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INTSORMIL

International Sorghum and Millet Collaborative Research Support Project.

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Welcoming Address

Dr. John Yohe,
INTSORMIL Program Director

On behalf of INTSORMIL, the Management Entity and each of the participating institutions in the program, I wish to welcome you to this conference. You will have an opportunity this week to exchange information and experiences on your collaborative research on sorghum and millet and to provide input on how INTSORMIL can better serve your programs.

We are very happy to welcome our guests from the INTSORMIL collaborating host countries, AID Washington, USAID/Niger, BIFAD, ICRISAT, SAFGRAD/Burkina Faso and our graduate students from around the world. There are three objectives for holding this conference. The first is to encourage you to become better acquainted with the INTSORMIL program worldwide. We are very proud of the excellent collaborative research activities between INTSORMIL U.S. institutions and Botswana, Colombia, Honduras, Mali, Niger, Senegal and Sudan. INTSORMIL represents an extensive network of collaborative research on sorghum and pearl millet which interlinks national research programs with some of the most outstanding sorghum and millet scientists in the world. Secondly, we wish to consider the future role of INTSORMIL in collaborative research as National Agricultural Research programs are strengthened and mature. What will our Global effort be in the 1990's. The third objective is to review what the targets of opportunity are for future and improved collaborative research activities as we consider what the research needs will be in the 1990's for collaborating sites.

INTSORMIL continues to be faced with many challenges. Our collaboration is maturing and as trained scientists return to their countries the expectations and level of our research collaboration is rapidly becoming a peer relationship between our U.S. INTSORMIL scientists and our host country INTSORMIL scientists. In times of declining budgets and growing needs for expansion of activities in each collaborating country we are faced with the problems of extending our limited resources to the limit. These are positive problems. Our collaborative research relationships are dynamic and growing more sophisticated as we endeavor to improve the production and utilization of sorghum and pearl millet in stressed environments. In addition to increasing the availability of food we must look to how our collaborative research can be oriented to addressing sustainable agriculture production systems and conservation of the environment.

The program for this conference has been designed to maximize your participation. Do not hesitate to ask questions, to interject ideas or to make suggestions on how we can be of assistance to you this week. I look forward to becoming better acquainted with each of you.

Session I: Setting the Stage for the Future

- Structural Evolution of INTSORMIL
- Directions and Opportunities
- Future INTSORMIL/ICRISAT Interaction
- Future Role of Social Sciences in INTSORMIL
- INTSORMIL in the 1990s
- Dreams beyond the 1990s

Session Chair: Dr. John Yohe

Speakers:
Dr. George Teetes
Dr. Lynn Pesson
Dr. Ron Gibbons
Dr. Glenn Johnson
Dr. John Yohe
Dr. William Furtik

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Structural Evolution of INTSORMIL or "Serendipity, Baskets and THE REAL THING"

George L. Teetes, Professor
Texas A&M University

I cannot recall how it came about that I was given this assignment of making a presentation to this group. I probably said something at the conference planning meeting, construed as volunteering as usual. I should have practiced oral decay prevention, sat still and kept my mouth shut. As usual, I didn't and now you all have to suffer the consequences. At least my presentation is early in the conference so it won't distract too much from the important events. The same people that asked me to make this presentation were probably the same ones that set the travel date to the conference on the same day as all the annual college football bowl games.

I have decided to change the title of the presentation I am to give today from "Structural Evolution of INTSORMIL" to "Serendipity, Baskets, and THE REAL THING." The latter title, I believe, more appropriately describes the evolution of INTSORMIL from its inception to its current mature state; from its incertitude to its present day confidence. Also, I might poke a little fun at us all. And, all I say came from Joan and Dottie, INTSORMIL secretaries.

Let me elaborate in a general way on the title change and then I will proceed with the significant changes that have taken place within INTSORMIL, and highlight some of our more impressive accomplishments over the last 10 years.

Serendipity - Five years ago, in January 1984 in this same city, I made a presentation to this group entitled, "The Critical Issues We Face". In that presentation, I divided the critical issues that INTSORMIL faced into ten categories, and discussed each one. I concluded that the major issue faced by INTSORMIL at the time was that its approach was one of serendipity; and I defined serendipity as "looking for a needle in a hay stack and finding the farmer's daughter". Other than being accosted by several female participants at the conference accusing me of being a chauvinist and wanting to know why the farmer's son wasn't found in the hay stack, everyone fairly well agreed that INTSORMIL had little planned direction and was basically using the opportunist approach to meeting CRSP objectives. Thus, Serendipity in the title, and I'll talk later about how this has changed. It was at that same conference that I was sporting a very attractive beard. I was also presented a package of razor blades. I had grown the beard to look like Kenny Rogers, but Joan Frederick said it made me look like Willie Nelson. Midwesterners never did appreciate country-western folks, or our favorite songs, like; "If I said you had a beautiful body would you hold it against me?", and "She use to kiss me on the lips, but now its all over".

Baskets - One of the most astounding realizations and surprises that I have ever experienced was the negative attitude of many USAID personnel toward the CRSP program. Resistance to change and resistance to a new approach to LDC involvement by a collaborative research mode was not given strong support by some and in many cases even worse. Some claimed that the CRSP programs were nothing and would be nothing more than financial aid to Universities and self-centered State Experiment Station research scientists. In many cases, the attitude of the USAID Missions was no better than that in Washington. A Mission ADO in Niger once told Darrell Rosenow and I that he was sick and tired of U.S. University professors traveling to LDC's, buying baskets and returning home. Thus, Baskets in the title. The change in attitude will be discussed later, but we all know what excellent support INTSORMIL now gets from the AID Missions where we collaborate.

The Real Thing - Despite the serendipitous beginning, and the uphill battle for acceptance, INTSORMIL has evolved beyond the expectation of the great majority that felt the concept had no real chance of success. INTSORMIL has become the "Real Thing". The Real Thing not from the standpoint of completing all its objectives, but the Real Thing from the standpoint that the concept of University/LDC collaboration has been proven to be a successful approach.

With this beginning, I would like now to briefly note some of the changes that INTSORMIL has undergone, not only in its structure, but also in its approach, and to briefly note some of the most interesting and impressive events and accomplishments. I guess it is always important to take a look back, as a matter of fact we at Texas A&M University are establishing a new institute to do just

what I'm trying to do here today. The Institute will be "Institute for Advanced Hindsight Research into What Should Have Been".

Also, it's good to look back ever so often just to get the proper perspective on things. I learned early on in my life that "things are not always as they seem" as illustrated here A reassessment is often appropriate. My presentation is a look back. A look back at the good and the bad.

INTSORMIL Directors

No discussion of the structural changes within INTSORMIL would do without a review of our management personnel. Despite some of the things I might say, INTSORMIL perhaps has been very fortunate, and may be a little lucky, to seem to have the right administrative person at the right time.

Earl Leng - Earl was rough and ready on almost all fronts, but could walk a fine line when things got tough, say in Washington, but he usually broke the china before he left. He was tough at times, but knew what it took to keep INTSORMIL alive in those early, very difficult years of suspicion. He lead INTSORMIL to form a contiguous group from a segmented group of agricultural scientists already involved in the international arena. Earl's approach was opportunistic, and perhaps that was appropriate for the time. I remember well that Earl would call a TC meeting, meet with the group to tell them the problems being faced and then leave the meeting. If the TC could not resolve the issue, Earl usually had a solution. Earl was quick to take on an opportunity. I went to India with Earl one time for two days to set up the SADCC training program, because many feared what Earl might commit to. In any case, Earl kept INTSORMIL alive, maybe when no one else could have.

Glen Vollmar - There was never a more opposite of Earl Leng than Glen Vollmar. Quiet, polite, dry sense of humor, and a farmer after work. Glen also went through difficult times with us, especially severe budget cuts, which has really been AID's most significant contribution. The thing I like most about Glen is that he always had donuts at the TC meetings and was great to travel with, especially for finding practical solutions to critical problems, like changing tires in Honduras while on a field trip to the remote areas.

John Yohe - John is the professional and was always a source of strength and support of INTSORMIL and always had the clearest and most sensible interpretation of what was going on or what action needed to be taken. That was true when he was in Washington, as it is now, as our Program Director. If anyone, he probably best understands AID and University researchers. He has been a great asset, but he is almost always gone to some other country.

Tim Schilling - I don't have much to say about Tim, he hasn't been with us very long. He comes to us with a good and very appropriate background.

I wouldn't dare say anything about Joan or Dottie - they run the show and I don't want them against me.

There are many events and groups that come to my mind when I recall the changes that have taken place in INTSORMIL's structure. I recall the Missouri group. Ed Runge was a major player in that group and we in Texas eventually got him for our own which is certainly a plus for our side. The days of the Missouri group were hair-raising days. There were alliances made and broken during those early days, and lots of proposal writing and rewriting. Most probably don't remember the magnitude of the Missouri group's activities. But from that group came the first form and structure of INTSORMIL from proposals that were submitted to them. One contribution was the addition of a Socioeconomics/Anthropology component. Good, bad or indifferent, INTSORMIL was born, and it was a bloody birth, and the blood shed was not to stop. Remember, where there's money, there's blood.

I've always been impressed with AID's contributions to the CRSP. The two most significant contributions that AID has made has been budget cuts and new word phrases. After listening to several AID officials recently at one of our many reviews, I decided to change the name of my project. I decided to change it from "Sorghum/Millet Entomology" to "Regionally balanced solutions to entomological constraints through the log matrix application of molecular, recombinant DNA biotechnology to establish sustainable agriculture by faunal analysis of the instability of the socioeconomics of global villages." Another significant contribution by AID was to provide solutions to the severe budget cuts. After suffering an unbelievable budget cut - one of many - AID's answer was to cut travel. Can you imagine, an LDC collaborative research program and the solution to budget cuts was to stop traveling. Luckily we didn't heed their advice and continued to do what was absolutely necessary. I asked the ladies in the Management Office to put together some statistics on the subject and do you know, INTSORMIL PI's have traveled to 50 foreign countries, have spent 10,653 hours in the air, and have traveled approximately 5,385,740 miles. That is equivalent to 5.1 Scientific Man

Years in the air and 216 times around the world, 480 cases of diarrhea, about the same number of cases of coca cola and lomotil - and a few baskets!

But the stellar group for INTSORMIL was and has been the TC. The first TC was appointed by a group of wise and courageous Administrative Advisors from each of the participating institutions. By the way, most all the original wise and courageous Administrative Advisors that appointed the first TC are no longer associated with INTSORMIL. Maybe that is why INTSORMIL is doing so much better now than it was then. In those first few days, it was the appointed members of the TC that put the structure to INTSORMIL, by that I mean the first projects and the first budgets, with lots of fine tuning. They also began to identify the role of the TC which was to become the key element within INTSORMIL for a long time. The first days, weeks, and months of that first TC were painful days. As I said before, where there's money, there's blood, and there was a lot shed. Project funding at the start, and project funding realignment when budget cuts came made for extremely difficult times. INTSORMIL is different now than it was then. For example, there were 44 projects at the start and now we have about half that. There were 52 PIs, and now there are 28.

There were special people during those times too. People who did far more than most of us - Darrell Rosenow is certainly one who comes to mind. Over the years you might think of others - John Axtell has been a champion for Purdue and Niger, Dick Frederiksen has been a champion for pathology, Lynn Gourley has been a champion for CIAT and Colombia, and many of us have been champions for ourselves.

Let's don't forget the Board of Directors. Woods Thomas is the only man I know that has served a 10 year consecutive term as Chairman of the Board of Directors. Maybe it just seems that way. As I always say - stick with your best. What about the EEP? Its changed members more than some Texans change underwear, and they all never participate in the same review. We just finished our fifth review. They've always said how great we are, except the entomologists don't work on stalk borers enough, and we don't work on *Striga* enough, and we don't have a large enough socioeconomics component, and we don't spend enough money in LDC's, and we don't work on millet enough, and we don't seek outside funding enough, and we don't present our accomplishments well enough, and we don't travel enough (they usually deleted this from the report when AID said we traveled too much). As a result of their efforts, Gary Odvody has been in and out of INTSORMIL 16 times, or maybe it just seems that way, and Kentucky is a non-revenue receiving participant. Who is Florida A&M? Arizona who? Lou Holtz, head football coach at Notre Dame summed evaluations up very well in October when he was asked what he thought about his team being ranked number one. He replied he would rather be ranked number one in October than in September, but rather number one in January than in October. Anyway, he said, if those people are so smart, why do they have to vote each week?

I recall certain events that were savers of INTSORMIL. The Five-Year Technical Research Report kept us alive when INTSORMIL almost died. Also, that was a great report; not that me being coordinator of it had anything to do with that.

