/Millet CRSP.

- A. Program Proposal for a Grain Sorghum/Pearl Millet Collaborative Research Support Program. AID-DSAN-C-0023. Prepared by University of Missouri, August 1978, 67 pp.
- B. Recommendations. Collaborative Research Support Proposal Grain Sorghum and Pearl Millet. Part I of the Final Report, Work Order 4, Contract AID/Afr-C-1139. U.S.A.I.D. and University of Missouri, March 1978, 64 pp.
- C. Supplementary Information. *ibid.* Part II of the Final Report, March 1978, 167 pp.
- D. Interim Report. Principal Constraints on Production, Marketing and Utilization of Grain Sorghum and Pearl Millet in Less Developed Countries, Part III of the Final Report, December 1977, 72 pp.
- E. Grain Sorghum/Pearl Millet CRSP Original Project Proposals. 2 volumes, loose-leaf, University of Missouri, 1978.
- F. Grain Sorghum/Pearl Millet Collaborative Research Support Grant, AID/DSAN/XII-G-0149, 27 June 1979.
- G. Sorghum/Millet CRSP Project Annual Reports, March 15, 1980, University of Nebraska (informal distribution).