The formation of the EZC, the Ecogeographical Zone Council, (what a name) was a big step. It was the sign that INTSORMIL had changed from the serendipity to the planned and structured. This group developed the Global Plan. It seems to have overrun the TC, but I'll assure you that will change since I was re-elected to the TC for the coming three years. The Global Plan defined Prime Sites of INTSORMIL activity and gives the program a concentrated effort. INTSORMIL now needs a Discipline or Technical Plan to meet the technical needs of identified Prime Sites in a coordinated manner. It is the technical strength of INTSORMIL that is of value, but it seems we have not yet focused in an organized manner the strengths with known crop production constraints in the Prime Sites.

There have been some great accomplishments by INTSORMIL scientists since 1979. Hageen Dura-1 made a big splash. Sureño has done the same. Significant accomplishments have been made in the area of drought, adaptation, pest and disease resistance and food quality.

It is not easy or simple to illustrate well the evolution of INTSORMIL, but it has evolved. Biological laws dictate that evolution comes about by imposed selection pressure, and we all know there have certainly been times of extreme pressure. These laws suggest that the fittest survive, but we might question that law in terms of different components within INTSORMIL. In any case, INTSORMIL is certainly more fit in almost all aspects than it was ten years ago. Roles and functions, major thrust areas by discipline and global region, and collaborators have been identified and research is well underway. The serendipity or opportunistic approach has been replaced, report preparation is more uniform and consistent, we have been accepted by the international community, we have a strong training element, a stable management, and except when money matters are involved, things run smoothly. All in all, I feel we can characterize INTSOR-

MIL and its activities as more defined, more structured, more focused, more positively involved internationally, and with more strongly placed partnerships than would ever have been expected. INTSORMIL has become THE REAL THING.

Certainly no one knows what the future holds for INTSORMIL or the entire CRSP endeavor. I recall a member of the EEP once asking me what my assessment of INTSORMIL was. I replied, "AID bought the lives of a lot of sorghum/millet experts very cheap." We are the best and the brightest. I really believe that, and regardless of what the Agency says, or anyone else, we know we have done well, considering the diversity of responsibilities we have and the many demands on our time as State University Professors. We will continue to do well. As we start another 10 years, we should do so optimistically and with the attitude of a famous far-east Texas philosopher who said "may the wind at your back, not be your own."

Agricultural Research and the CRSPs Under New Foreign Assistance Legislation - Directions and Opportunities

Dr. Lynn L. Pesson, Executive Director
BIFAD Board Support Staff

Title XII can be justly proud of its contributions to the so-called, "green revolution". Along with the IARCs and NARS, U.S. universities have done a magnificent job in partnership with A.I.D. As one surveys the developing world, many countries now have viable agricultural research systems, capable of developing the applied technology needed to support agricultural development programs. The CRSPs have been an integral part of this gigantic undertaking. In fact, I would have to class the CRSPs as perhaps Title XII's most significant contribution. The collaborative research work you do with host country scientists and institutions has been a crucial ingredient in this progress.

There is still much to do, however. The demographers tell us that there will be over a billion new mouths to feed by the turn of the century. This twenty percent increase in population will come primarily in the developing world, and the lion's share of these people will live in the cities.

Sub-Saharan Africa is a special case. Not only is it the fastest growing area population-wise (between 3-4 percent per year), but it is also the area where food security problems are the most acute. Increases in food production have not been keeping pace with population growth; in fact food production has been basically static.

The challenge to all of us is that the battle with hunger is still with us. Even with the advances made, the World Bank estimates that there are 730 million people in the world whose diets are below the level necessary to maintain their health and to work at a normal level. Ironically almost half of those are in India, a country that has achieved self-sufficiency. The hungry lack resources to either produce or purchase food, and food supplies are not always where needed. The current situation in some East African countries is a case in point of the latter.

Some Problem Areas

The economic problems of the 1980's are having their effect in agriculture. After a significant period of rising production levels, world grain production has generally leveled off. Yield ceilings of the improved grain varieties have plateaud. To illustrate IR-8, the first of the new, improved varieties developed by IRRI in the early 1960's set a yield ceiling in Asia that has yet to be surpassed. Improvements in characteristics such as taste and pest resistance have been made, but not one new release has passed that original yield ceiling. CIMMYT, on the other hand, has reported modest increases recently of up to ten percent with their new wheat lines. In essence, unless dramatic breakthroughs are made through one of the new biotechnology processes, dramatic yield increases for the foreseeable future in the major cereals are not likely.

If one examines where the dramatic improvements in crop production have been made, it is very clear that the fertile lands of the developing world have been the focal point. These good soils, together with the new varieties and basic inputs - fertilizers, pesticides - and infrastructure improvements - irrigation, machinery, storage, etc. - have been the primary ingredients.

This leaves several areas where lesser achievements have been made, the fragile lands and some crops such as sorghum, millet and vegetables. With increasing population and with the general leveling off of food crop productivity, these areas deserve and need much increased attention. INTSORMIL, of course, is right in the middle of it. The work that you are doing is basic to improvements on both of these questions, the fragile lands improved and sorghum and millet varieties for the dry lands areas of the world.

There is also the question of sustainability, the degree to which agricultural production systems maintain and/or enhance the environment in which they exist. The CO_2 problem generated by slash and burn agriculture, the degradation of the soil caused by overly intensive cropping in fragile lands, the over use of pesticides, pollution of water sources, etc. These are questions with which our research efforts must deal. It is no longer a question of dealing only with isolated variables. We must look at the larger questions, the inter-relatedness of many variables as they impinge on the question of sustainability. And what is perhaps most important, the farmer must see economic benefit to himself if he is going to adopt sus-

tainable agricultural technologies. These are challenges that we must meet.

Title XII Challenges and Opportunities

The foreign assistance business is changing. Budgets are going down, and the needs in many parts of the world are undergoing a metamorphosis. In large parts of Asia, the Near East, and in South America, agricultural research and education systems, for example, are now ongoing institutions. In most instances, these are organizations the U.S. helped to build through technical assistance projects. Many of them are now facing second generation problems such as lack of clarity of mission and unclear objectives. Further, the professional staff of many of these institutions are suffering from intellectual isolation, and, as a result, are provincial in outlook. Clearly, they need the stimulation of contact with the larger world scientific community.

Several major challenges and opportunities stand out for the future. These include the following:

- The need for collaborative and linkage activity. Title XII programs of the future, particularly with the more advanced developing countries, will emphasize collegial relationships and activity between host country and U.S. scientists. There is a great deal of mutual benefit to be gained, but, more importantly, it is the boost that such a program can give developing country scientific productivity. The demand for linkage programs and collaborative research activity is literally exploding in the developing world.

- Collaborative research activity will increase at the scientist-scientist and the department-department levels. While large collaborative research networks such as INTSORMIL are clearly major factors on the world scene, smaller scale collaborative activity is going to grow significantly as the need to help on-going developing country research staff and university faculty not only mature as researchers and scholars but also be intellectually abreast of the frontiers of science.

- The CRSPs have major challenges in front of them not only to improve their research output but also to dovetail their activities into the framework of sustainable agricultural systems. More and more, the challenge will be for the activities of the various CRSPs to mesh with each other's programs as we seek to establish sustainable agricultural systems. Special challenges to Title XII are the fragile lands and the slash and burn agricultural systems.

In summary, the challenges to solving the world's hunger problem is still with us and may in fact get more serious as the population explosion continues. Agricultural research is still the basic ingredient in generating new technology, and the CRSPs are Title XII's contribution to that effort. Our efforts in the future must be guided by the concept of agricultural sustainability, maintaining if not enhancing the environment in which agricultural production takes place.

INTSORMIL/ICRISAT Interaction in the Nineties

R.W. Gibbons
Executive Director ICRISAT Sahelian Center
and West African Programs

First let me say that it is a great pleasure to be present at this INTSORMIL conference in Scottsdale, Arizona, as one of ICRISAT's representatives. The other representative, Dr. L.R. House, who is ICRISAT's Executive Director for Southern Africa (SADCC), is very well known to all sorghum and millet scientists. I am not as familiar with INTSORMIL programs as Dr. House because from 1976-1986 I was leader of the ICRISAT Groundnut Program in India. However, since 1986, when I transferred to West Africa, my involvement with both sorghum and millet, and also with INTSORMIL programs in West Africa, has considerably expanded. As a serving member of the Board of Directors of the Peanut CRSP I am also familiar with the workings of the Title XII Programs. I find many parallels in the two CRSP programs.

Relations with INTSORMIL in the Eighties

One only has to read INTSORMIL and ICRISAT publications to realize the relationships between the two organizations, since the inception of INTSORMIL in 1979, are very strong indeed. These interactions have been very close at both the management and scientist levels. I quote from the INTSORMIL 1987 Annual Report where it states on page 14 of the Introduction "INTSORMIL has a history from the inception of the program of coordinating and collaborating with ICRISAT, the ICRISAT scientists located at CIMMYT for Latin America, with CIAT, and with ICRISAT regional activities located in West Africa. ICRISAT management staff have attended INTSORMIL annual conferences and INTSORMIL staff have met with ICRISAT management staff to discuss coordination and collaboration in order to avoid duplication of activities". The report goes on to mention recent specific areas of collaboration. These areas included:

a. Joint planning with ICRISAT to place an INTSORMIL Scientist at CIAT to work on adaptation of sorghum to acid soils.

b. A jointly sponsored workshop by INTSORMIL/ICRISAT and CIAT on the topic of adaptation to acid soils.

c. Two joint workshops with ICRISAT on Sorghum Seed Production and an International Workshop on Pearl Millet.

d. Collaboration and participation in ICRISAT/SAFGRAD workshops in both East and West Africa.

The 1987 report also lists all the projects and it is heartening to see how many projects have ICRISAT Scientists, by name, as collaborating scientists. Of the 31 projects, 18 have ICRISAT listed scientists as collaborators and the collaboration extends to five of the six INTSORMIL institutions.

The country reports in the 1987 Annual Report of INTSORMIL also point out the excellent collaboration that exists with ICRISAT in various countries.

Another area of excellent cooperation has been training, particularly in collaboration with USAID funded ICRISAT programs in Mali and the SADCC region. Many national scientists have received or are receiving first or advanced degree training in the INTSORMIL universities. The SADCC training program has been subcontracted to INTSORMIL. Several ICRISAT scientists have also taken sabbatical leaves in the USA with the INTSORMIL universities which has strengthened links. There has also been mutual benefits in the reciprocal use of consultants and membership of technical advisory committees.

ICRISAT Reorganization and changes in Emphasis

In 1986 ICRISAT made some major changes in their management and research structure. The Sorghum and Millet Programs were merged as the Cereals Program under a Director. The Pulse and Groundnut Programs were also merged into a Legumes Program and Farming Systems and Economics became the Resource Management Program, both with Directors. Executive Directors were appointed for West and Southern Africa respectively. All the Directors are members of the ICRISAT Management.

In 1987 a ten year plan was published that clarified and revised ICRISAT's research goals and priorities for the

next decade. With the new five year budgeting system proposed for the CGIAR System, ICRISAT program commentaries were also more sharply defined for the period 1989-1993, including funding requirements.

The research goals stressed in the 10 year plan and the 5 year budget document recognize the approaching Asian and Latin American self-sufficiency in cereal grain production and gives, therefore, more emphasis to alternate uses of these crops, including their use as livestock feed, as well as exploring innovative uses of sorghum and millet. This is also being implemented for ICRISAT's cereal program in some countries of the SADCC region, and for specific uses such as commercial beer brewing in Nigeria since barley imports have been halted.

There are also plans for the initiation and expansion of the uses of biotechnology in crop improvement programs, particularly at the ICRISAT Center. The Cereals Director, Dr. J.M. de Wet, has and will continue to play a major role in the direction of our biotechnology program. The center program will also concentrate more on strategic research problems.

More specific plans for sorghum and millet include:

a. The appointment of a Principal Scientist to head a new coordinating unit for cereals. This post is to coordinate our global cereals testing programs and the unit is entitled the Cooperative Cereals Research Network (CCRN). It will coordinate trials and nurseries throughout the world, and will help to strengthen national programs by supplying breeding material and promoting the rapid transfer of ICRISAT-bred material to national programs and ICRISAT's regional centers, teams, and networks.

b. More emphasis will be given to the breeding of hybrids, particularly the breeding of male steriles, at the ICRISAT Center and in certain African countries, such as Nigeria and Zimbabwe, where the infrastructure exists to produce and utilize hybrids.

c. More emphasis will be given to breeding finger millet for both grain yield and for human food in southern Africa, and to breeding pearl millet as a forage crop.

d. Emphasis in cereal biochemistry is shifting from primarily analyzing samples to support the breeding program to research on replacing wheat, maize, and rice with sorghum and pearl millet in foods. A food technology unit for cereals is being established in southern Africa: where the emphasis will be on developing new industrial uses for sorghum and pearl millet. In Hyderabad the biochemistry unit will concentrate on maintaining food quality in high-yielding cultivars, improving methods of food preparation, and substituting sorghum and millet for wheat and maize in food crops.

e. In West Africa ICRISAT has relocated its regional sorghum team from Burkina Faso to Nigeria and Mali. Currently, there is a three-man team based in Kano, Nigeria, comprising a breeder, an agronomist and an entomologist, who is also team leader. It will be strengthened in 1989 by a small, Italian funded, team working on drought physiology. A core funded pathologist is to be added in 1990. In Mali the sorghum group will be considerably strengthened in 1989 by the addition of four French scientists. The Mali team will cover the wetter end of the sorghum zone (Northern Guinea zone). The program will be coordinated through the ICRISAT Sahelian Center and the headquarters in India. The millet breeder who is responsible for the transition zone, and was based in Burkina Faso with the sorghum team, will also relocate to Mali after his sabbatic leave at the University of Nebraska. The two-man sorghum teams in Mexico and Kenya are presently coordinated by the Program Director and the CCRN.

All these changes in emphasis and organization, we feel, will lead to more sharply focused research on our cereal crops and could lead to more effective cooperation with INTSORMIL.

INTSORMIL-ICRISAT Linkages in the 1990's

a. Sorghum in the Nineties

Following the highly successful joint ICRISAT/INTSORMIL Workshop on "Sorghum in the Eighties" initial discussions on the next conference "Sorghum in the Nineties" are already underway. Initial plans, yet to be discussed in detail within ICRISAT or with INTSORMIL, would locate this meeting for the first time in Africa. West Africa would be a good venue. During this meeting I am sure that Dr. L.R. House, who will be the chief conference coordinator for ICRISAT, will wish to discuss this conference in depth with our INTSORMIL colleagues.

b. The West Africa Pearl Millet Improvement Program

We would like to see more active cooperation between our regional Pearl Millet Program, based in Niger and Mali, and INTSORMIL. In Niger and Mali we have excellent collaboration with the national research programs and participate in joint planning meetings. We also hold regional meetings and tours each year. At the last meet-

ing, held in Nigeria, and with representation from 13 countries in the region ICRISAT was asked to initiate a formal Regional Pearl Millet Network with a steering committee. INTSORMIL could participate in this network and contribute regionally to the cooperative research activities.

The aspects of cooperation could be:

biology and screening techniques relating to *Striga*.
coordination of short-term training courses for breeders collaborative work on pearl millet grain quality as has been done so successfully with sorghum collaboration in areas of insect pest resistance such as pheromones and diapause termination etc.

c. Cooperation in Agrometeorology

ICRISAT has full time agrometeorologists in Hyderabad, India and Niamey, Niger working within the Resource Management. It is hoped to extend this research to the SADCC region also. The scientists work closely with colleagues in the RMP program and crop improvement programs. In West Africa we have access to a large data bank and have produced reports on the agrometeorology of Mali and Burkina Faso. A similar report on Niger is under preparation. Research on predicting the length of the rainy season in the drier zones of West Africa is well advanced. The West Africa agroclimatologist, Dr. M.V.K. Sivakumar, has recently completed a sabbatical in the USA and had an opportunity to discuss further possible collaborative research with USDA, US universities and INTSORMIL. We feel that agroclimatology is an essential aspect of all research in the semi-arid tropics and would be of interest to all INTSORMIL projects in Africa.

d. Forage

ICRISAT has joint research with the International Livestock Center for Africa (ILCA) in Niger and Zimbabwe on improving the forage quality of sorghum and millet. We would welcome participation in these projects from INTSORMIL.

e. Economic and Socio-economic studies.

ICRISAT has strong global economic research thrusts within the Resource Management Program. We also have collaborative projects with the International Food Policy Research Institute (IFPRI). Currently ICRISAT has no formal collaboration with the socio-economic projects of INTSORMIL, particularly Project PRF-105, the "Economic Evaluation of New Technologies in Sorghum and Millet Production in INTSORMIL Priority African Countries" managed by Purdue. We hope that in the future we could discuss ways of collaborating with the INTSORMIL socio-economists.

The above list is by no means exhaustive and we would like to explore more possible collaboration with INTSORMIL to build further on the excellent relationships that have developed since the inception of INTSORMIL.

The Future Role of the Social Sciences in INTSORMIL

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In this paper I first discuss the multidisciplinary nature of INTSORMIL's work, then three kinds of agriculturally related research, and the four driving forces for improving agriculture. Following this, I present a view of INTSORMIL as a group of multidisciplinary subject matter projects and attempt to establish some perspective as to how agricultural college departments and basic disciplines fit together for conducting agricultural research in general and in INTSORMIL in particular. This is followed by a very brief history of INTSORMIL's rural social science and basic social science disciplinary research that culminates in a description of the current status of rural social science research in INTSORMIL. I close the paper with a consideration of INTSORMIL's rural social science and basic social science disciplinary research needs, financing and staffing which I hope will be useful to INTSORMIL's Management Entity and Technical Committee.

The Multidisciplinary Nature of INTSORMIL's Work

It should be stressed and specifically recognized at the beginning that INTSORMIL's main obligation is to generate and introduce improved sorghum/millet technologies. It is concerned with generating knowledge on multidisciplinary subjects useful in solving various rather well-defined sets of problems involving sorghum and millet technologies faced by various rather well-defined sets of decision makers concerned with sorghum and millet. For instance, INTSORMIL researches sorghum/*Striga* interactions for the sorghum producers of Niger. It also researches aluminum toxicity and the development of new sorghum varieties for potential grain producers in the Llanos region of Colombia. Such work by INTSORMIL is multidisciplinary as well as multidepartmental within colleges of agriculture and agricultural research organizations. The mixes of departments and disciplines and what roles should be played by the social sciences are determined by the subject being researched, not by the disciplinary interests of academicians. No basic science or discipline, and this includes the basic social sciences, has an inherent right or role to play in research of the type done by INTSORMIL; participatory rights depend on the nature of the subject being researched.

The Spectrum of Agriculturally Related Research

The research of agricultural scientists, including that of the rural social scientists, ranges across a spectrum stretching from problem solving work at one extreme to work in the science disciplines [Johnson, 1986] at the other.

Problem Solving (PS)	Subject Matter (SM)	Disciplinary (DISC)

Problem-solving (PS) research is defined here as research on a specific practical problem of a real world decision maker in either the public or private sectors. In using this definition, it is important to note that the phrase "practical problem" does not include the disciplinary questions (sometimes called problems) that disciplinarians encounter in trying to improve their disciplines. An example of PS research would be an attempt to solve a problem of conserving rainwater faced by a Nigerien farmer producing millet in a specific field in Niger. Solving such a specific problem involves a unique mix of multidisciplinary and multidepartmental knowledge -- hydrology, meteorology, physics, soil science, agricultural engineering, chemistry, and even economics. Such PS research is more likely to be conducted within a firm household, or public agency using results of less specific kinds of SM research of the type discussed in the second paragraph below.

At the other end of the spectrum of the research agricultural scientists do is disciplinary (DISC) work defined here as work to improve the theories, basic measurements and techniques of a specific discipline such as chemistry, anthropology, genetics or sociology. An example in INTSORMIL is some of the research done at Purdue University on the sorghum root exudate, sorgoleone.

In between these two extremes are various kinds of work on multidisciplinary subjects. Subject matter (SM) work is defined here as work on a multidisciplinary subject important for rather well-defined sets of decision makers addressing a rather well-defined set of problems. An example is INTSORMIL's research on drought resistant (stay-green) sorghums. Though the knowledge

produced by SM research is useful in solving individual problems in the problem set, it is typically insufficient to completely solve any specific problem as each specific problem requires unique mixes of knowledge for its solution.

Most agricultural research is administered in SM departments of the agricultural establishment that stress multidisciplinary subjects and only occasionally do research to directly solve specific practical problems. For instance, the Department of Crop and Soil Sciences at my own university addresses various multidisciplinary subjects involving chemistry, bacteriology, physics, genetics, botany, pathology, geology, biology, entomology, etc., for different sets of farmers of Michigan and growing different crops on different soils in Michigan. Similarly, the rural social science (RSS) departments of colleges of agriculture and other agricultural institutions are SM departments more like multidisciplinary institutes than the basic disciplinary departments found in the arts, pure sciences and humanities of traditional universities. The rural social sciences function well and receive support from the agricultural community when they generate different multidisciplinary mixes of knowledge important to different sets of decision makers facing different sets of practical problems

PS work and SM work are almost always multidisciplinary yet both depend fundamentally on the basic disciplines. Like the technical agricultural science departments, a rural social science department is typically a multidisciplinary one drawing on (1) its parent basic social science discipline, (2) other basic social science disciplines, (3) several of the other technical multidisciplinary agricultural SM areas such as agronomy and animal husbandry, and (4) the basic biological and physical science disciplines necessary to understand technical agriculture.

Disciplines stress disciplinary research to improve themselves. By doing such disciplinary research, disciplines may strengthen the ability of the RSSs to participate in INTSORMIL's SM work. INTSORMIL's resources are so limited that they should not be used for basic social science disciplinary work unless such work is so relevant for INTSORMIL that it can be directly expected to improve RSS contributions to INTSORMIL's SM work.

This view of the research of technical agricultural and rural social scientists makes it clearly appropriate that the rural social sciences in INTSORMIL stress SM research. Only occasionally will it be important for the RSSs to do DISC research in INTSORMIL.

The Four Driving Forces for Improving Agriculture

Increasing rural agricultural productivity turns on our ability to improve four basic driving forces. The four forces are:

(1) technological advance [Ruttan, 1971],

(2) institutional and policy improvements [Ruttan and Hayami, 1984],

(3) the development of human capacity [Schultz, 1961], and

(4) the enhancement and conservation of both natural and manmade resources [Bromley, 1988].

These forces must be regarded as individually essential but individually insufficient for increasing the productivity of agriculture [Johnson, forthcoming].

INTSORMIL concentrates on sorghum/millet technology with varying lesser emphases on the other three driving forces. This is appropriate. By and large, the farmers, agribusinessmen, and administrators of agencies served by INTSORMIL must depend on non-INTSORMIL research for much of the knowledge of institutions and policies, human development and resource conservation and enhancement that they may need to solve their many different specific problems. INTSORMIL cannot provide all of the knowledge on all of the driving forces that may be needed to solve all practical products without self-destructing its primary mission of improving sorghum and millet technologies. Several CRSPs dealing with institutional and policy improvements, human development and resources are badly needed to complement the work being done on technology in the present CRSPs; these, unfortunately, have not been established.

INTSORMIL As A Group of Multidisciplinary Subject Matter (SM) Projects

To repeat from the above, INTSORMIL can best be viewed primarily as an evolving group of multidisciplinary SM projects having as their primary objective the improvement of sorghum and millet technology. At times, but only rarely, INTSORMIL becomes involved in doing direct PS research on a specific problem of a specific private or public decision maker, the possible important exception being the work INTSORMIL does to solve its own administrative, staffing and funding problems. [Johnson, 1984, unpublished-a, unpublished-b]

Recently, a private industry person characterized the problem of administering academicians as similar to that of "herding cats." In this connection, INTSORMIL has two strengths for doing SM work that are particularly worth noting here. The first is that INTSORMIL has been remarkably successful in "herding" biological and physical science "cats" into doing needed multidisciplinary SM research on sorghum and millet. The second strength is that its researchers and administrators provide mutual support for each other. To date, INTSORMIL has been less successful in "herding its social science cats," into doing SM research for INTSORMIL. More attention is given to this difficulty later in this paper.

Perspectives on How Agricultural College Departments and Basic Disciplines Fit Together in Agricultural Research With Emphasis on INTSORMIL

In providing this needed perspective, the first task is to relate the three kinds of work -- PS, SM, DISC -- to the four driving forces. This is done graphically in Figure 1 below. As discussed above, the primary emphasis of INTSORMIL is on SM research, vis-a-vis, the improvement of sorghum and millet technology. This emphasis is indicated by the shaded square in Figure 1.

As we have noted above, INTSORMIL also does some PS and DISC research. Still further, improving sorghum/millet technology also requires some attention to the other three driving forces because institutions and agricultural policies do influence the rates of adoption of sorghum and millet technologies as do the characteristics and capacities of people and the nature of the natural and manmade resources at the disposal of farmers and agricultural administrators. An inadequacy of Figure 1 is that it does not relate INTSORMIL's work on the four driving forces to the agricultural college departments and basic disciplines. Figure 2 takes the first step in exploring that departmental and disciplinary linkage by introducing the roles of the RSSs. We start out here with the RSSs because the title of this paper indicates that particular attention is to be given to the roles the RSSs play and should play in INTSORMIL. Social scientists should realize, of course, that the RSSs are not as prominent in INTSORMIL as the technical agricultural sciences because INTSORMIL's primary mission is that of improving sorghum/millet technology. Figure 2 expands Figure 1 to include a third dimension dealing with such RSS subjects as rural political science, agricultural history, resource development, home economics, rural sociology, and agricultural economics.

A particular RSS such as rural sociology is represented in Figure 2 by a vertical slice involving all three kinds of research on all four of the driving forces. Our previous discussion of INTSORMIL's concern with the three kinds of work on the four driving forces indicates that the main concern of rural sociologists in INTSORMIL should be

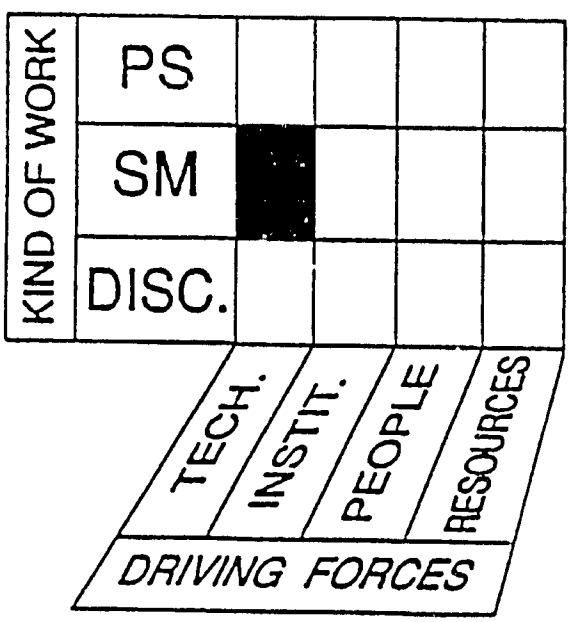

Figure 1.

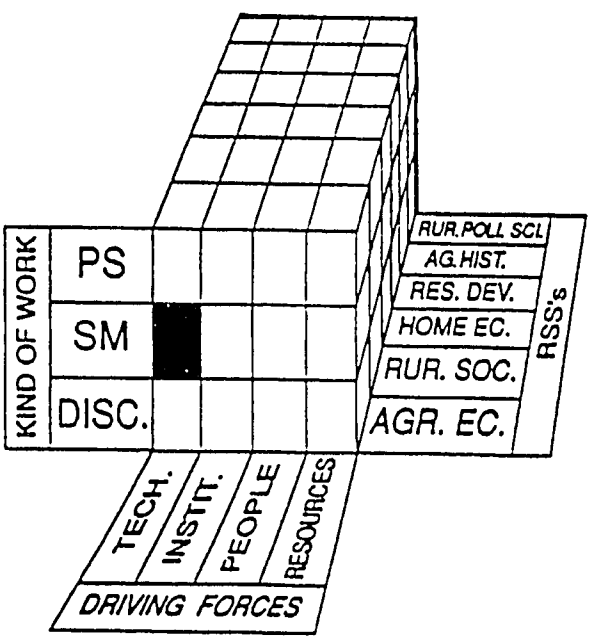

Figure 2.

with SM research on improving sorghum/millet technology. The same is true for agricultural economists. Rural sociologists, agricultural economists, home economists and "rural" anthropologists can help most when INTSORMIL needs institutional and policy, human development and resource knowledge to overcome technological constraints on sorghum and millet. To repeat still once again, the RSSs and BSSDs have to recognize that the main emphasis of INTSORMIL is on SM research involving sorghum and millet technologies. Very rarely if ever, will INTSORMIL be concerned with basic disciplinary social science research on institutions and policies, human development or resource conservation, utilization and enhancement. Rural social scientists, in attempting to help with INTSORMIL's SM research on improving sorghum/millet technology, will often find it necessary to cooperate with each other. Such cooperation is easily envisioned in Figure 3. An inadequacy of Figure 2 is that it does not consider the basic social sciences that underlie the work of the RSSs. Though less so in RSS work for INTSORMIL than in other work done by the RSSs, the RSSs do need to draw on their basic underlying disciplines in assisting INTSORMIL. Thus, Figure 3 adds the basic social science disciplines to the RSS disciplines to indicate how the RSSs working on INTSORMIL projects draw on their parent or basic underlying social science disciplines.

By now, we should be painfully aware that Figure 3 is also very inadequate for INTSORMIL. INTSORMIL is primarily dependent on the technical agricultural sciences and their underlying disciplines for improving sorghum/millet technology. In Figure 4 we ignore details with respect to the RSSs by collapsing them into a group. We do the same thing with respect to the BSSDs. This permits us to add two more sections in Figure 4, one to represent the technical agricultural sciences such as soils, crops, plant breeding and the like (treated as a group) and another for the group of basic biological and physical sciences including chemistry, physics, cell microbiology, genetics and the like that underlie the technical agricultural sciences. Figure 4, therefore, permits one to envision the roles played by the multidisciplinary agricultural SM departments (both technical and social) and the basic disciplines (both social and biophysical).

The comprehensiveness of Figure 4 permits us to envision INTSORMIL as a SM research activity crossing the agricultural departments and basic disciplines of a university with primary stress on the long technology ver-

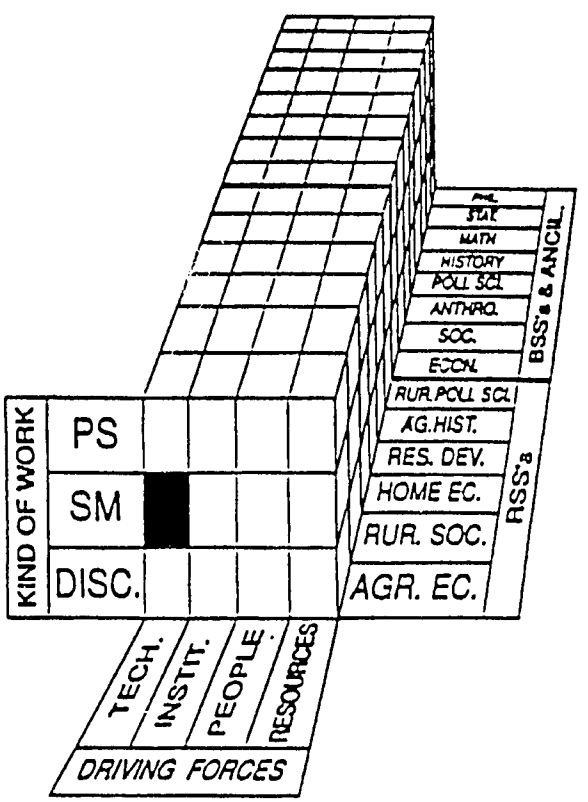

Figure 3

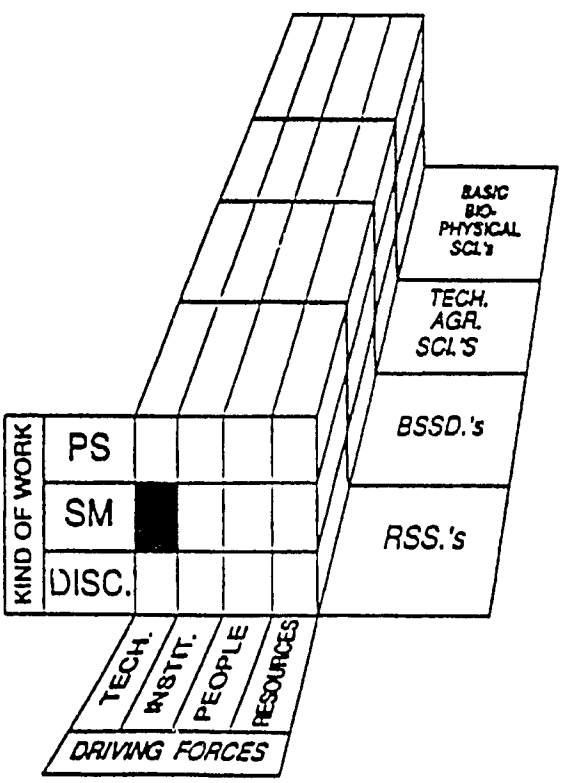

Figure 4

tical slice but with room for research on closely related institutional, human development and resource enhancement and conservation represented by the other three long vertical slices. Figure 4 also permits us to envision INTSORMIL's lesser interests but sometimes very important interests in DISC and PS research.

History of Rural Social Science (RSS) and Basic Social Science Disciplinary (BSSD) Research in INTSORMIL

The social sciences have not been ignored in the history of INTSORMIL. In fact, at its inception, INTSORMIL's plans for the social sciences were larger than its budget despite the fact that INTSORMIL anticipated at that time much larger budgets than have materialized. In a sense, INTSORMIL's eyes (its plans) were bigger than its stomach (budget). This plus a kindly attitude in INTSORMIL towards the social sciences combined with poor understanding of the RSSs and BSSDs to result in too many overly ambitious and inadequately financed RSS and BSS projects in INTSORMIL's early flush financial years. There was inadequate understanding of how RSS and BSSD efforts should be oriented to INTSORMIL's primary emphasis on the generation of new technology. This resulted in some social science projects with disciplinary objectives of questionable relevance for sorghum and millet.

It was noted earlier that while INTSORMIL has been successful in herding its biological and physical science "cats" into productive SM research on sorghum and millet, it has been less successful in channeling rural and disciplinary social science "cats" into SM efforts appropriate for INTSORMIL. When the financial crunch hit INTSORMIL in the mid-1980s, it became necessary to reduce the number of RSS and BSSD projects in INTSORMIL. At that time, social science projects of questionable relevance for INTSORMIL's primarily technological emphasis were eliminated. Also, SS projects too ambitious for their budgets were either eliminated or reduced in scope. As a member of INTSORMIL's EEP at the time these adjustments were made in INTSORMIL's RSS and BSSD projects, I approved of them. I believe that they were necessary not only for the good of INTSORMIL but for the good of the RSSs and BSSDs themselves. Social scientists have little to gain from doing research of questionable relevance in a project that is supposed to focus on sets of practical problems faced by rather well-defined sets of decision makers facing those problems. Still further, they have virtually nothing to gain and much to lose by being overcommitted to overly ambitious, inadequately financed projects.

The Current Status of the RSSs in INTSORMIL

Social science research is now almost non-existent in INTSORMIL. Some related and partially funded research on farming practices is going forward in Niger in connection with Purdue's cereal grains project. Related sociological and anthropological work is going forward at the University of Kentucky without INTSORMIL funding. Perhaps the most germane research in INTSORMIL relative to social science interests is that being done by non-social scientists. This includes taste preference research being carried out in villages in Niger. In Mali, similar objectives are being attained with laboratory tests. At both Purdue University and Texas A&M, a considerable amount of research on the development of new sorghum food products is going forward with INTSORMIL support. Also in this connection, food quality assessments and preference research efforts are being carried out with direct INTSORMIL support. Such work on food preferences and food quality assessments provide direct building block work for demand analysis and marketing research now needed by INTSORMIL.

INTSORMIL's RSS and BSSD Research -- Needs, Financing and Staffing

INTSORMIL has several needs for social science research that are closely related to the development of sorghum and millet technologies. Fortunately, several of these needs can be met using financing external to INTSORMIL and without adding much additional INTSORMIL staff. It appears that now is the time for INTSORMIL to expand its social science research.

A pressing need of INTSORMIL is for additional research on farming practices involving use of the new technologies it is generating. This research is needed to (1) guide (in the farming systems sense) INTSORMIL technical researchers to the kinds of technologies still needed by farmers and (2) facilitate utilization of the technologies that have been generated by INTSORMIL. Such research is so closely related to INTSORMIL's technological objectives that it should be financed and staffed by INTSORMIL as an integral part of its research program.

INTSORMIL and other sorghum breeders have made great strides in improving the food and feed qualities of sorghum varieties. These higher quality food and feed grain sorghums are not produced as extensively in either

the United States or the LDCs as they should be. Demand analysis and market development studies are needed to facilitate the adoption of higher quality sorghums now being developed. There is an important potential for increasing the share of U.S. produced grain sorghums in the world livestock feed markets. There are also developments taking place in food technology with respect to the utilization of sorghum as a food grain both in the U.S. and abroad. These developments have to do with the use of sorghum in the production of tortillas, fermented beverages, and for parboiled sorghum as a vegetable for use in salads and as a rice substitute. Here again demand analyses are needed for these new products and uses to be followed by the development of marketing strategies to expand the use of sorghum as a food grain. Though somewhat different, demand analyses and market development studies are needed to expand the market for sorghum as a food and feed grain cereal in the LDCs. As most of the grain producing states in the U.S. have rather fully developed agricultural economics departments with responsibility for doing demand analyses and market development studies for products important to them, INTSORMIL should be able to work out cooperative arrangements with such agricultural economics departments to get such research done with little extra staffing or funding. In some instances, the association of U.S. grain sorghum producers might help obtain public or industry financing for the needed demand analyses and market development studies. AID's food security project is a potential collaborator with INTSORMIL.

Little millet is produced in the U.S. and it is relatively unused here. It is a rather high quality grain for animal and some human uses. Because so little millet is produced and used in the U.S. and because INTSORMIL is likely to make improved millet cultivars available for potential U.S. producers in our drier, more droughty environmental niches, demand analyses and market development studies for millet should also be started. Again, existing agricultural economic departments and experiment stations have responsibilities for such analyses and studies. The crop and animal scientists and human nutritionists also share in this responsibility. Thus, INTSORMIL should be able to stimulate some of the needed research in the land-grant universities and the USDA with little additional funding and staffing.

The CRSPs are an important institutional innovation for doing SM research to assist LDC agricultures. At this conference this was stressed by Lynn Pesson, George Teetes and William Furtik. In some ways they may be superior to the International Agricultural Research Centers (IARCs). Their accomplishments and advantages need to be documented before they are whittled away in AID's budget processes to become AID's latest forgotten fad. The CRSPs, in general, and INTSORMIL, in particular, have now been underway long enough to have accumulated considerable experience and to have developed a pipeline of new technologies several of which will be utilized in the fairly near future. Considerable benefits are accruing to U.S. sorghum producers and agribusinesses. Humanitarian objectives in LDCs abroad are being furthered. Institutional analyses of CRSP (and INTSORMIL) experiences are now needed. Also, assessment studies should be started for the CRSPs and, more specifically, for INTSORMIL. Hageen-Dura 1 is an INTSORMIL sorghum variety now being used in Africa. Technology assessments can be done either before or after adoption. It is probably best to start such assessments at about the time promising results become available so that the necessary data can be recorded during the process of adoption. In the case of the international research centers that improved corn, wheat and rice, the technology assessment studies took place mainly "after the fact." Most of these studies were carried out by interested social scientists not directly connected with the centers. This made the assessments credible and enhanced their acceptability in the international donor community which responded with increased support for the IARCs. INTSORMIL should now encourage institutional studies of its organization and the initiation of assessment studies for its work by agencies and institutions not directly associated with INTSORMIL. This can be done by (1) calling the attention of such agencies to the need for such work and (2) making INTSORMIL data and other information readily available to external analysts, assessors and evaluators. One approach would be for a high-level social science administrator from a U.S. INTSORMIL institution to encourage a non-INTSORMIL institution to initiate such work. For example, Dean Robert Thompson of Purdue University might approach Dean Edward Schuh at The Humphrey Institute, University of Minnesota, to initiate such studies. In turn, INTSORMIL could even provide support for applications of assessors for financial assistance from the National Science Foundation and other agencies that have supported such assessments in the past.

INTSORMIL's research and expertise have potential application in two areas of the U.S. Social scientists have much to contribute to investigations of potentials in these two areas. One potential area is the southeastern United States that need feed grain and new uses for some of its droughty soils. Presently the work on sorghum and millet in the southeastern U.S. is mainly in Mississippi and Georgia. While the commercial companies have apparently concluded that there is not a potentially profitable market for hybrid sorghum seed in the

southeast, this does not preclude the existence of socially advantageous opportunities to develop a sorghum industry in the southeast through research and extension and, for that matter, a millet industry as well. The southeastern states have agricultural experiment stations that include rural sociology, home economics, and agricultural economics units with responsibility for researching new opportunities for the agricultures of their state. INTSORMIL should take steps to encourage research on the potentials of grain sorghum and millet in the southeast states by indicating a willingness to help expedite technological research on sorghum and millet for the southeastern states if studies indicate that such markets are likely to be feasible. A second potential for sorghum and millet production may exist in the Lake States. Cold tolerant germplasm from North China offers the possibility of creating sorghum varieties for livestock feed (grain as well as silage) in the Lake States. Sorghum is now used in the Lake States mainly for dairy silage. Present sorghum varieties set little seed in the Lake States and the seed that is set goes largely undigested in silage fed to dairy cows. Purdue, an important INTSORMIL research university, has some cold resistant North China germplasm. More could be obtained. Regional cooperation could use Purdue facilities to generate new varieties to be screened and evaluated at Lake State sites. The Lake States contain large acreages of soils not used for corn production because of drought risks. These areas may possibly be used to produce both grain for dairy concentrate rations and forage sorghum for silos. Also in the eastern Lake States there may be an opportunity to double crop soft white winter wheats on droughty soils with short-season millets. An alternative double cropping opportunity is canola, the Canadian rape seed, now grow extensively in Canada for oil. Either alternative would require demand analyses and market development work. INTSORMIL should encourage studies of the potentials of both sorghum and short-season millet versus canola in the Lake States, Ontario and even the Dakotas.

AID's soybean project centered at the University of Illinois encountered severe political problems as the result of the "Bumpers' amendment" that limits the use of AID funds to finance technological research for LDC crops that are competitive with American producers [Thompson, forthcoming-a, forthcoming-b]. So far, Bumpers' amendment questions have not been raised with respect to INTSORMIL's AID supported research on sorghum and millet in the LDCs. Actually, the U.S. grain sorghum industry benefits substantially from the germplasm and technical knowledge imported into the U.S. by INTSORMIL. Further, as the U.S. has virtually no millet production, the potential benefit from INTSORMIL's millet research runs very much in the U.S.'s favor. Before Bumper's amendment questions are raised concerning INTSORMIL's research on sorghum in LDC countries, studies of the existing and potential benefit of INTSORMIL's work to U.S. producers should be carried out and made available. Again, it is likely that such studies can be encouraged by other institutions with INTSORMIL playing the primary role of facilitator and source of knowledge.

I want to close by stating that I believe it is now time for INTSORMIL's Management Entity, Technical Committee, its Principal investigators and AID to initiate the RSS SM research needed by INTSORMIL. I stand ready to be of help if such help is needed and desired.

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INTSORMIL in the 1990's

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INTSORMIL Program Director

Though welcoming remarks have already been extended, I wish to take this opportunity on behalf of the Management Entity to welcome our guests from Sudan, Niger, Mali, Botswana, Honduras, Colombia, Burkina Faso, Zimbabwe, our SADCC students, AID/Washington guests, the EEP, our Board of Directors, and all of our U.S. P.I.s.

INTSORMIL is in its 10th year. This is a time to reflect where we have been and where we are going. This presentation is one of reflecting on the past and then looking into the future for the next 10 years of INTSORMIL activities.

You have already heard about the evolution of the INTSORMIL program from our previous speaker Dr. George Teetes. George has been one of the INTSORMIL scientists who has helped this program to grow and to become what it is today. There are seven CRSP programs organized similarly to INTSORMIL. In 1984 when the first five year grant periods of the CRSPs began to mature and the programs began the process to extend those grants, the Office of Agriculture, Science and Technology Bureau, AID, in collaboration with the BIFAD Staff, had to develop a set of procedures by which these extensions could be processed. A.I.D. and BIFAD were already in the process of revising the CRSP guidelines which would spell out those procedures in detail. One of the elements which was in the guidelines was the requirement for a "Global Plan". Now, INTSORMIL is a multi institutional and multi disciplinary collaborative research support program which at the time was working in sixteen countries. It was obvious that the program did not have the resources to develop a multidisciplinary program in each of these countries. The funds were not there and the scientists were not there. The program recognized the need to concentrate its efforts and resources if it was going to meet its goals and objectives. In response to the need to articulate the "Global Plan" the Management Entity, the Technical Committee and several key scientists in 1984/5 began working on a global plan concept that could be used in partial fulfillment for attaining the first grant extension. Out of this concept arose the INTSORMIL Global Plan which calls for concentration of efforts in Prime Site Countries within an ecogeographical zone. This concentrated the major effort of the program from sixteen countries down to six, the prime site zones of West Africa, East Africa, Southern Africa, Asia, South America and Central America. Each zone had a Prime Site Coordinator appointed who became responsible for coordination of program development within that zone. The concept was to network with neighboring countries from the prime site. This has evolved a little differently in practice. Thus a process and a plan was established for development of a multidisciplinary program for each zone. The Coordinators became the Ecogeographic Zone Council. Each of these Coordinators has a host country counterpart coordinator for the National program. This has laid the ground work for the further development and the maturation of the INTSORMIL Program in the 1990's.

The 1988 World Bank Development report says that poverty in the developing countries is on the rise. Between 1970 and 1980 the number of people with inadequate diets in developing countries (excluding China) increased from 650 million to 730 million. Since 1980 matters have turned from bad to worse: economic growth rates have slowed, real wages have dropped, and growth in employment has faltered in most developing countries. Precipitous declines in commodity prices have cut rural incomes, and governments have reduced their spending on social services.

The 1986 World Bank Development report says that in the long run people can attain food security only if they have adequate incomes. Food security is access by all people at all times to enough food for an active and healthy life. Food security is important because improved nutrition is an investment in the productivity of a nations population. Problems with food security do not necessarily result from inadequate food supplies; they arise from a lack of purchasing power on the part of nations and households.

The overall goal of INTSORMIL is to improve quality of life, both economically and nutritionally, in LDC's where sorghum and millet are principal food crops through increasing sustainable production of these crops. This will be achieved as our efforts to develop new technology for improved production and utilization is successful. The bottom line is for new technology to contribute to economic sustainable production that will in the end result in greater income for the small rural LDC household. For these efforts to be successful we must con-

tinue to focus on what has been the proven to be successful so far.

Keys to Success in the 1990s

Experience has shown the following factors to be key in determining success in development of collaborative research programs:

- Collaborative research and planning with National Programs.
- Training of research scientists from all disciplines associated with the INTSORMIL program.
- National program strengthening through improved networking, training, coordination and institutional development (equipment and supplies).
- Networking and collaborating with regional and international efforts in sorghum/millet research by the IARC network of research institutions.

The Collaborative Research Support Programs have made possible collaborative networking with world sorghum and millet premier scientists on a sustained, continuing basis with developing country scientists. As institutions develop, manpower resources are developed, research infrastructure is improved, the Collaborative research institutions in each of the countries where INTSORMIL cooperates, will develop their own solutions to the constraints to production and utilization of sorghum and millet in their particular ecogeographic environments.

Scientific Developments for the 1990s

Where we have already made break throughs in the development of

1. New varieties (Niger, Sudan, Honduras, Colombia, Botswana, Mexico, etc.);

2. Better understanding of water use efficiency under different cropping patterns and cultural practice regimes;

3. Major new understandings about the parasitic pest, *Striga* on sorghum;

4. Breakthroughs on fungal, virus and bacterial disease control in sorghum and millet;

5. Breakthroughs on understanding and control of sorghum head bug, long smut, and the langosta complex of sorghum in Central America.

6. New technologies for alternate uses in food products for both sorghum and millet.

7. We have baseline data for technology adoption in Honduras, Sudan and Mexico. This information needs to be validated in context of change over the past four years.

Funding in the 1990s

The INTSORMIL program has evolved into more than just a AID funded project. It is rapidly becoming an international entity in its own right, that is developing a life beyond its entire dependency upon AID. Agency support is vital to the core support of the program. But as other donor organizations such as the Occidental Petroleum Foundation, Al Caravan Foundation, in Colombia, AID Missions, Foundations, i.e. Rockefeller, Mcknight Foundation, etc, the program will continue to grow. There are opportunities that will be followed up with the International Development Banks. I believe by mid 1990 that the funding base for INTSORMIL will be much wider than it is today. This will strengthen the research capabilities. The critical concern we need to continually be aware of is to remember that the INTSORMIL program is based on the collaborative research capabilities of the U.S. INTSORMIL institutions and that we must not let increased activity demand from other sources erode the core research program within the INTSORMIL institutions. We must develop growth in an orderly orchestrated manner.

INTSORMIL Networking in the 1990s

We will continue to validate the findings and advancements made to date. We will build upon those advancements as that technology is made available to the world.

INTSORMIL will continue to collaborate with ICRISAT, CIAT, ICRISAT/CIMMYT - CLAIS for the development of new technology that is cost effective and appropriate for use in the developing country context. We will continue to seek out opportunities for cosponsorship of workshops and other avenues of information dissemination and reporting of research results.

INTSORMIL has the opportunity to collaborate with other CRSP Programs in areas of intercropping systems, rotations, small ruminant feed stuffs, and for collaborating in understanding the small farm enterprise to where her/his or their net incomes can be maximized and continue to grow. This type of networking will permit integration of assistance efforts by the Office of Agriculture of the Science and Technology Bureau of AID.

Future Potential Opportunities

As resources are identified I believe that INTSORMIL must solidify its programs in the present prime sites where it is operational. Then as new opportunities with adequate resources are identified I believe that we look for opportunities to develop programs in :

Cameroon
Greater collaboration with SADCC/ICRISAT in Southern Africa
Pakistan
India
China (if foreign assistance restrictions are lifted)
Brazil
Mexico

and others. The expansion of program obviously will place a great strain upon the capacity of the program to take on greater responsibility. This cannot be done without identification of greater resources, both in funding and manpower.

Impact of INTSORMIL

INTSORMIL has the opportunity to strongly impact the lives of 82 million people in the countries where we have maturing collaborative programs. INTSORMIL technology is already influencing sorghum/millet production in countries of Africa alone where another 200 million people live.

The Collaborative research mode of conducting research is one of the most unique, effective models for providing technical assistance to developing countries of the twentieth century. In the 1990's we will see this concept be strengthened. As funds become available INTSORMIL can tap the expertise of at least another 20 scientists in the U.S. INTSORMIL institutions for collaboration in the Host INTSORMIL institutions. This is almost equal to the number of U.S. investigators involved now. As the host country institution manpower base grows, they will assign more highly qualified scientists to be counterpart collaborators. The network will grow.

Conclusion

The environment will continue to change, political commitment will continue to vacillate to accommodate the latest trends in order to be at the forefront. INTSORMIL in the 1990s must do a better job of informing donors, informing the public sector in the U.S., and communicating with our collaborating host country INTSORMIL institutions in order to establish an effective base for long term commitment to resolving constraints to production and utilization for these two crops.

Because each of the INTSORMIL Institutions, both U.S. and LDC, are making economic investments in the development of this program there must be mutual benefits which will accrue to both. The benefits to the host country national programs has already been discussed. But for the U.S. we will continue to see the following in the 1990s:

1. Development of millet hybrids for use on the dry, sandy soils of the high plains of the Midwest.

2. Improved germplasm for drought resistance for the private seed sector.

3. Improved disease and insect resistance germplasm for the private seed sector.

4. Improved food grain germplasm for the private seed sector.

5. Improved sorghum/millet processing technologies for poultry, livestock and human food consumption.

As we move into this conference, let us commit ourselves to quality work, quality science, quality communications, and to placing into practice the technological developments you as collaborating scientists have discovered. We will become even more interdependent upon one another as the world becomes even smaller through improved communications. Where we have almost instantaneous communication with the International Centers, INTSORMIL Mali, and A.I.D. through DIALCOM, electronic mail, and by FAX with Honduras and the International Centers. I envision we will have these communication capabilities with each of our collaborating institutions in the 1990s. This means that we will be able to develop joint research journal articles, reports and other documents with greater ease and facility. Our job is to help feed the world through science. Let us do it with diligence and commitment. Thank you!

I Have a Dream
A Dream about the Future of INTSORMIL

Dr. William R. Furtick
Agency Director for Food and Agriculture
Agency for International Development

In less than two weeks the United States will honor, with a national holiday, one of its best known and respected black leaders, Martin Luther King. Perhaps his most famous speech was made from the Lincoln Memorial in Washington, D.C. to a crowd that stretched further than the eye could see. His opening, closing and often repeated phrase during this speech is now famous -- "I have a dream". I too have a dream -- a dream about the future of INTSORMIL that I would like to share with you tonight.

In preparing for the presentation, I reviewed many of the past speeches I have made as an Administrator and found that, although they were generally "on target", they tended to be at least ten years premature. Therefore tonight, I will speak as a fellow scientist, not as an A.I.D. Administrator.

However, even as a scientist, many of my activities tended to be premature. Many years ago, I started perhaps one of the first, collaborative research networks. That was probably the basis on which I became the youngest agronomist to be named a "Fellow" by the American Society of Agronomy. This fact at least legitimizes my speaking to you as a fellow scientist.

With these factors in mind, tonight please come with me to the INTSORMIL global meeting of 1999, while I provide the management entity overview of the status of INTSORMIL at the close of the 1990s decade as a basis for its program development for the 21st century.

The meeting has changed significantly from the 1989 meeting.

The central meeting is much larger, yet globally decentralized with local collaborating groups all over the world participating in both plenary and breakout sessions via teleconferencing.

The Research reporting and planning breakout session scientists are pleased that they had received, well in advance, compact disk updates that include the entire global literature and data base on sorghum and millet.

There is much more diversified participation as improved political relations have brought active participation by East and West Block European researchers and those of China together with those of LDCs, IARCs and various industrial country NARS.

A lot of U.S. participants are from non land grant universities or departments outside Colleges of Agriculture because biotechnologies and partnership in basic research with the private sector have brought new disciplines into the program.

Many of the participants are from the private sector who now provide most of the finished planting stock based on their utilization of biotechnologies and provide much of the farm level extention information.

Most of the major bilateral and multilateral donors are represented as they are major contributors to the network by financing LDC NARS and their own participating institutions.

The A.I.D. representatives are proud that their financial support has steadily increased during the 90s decade even though they are now a minority contributor.

Leaders of the U.S. agricultural organization and commodity groups are attending along with Congressional staff because of the importance of INTSORMIL to U.S. competitiveness in a globalized Agriculture economy.

Senior Administrator from the corn belt States are present as the fear of global warming with decreased rainfall have made sorghum and millet vital to their agricultural future and caused major research investments.

The environmental organizations have strong representation because sorghum and millet are a vital ingredient of sustainable agriculture and feeding the increasing population while protecting the more fragile environments. These less well endowed agriculture lands are now vital to food security.

The management entity is pleased to report that other CRSPs are full participants in the meeting because of

either joint research or shared sites and management functions.

The graduate students have formed their own session to address their particular interest. These are heavily mixed between American and overseas students.

The management entity is pleased to announce that all graduate student requests have been accommodated in spite of the flood of applicants caused by: (a) U.S. efforts to internationalize it's science; and (b) The renewed LDC efforts to revitalize NARS and devolution of major research responsibilities from IARCs to NARS.

A report is given on the large program of sabbatic and scientist exchanges.

The major issues suggested for the 21st century are: (a) The shift in emphasis from food to feed, and (b) The impact of shifting to industrial uses of sorghum and millet as an outgrowth of the 1990 U.S. Farm Bill and similar change in the EEC from supply control to demand enhancement policies.

I Hope I can attend in 1999 to see how much of this was dream and how much was reality.

Session II: Development, Improvement, and Sustainability of Long Term Collaborative Research

Session Chair: Dr. Henry Pitre

Speakers:
Dr. Lucas Gakale
Dr. Dorance Munoz
Dr. Roduel Rodriguez
Dr. Oumar Tall
Dr. Idrissa Soumana
Dr. El Hilu Omer

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Botswana

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Introduction

The Botswana/INTSORMIL collaborative research program started more or less on an informal basis. From about 1979 informal staff-students relationships developed between Botswana students and some staff at the University of Nebraska. These relationships resulted in joint research programs with little or no direct INTSORMIL funding. The first of these joint research efforts was between Drs. Max Clegg and Jerry Eastin with L. Gakale after the latter completed M.S. degree in Agronomy at Nebraska. A program for Ph.D. studies was developed by Clegg/Eastin/Gakale, for the thesis work to be done in Botswana. The program was approved by both the university and the Government of Botswana (GOB) and USAID (Gaborone) provided funds to enable Dr. Clegg to make two on-site supervisory trips to Botswana.

By this time a number of developments were taking place, notably the establishment of the Agricultural Technology Improvement Project (ATIP) in 1982 funded by USAID and GOB contracted to MIAC with Kansas State University as the lead institution. ATIP, a farming system project, provided for a position of a cereal agronomist to be based on-station to support the on-farm research program but this position was not filled. Realizing the importance of sorghum and millet in Botswana INTSORMIL took the opportunity to provide the cereal agronomist with partial funding support from ATIP. By the fall of 1983, Gakale returned to Nebraska to complete his Ph.D. studies. Realizing the long term rotation studies initiated by Gakale would stop whilst Gakale was still out of the country, INTSORMIL provided a junior scientist to continue Gakale's program. This junior scientist was married to a graduate student who proceeded with the husband to Botswana were she carried out her thesis work in the area of yield stabilization under dry environments, under an assistantship from Dr. Clegg, an INTSORMIL P.I.

By this time other collaborative research programs had developed between other INTSORMIL scientists, not notably L. Mazhani/Dr. Bill Ross, later Prof. Dave Andrews on sorghum and millet breeding: Chris Manthe/Dr. G. Teetes on sorghum entomology: B. Motalaote/Dr. G. Odvody on sorghum pathology and M. Mortlock/Dr. R. Vanderlip. These collaborative research programs are continuing and will be sustained beyond the Botswana scientists' student days.

Goals of Botswana Five Year Plan with Reference to Agricultural Development

The four major development goals during the current National Development Plan 6 (NDP6) (1985-91) are social justice, sustained production, economic independence and economic growth. Agriculture, especially increased crop production, has been recognized as the major potential contributor if these goals were to be realized.

1. Social justice

Most Botswana households are either directly engaged in agricultural production or derive some income from agricultural employment. Although 80% of the agricultural GDP is derived from the livestock subsector, the majority of the rural people do not own livestock and hence have to rely on crop production for their subsistence. NDP 6 thus recognizes that social justice can only be attained through improvements in the arable crop subsector to increase rural employment, raise rural incomes through sale of grain surpluses and thus achieving better distribution of wealth.

2. Sustained production

Agricultural research and development are seen as needed to find ways of introducing better crop, range and livestock management systems to ensure sustained production through years of drought and other natural disasters. This is necessary from both a conservation and efficient resource utilization point of view.

3. Economic independence

Botswana is a net exporter of meat, accounting for about 80% of agricultural GDP, but a large importer of

food grains and other agricultural products. At present even in good years, the country can only produce 60,000 - 80,000 tons of its estimated 300,000 ton food grain requirements. This is a very unsatisfactory situation especially in a world where food is sometimes used as a political weapon. It is thus the country's goal to produce a greater share of its food requirements locally.

4. Economic growth

Botswana's economic growth has heavily relied on two export commodities, namely minerals (especially diamonds) and beef. It is anticipated that before the end of the current plan period, slower growth will be experienced especially in the mineral sector. Agriculture is expected to take the lead to ensure sustained economic growth into the 1990s.

Agricultural Research is expected to provide the technology to ensure that the development goals are achieved. To achieve these goals Agricultural Research will have to come up with improved production and management systems to ensure that crop yields are increased from the current 200-300 kg/ha levels to at least three to four times. This can be accomplished through research in the areas of:

(1) better and more adapted varieties;

(2) production systems that ensure better management and utilization of resources especially soil and moisture;

(3) development of machinery and implements that ensure good seedbed preparation yet require low energy input because of drought power constraints;

(4) systems that are self-sustaining e.g., rotations, etc.; and,

(5) systems which impound rainfall efficiently - water harvesting.

This research should have strong on-station and on-farm testing components so that technologies tested and selected have greater practical relevance to the local farming system. At the current levels of production it is my contention that improved production and management practices will have a greater impact on yields and total crop production than the introduction of new varieties.

How INTSORMIL Can Best Assist Botswana Attain Development Goals

The major areas where INTSORMIL can best assist the Botswana National Agricultural Research system improve its research capabilities are training, professional backstopping, provision of special funding for research equipment and provision of on-site research personnel (i.e., U.S. technicians). All of these activities have already been going on either sponsored by INTSORMIL directly or supported by funding from other sources such as USAID, Botswana Government and SADCC/ICRISAT.

Training

As already pointed out in the introductory paragraph a number of Botswana students have either finished training or are still being trained under INTSORMIL supervisors. Much of this training has been formal degree programs. In most cases after the formal training, collaborative research initiatives have been established with the student in his/her home country. To date the following Botswana students in the Department of Agricultural Research have received training under INTSORMIL supervision:

Name	Degree	Sponsor	Status
L. Gakale	M.S. Agronomy	USAID	Complete
	Ph.D. Agronomy	SAFGRAD	Complete
L. Mazhani	M.S. Plant Breeding	SAFGRAD	Complete
	Ph.D. Plant Breeding	INTSORMIL[a]	Incomplete
C. Manthe	Ph.D Entomology	USAID	Incomplete
B. Motalaote	M.S. Plant Pathology	INTSORMIL	Complete
B. Sebolai	M.S. Biometrics	INTSORMIL[a]	Incomplete
D. Malepa	M.S. Agronomy	USAID	Complete
M. Mogorosi	B.S. Agronomy	INTSORMIL[a]	Incomplete

[a] Funding from SADCC/ICRISAT/INTSORMIL Training Project

Currently one Ph.D. candidate has submitted applications for admission to pursue Ph.D. (Soil Science) studies at the University of Nebraska under the SADCC/ICRISAT/INTSORMIL Training Project and it is hoped more candidates will be identified to study under the same project funding in the areas of soil and water management, millet breeding, entomology, plant pathology, weed science and food quality.

So far training has been mostly at the graduate level. It is perhaps at this stage, still appropriate to consider training at the undergraduate level especially in the case of small national agricultural research systems such as

Botswana as there may be fewer people qualifying for graduate training. The case of technician training should also be considered. A large volume of INTSORMIL work is supported by technicians who may never have an opportunity to enter a University and I feel consideration should be given to improve their technical skills. Such training could be arranged at Regional Sorghum and Millet Research Centres such as SADCC one at Matopos in Zimbabwe.

Professional Backstopping

Professional backstopping can be in the form of collaborative studies with the supervisor after a student completes his/her degree training. This could be much more relevant and beneficial for young scientists who may need assistance in research program development and funding support. Short term site visits by the supervisor to discuss projects and observe progress can facilitate the young scientist professional development. Support for publications/reporting of research results can also be an effective way of developing a young scientist.

Provision of On-site Principal Investigators

Our national research systems is still short of skills in key areas. Botswana would still need on-site long term technical support to implement its research programs. At present INTSORMIL has provided two such positions, namely the Cereal Agronomist and the Soil and Water Management Specialist. Botswana being a very dry country, these scientists have concentrated their research effort in trying to use various tillage and water harvesting techniques to direct and concentrate water in the root zone for a growing crop. The Agronomist studies the impact of these practices on the yield per se whereas the Soil and Water Management specialist tries to identify and quantify the intrinsic factors that account for the observed effects of the management practices. This work has a strong collaborative support from ATIP and other on-farm and on-station research groups interested in tillage and its effects on soil and moisture conservation and utilization.

The replacement of a scientist going away for studies with an INTSORMIL scientist can also be an effective way of assisting our national agricultural research. Many of our programs have only one scientist and when he or she leaves for further studies the whole program remains in the hands of technical staff who may not be qualified to see the program through. INTSORMIL has already had experience with this arrangement in the case of Gakale/Youngquist and things worked pretty well. Care should, however, be taken to ensure that the replacement scientist is knowledgeable and has sufficient interest in the student's area of research.

Summary

INTSORMIL scientists have had considerable interaction with Botswana students from the Department of Agricultural Research studying in the USA which have in most cases developed into formal and informal collaborative research programs. These have facilitated further training, professional backstopping and provision of on-site research support in the host country. The Department of Agricultural Research have found these arrangements mutually beneficial and would like to see such continued support as we enter the 1990s. Our local research capacity in sorghum and millet is still limited and we believe INTSORMIL working together with the IARC with the sorghum and millet mandate (ICRISAT) can assist us in reversing the situation thus contributing more positively towards achieving our national agricultural development goals as spelled out in NDP 6.

References:

Ministry of Finance and Development Planning. 1985. National Development Plan 1985-91. Government Printer, Gaborone, Botswana.

INTSORMIL Annual Report 1986, 1987. Sorghum and Millet Collaborative Research Support Program. University of Nebraska, Lincoln, NebraskaUSA.

Colombia

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Crop Importance

The development of the poultry industry throughout the last twenty-five years has caused ICA to look for sources of energy and protein which are more economic and higher quality than traditional sources. Some of the factors that have contributed to sorghum filling this need in Colombia are its broad adaptation, short vegetative period and relative easier agronomic management. This cereal is used mainly as a raw material in the manufacture of feedstuffs. From 1981-1987, broiler production increased from 74 to 99 million birds per year and egg production from 3430 to 4142 million eggs per year. This is why the expansion of the sorghum and poultry industry has grown together.

The commercialization of sorghum in Colombia began in 1957 with the evaluation of R-10 and R-12 sorghum hybrids in the Valledupar and Codazzi regions (Department of Cesar). Since this time a rapid increase of the area planted and production has occurred. In 1960 there were 2,800 planted hectares with an average yield of 2.2 t/ha for a total production of 6,100 tons. By 1988, there was 270,455 hectares with an average yield of 2.75 t/ha for a total production of 739,015 tons of sorghum grain. Even with this enormous increase in production of this cereal, national consumption has exceeded domestic production, which is why it is necessary to import additional grain as shown in Figure 1.

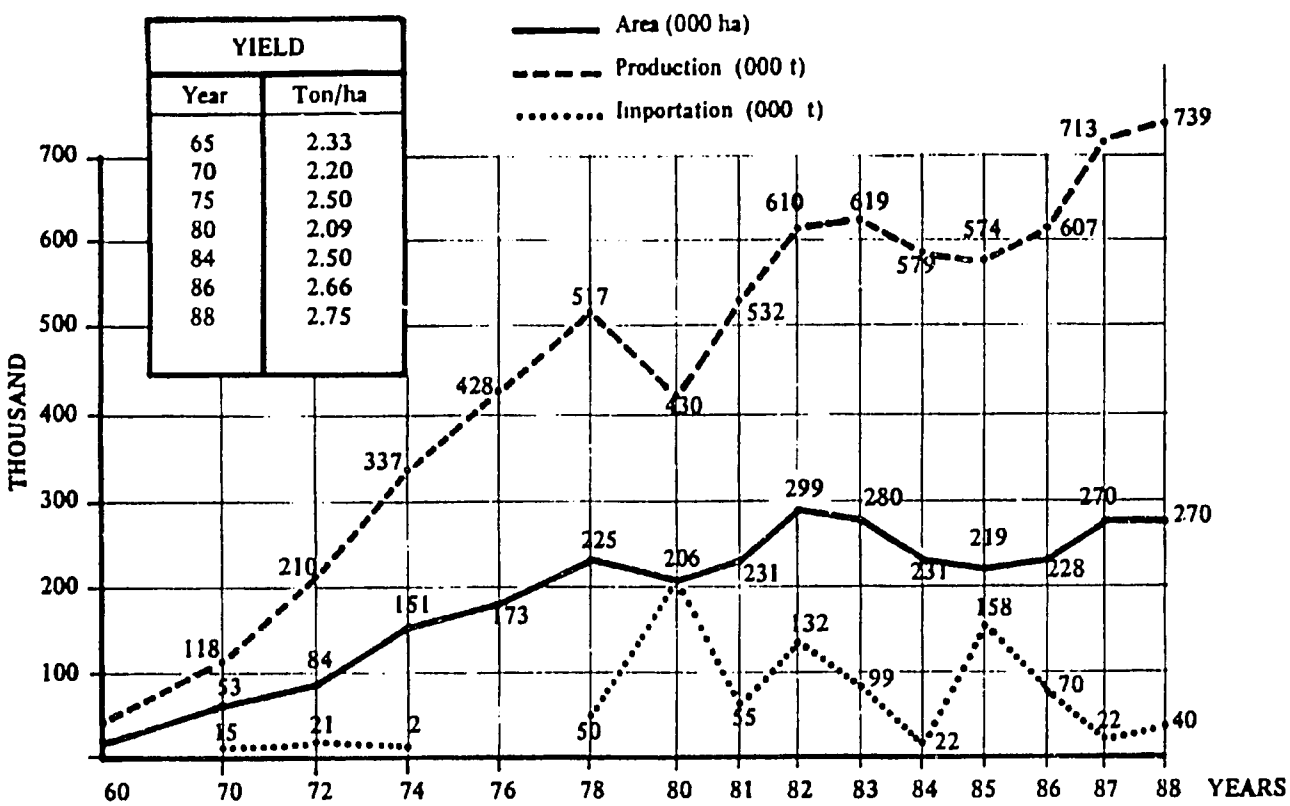


Figure 1. Cultivated area, production, yield and importation of sorghum, 1960-1988

Figure 2. Colombia Sorghum Regions, 1988. (Check Table 1 for area and production).

This crop represents a viable agronomic alternative for those agricultural zones where other crops such as corn and rice are not adapted. It also has become important in rotations with other crops. The major constraints to sorghum production are the lack of improved varieties and hybrids for regions with specific ecological characteristics, high attack of foliar, root, stalk and panicle diseases, viruses, insects, as well as soil, and related agronomic problems. In addition to these constraints, the market price of sorghum is lower than the cost of production which contributes to other socio/cultural and economic problems. It is necessary to improve production and productivity of this cereal by means of improved commitment to research, technology diffusion and marketing.

The purpose of this article is to present the actual situation of sorghum production, constraints and the Colombian Agricultural Institute's (ICA) five year plan of research, and ways INTSORMIL can best assist Colombia accomplish its plan.

Sorghum Regions and Yield Per Hectare

Eight different sorghum producing regions can be identified in Colombia based upon their predominant conditions of temperature, rainfall, type of soil, fertility, disease and insects. Figure 2 and Table 1 show the regions and the sorghum yield per hectare. The region located in the Valle del Cauca and Quindio Departments has the most favorable environment for growing sorghum in Colombia. For this reason this region produces the highest yield per hectare (4.1 t/ha) and 31% of the country's total production. The region located in the Tolima - Huila Departments is the largest area sown (88,350 ha) and the second in the country's total production (28%). The rest of the regions listed in their importance are shown in Table 1.

Table 1. Colombia Sorghum Regions and yield per hectare, 1988.

Department (Regions)		1988 A Hectares	1988 A t/ha	1988 B Hectares	1988 B t/ha	Total Hectares	Total t/ha
Valle - Quindío		25,000	4.2	30,500	4.1	55,500	4.1
Tolima - Girardot		20,000	2.2	46,950	2.4	66,950	2.3
Huila		10,400	2.3	11,000	2.5	21,400	2.4
Córdoba - Sucre - Bolívar (South)		22,200	3.1	4,650	2.0	26,850	2.5
Mojana - Sereno				14,000	2.3	14,000	2.3
Atlántico - Magdalena - Bolívar (North)		4,000	3.0	22,600	2.4	26,600	2.7
Cesar Norte - Guajira		6,750	1.5	8,570	1.9	15,320	1.7
Cesar Sur - Sabana Torres		16,000	2.3	4,785	1.5	20,785	1.9
Santander Norte		1,900	3.3	860	3.5	2,760	3.4
Meta				20,000	2.2	20,000	2.2
Caquetá				230	2.0	230	2.0
Urabá				60	3.0	60	3.0
Total:	Hectares	106,250		164,205		270,455	
	Yield (t/ha)		2.9		2.6		2.75
	Production (t)	306,935		432,080		739,015	

Source: FENALCE

Constraints of the Sorghum Regions

The major constraints to sorghum production in each region are presented in Table 2. The most prevalent sorghum diseases are the foliar diseases, anthracnose (*Colletotrichum graminicola*), zonate leaf spot (*Gloeocercospora sorghi*), gray leaf spot (*Cercospora sorghi*) and leaf blight (*Exerohilum turcicum*); root and stalk diseases, anthracnose stalk rot and charcoal rot (*Macrophomina phaseolina*); panicle diseases, grain mold (*Fusarium moniliforme*), panicle anthracnose, *Curvularia* sp.. Viruses include mottling (*Sugarcane mosaic virus strain H) and necrotic (Maize dwarf mosaic virus strain A*). The major insect pests are midge (*Contarinia sorghicola*), webworm (*Celama sorghiella*), *Diatraea* spp, and fall armyworm (*Spodoptera frugiperda*).

Aluminum toxicity and acid soils are major constraints to sorghum production in the big potential zone called the Llanos Orientales (Eastern plains). Water stress is also a major constraint in the sorghum areas located in the Atlántico, Magdalena, Bolivar, Guajira and Cesar Departments. Marketing grain sorghum is the major problem at the Caquetá and Urabá regions which are potential zones of production.

Research Centers and Five Year Plan

The Colombian Agricultural Institute is conducting research on sorghum at five research centers and one location in Arauca region. These sites represent the different sorghum growing regions of the country (Figure 3).

A brief summary of the major goals of the ICA five year plan with specific inference to agricultural development is as follows:

1. To increase or maintain the growth achieved so far in production, yield, and area seeded.

2. To reach self sufficiency in production and to introduce composite flour in wheat flour substitution to make bread.

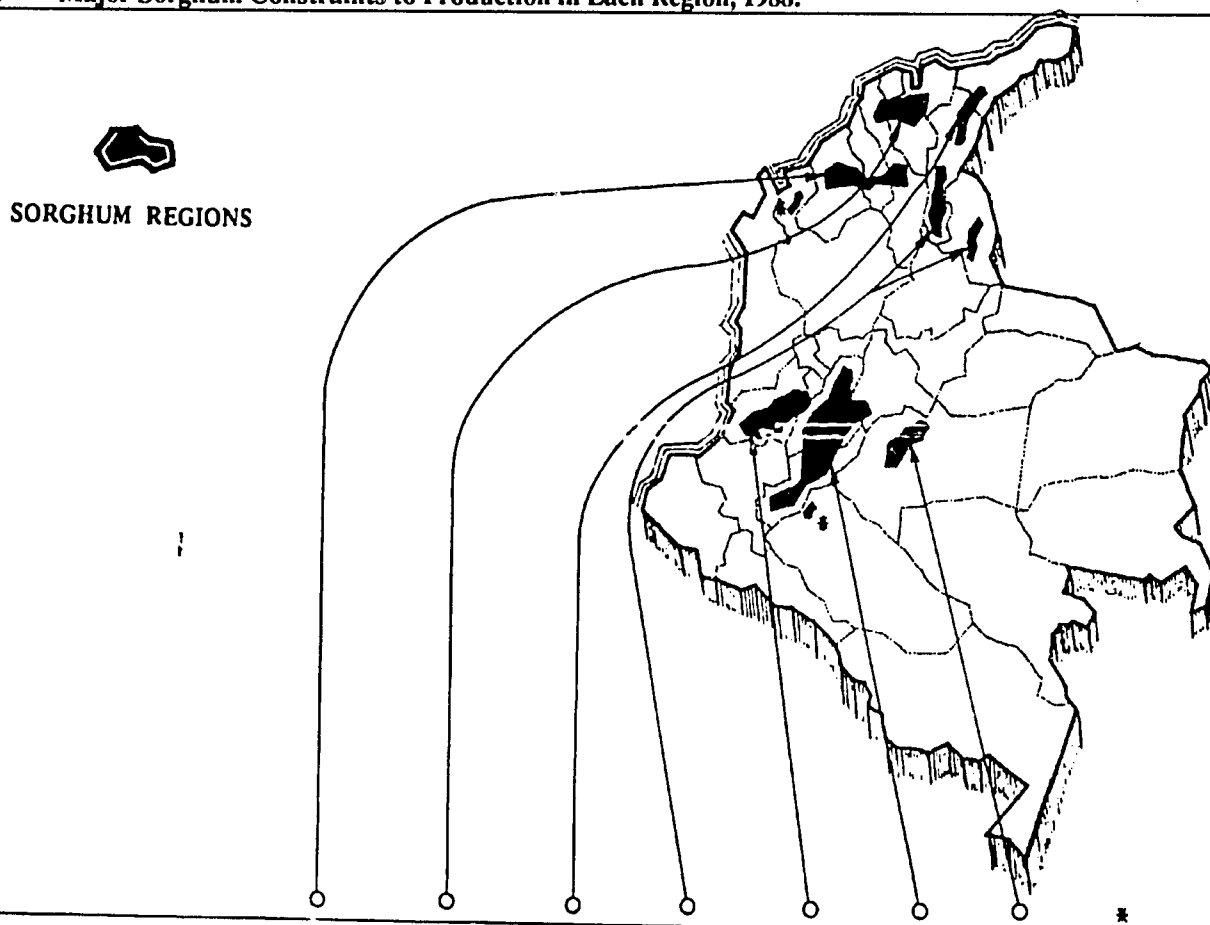
3. To increase overall productivity

4. To decrease production costs

5. To orient research to solve the problems identified in conjunction with farmer participation.

The research projects to accomplish these objectives are focused on the following aspects:

Table 2. Major Sorghum Constraints to Production in Each Region, 1988.



CONSTRAINTS	Córdoba Sucre Bolívar	Atlántico Magdalena Bolívar (N)	Guajira Cesar (N)	Cesar (S) Cúcuta	Valle Quindío	Tolima Huila	Meta (East plains)	Cáqueta Urabá
FOLIAR DISEASE								
Leaf anthracnose	X	X	X	X	X	X	X	X
Zonate leaf spot	X					X	X	X
Acremonium						X		
Gray leaf spot	X	X		X	X	X	X	X
Leaf blight	X		X		X	X	X	X
ROOT AND STALK DISEASE								
Antracnose stalk rot	X			X		X	X	X
Charcoal rot		X	X			X		
PANICLE DISEASES	X			X		X	X	X
VIRUSES				X	X	X		
INSECTS								
Midge	X			X		X		
Panicle moth		X	X	X				
Stem borers	X						X	X
ALUMINUM TOXICITY							X	
ACID SOILS							X	
WATER STRESS		X	X					
MARKETING								X

TABLE 2. Major Sorghum Contraints to Production in Each Region, 1988.

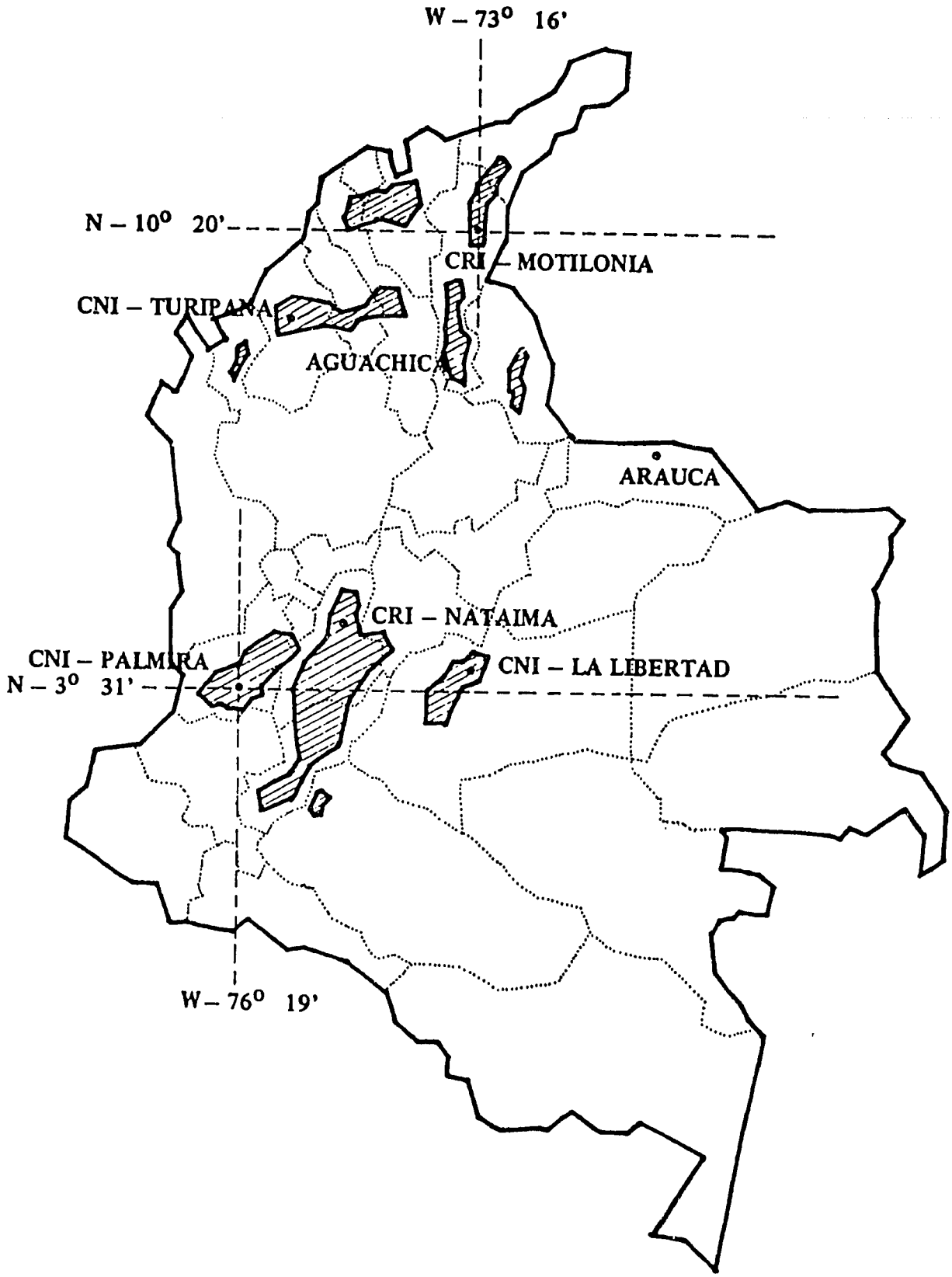


Figure 3. Colombian Agricultural Institute (ICA) Centers with Research on Sorghum.

1. Development of high yielding varieties and hybrids

2. Incorporation of genetic sources of resistance to diseases and insect pests in promising and well adapted genetic materials

3. Development of varieties and hybrids tolerant to aluminum toxicity for production in the acid soils of the eastern plains.

4. Development of adapted varieties and hybrids for the regions with water stress problems.

5. Development and implementation of agronomic management practices specific for each region and commercial material.

6. Determination and prioritization of the most limiting factors to economic production.

7. Reduction of production costs by means of appropriate agrochemical use.

8. To develop low tannin food quality sorghum for use in composite flour with wheat for bread production.

9. Intensify the diffusion of new technologies and the participation of farmers in extension activities.

ICA and INTSORMIL Program

INTSORMIL can best assist ICA to accomplish these project objectives through the following collaboration:

1. Providing germplasm with the following characteristics:

   a. Tolerance to aluminum toxicity and acid soils
   b. Resistance to diseases and insect pests which are prevalent in Colombia
   c. Drought tolerance.

2. Provision of Equipment

   a. Electrophoresis (1)
   b. Computer (1)
   c. Moisture tester (4)
   d. Cold rooms (2)
   e. Plot Threshers (4)

3. Test promising germplasm developed in Colombia for downy mildew resistance.

4. Provide technical information and publications

5. Training: Short courses and scientific visits.

   a. Short courses for 4 agronomists (2 - plant breeding, 1 - cultural practices and 1 - grain quality)
   b. Scientific visits for 2 M.S. and 2 Ph.D.
   c. Scholarships for 3 M.S. and 2 Ph.D level trainees.

Honduras

Dr. Roduel Rodriguez
Honduras National Research Department

Introduction

Sorghum is the third most important cereal in Honduras, after maize and rice. It is grown for grain and forage and is utilized for human consumption and animal feeding. Sometimes it replaces maize for making tortillas. Grain sorghum feeding value represents 96 percent efficiency as compared to maize. Its forage is primarily used for livestock feeding during the dry season. Despite the fact that sorghum is a profitable crop when appropriate cultural practices are used, its cultivation has remained at the subsistence level. Nevertheless, sorghum grain consumption shows a growing tendency, as a result of an increasing demand from the new animal feeding industries established during the last four years.

Background Information

Sorghum was introduced to Central America during the colonial times. Since its introduction, sorghum has become one of the most important crops along the Pacific Coasts of Nicaragua, Honduras, El Salvador and Guatemala; where it is usually intercropped with maize and sometimes with beans in different spatial and chronological arrangements.

In the last few years, acreage planted to sorghum has increased; however, production has decreased as a result of low productivity (Table 1). National production has not been able to supply these industries with all the sorghum grain demanded; so that small grain imports has been required (Table 2).

Table 1. Tendencies in sorghum production in Honduras 1970-1985

Year	Hectareas	Tons	Kg/Ha
	- - - - - Thousands - - - - -		
1970	33	47	1.424
1972	29	40	1.379
1974	55	39	0.709
1976	57	47	0.825
1978	62	44	0.710
1980	56	42	0.750
1982	66	58	0.967
1984	66	56	0.848
1985	48	60	1.250

Table 2. Sorghum imports to Honduras 1983 - 1987

Year	Ton*
1983	4.3
1984	0.6
1985	25.4
1986	67.8
1987	69.0

*mostly sorghum seed.

Low productivity is directly related to the following factors:

1. Planting in marginal lands or hillsides. Agricultural lands are devoted to grow high cash crops, such as cantaloupe, sugarcane and cattle raising.

2. A continuous and accelerated process of fertility deterioration on the marginal lands planted with subsistence crops. Soil conservation practices are scarce, which in conjunction with a reduction in the number of years with fallow, as a consequence of a growing food demand by a fast increasing population (3.4% annual growth rate) demand socio-economic readjustments to reduce soil erosion.

3. Use of low yielding cultivars with low response to agricultural inputs, such as fertilizers. Maicillos criollos do not represent the best sorghum type to maximize yield. Their low yield potential make the adoption of improved technologies difficult to implement.

4. Production and availability of improved cultivars. Seed production of the improved cultivars released by the NSIP is low due to the lack of private seed industry involvement.

Sorghum research officially began early in the sixties with the establishment of Inter-American Service of Agricultural Cooperation (STICA). Different cultivars were evaluated and as a result some grain type sorghum cultivars like Tempraneru 1 and Temprenero 2 (1969) and forage types like Sart, were distributed among several farmers in the southern area. No efforts were done to do

research on maicillos criollos, their cropping systems and production practices.

In the early 70's germplasm collection of maicillos criollos started. In 1975 a Peace Corp volunteer was appointed to Choluteca. His activities are to have a tremendous impact on scientific sorghum research. From that year on (1975), a multidisciplinary approach took place. The breeding, agronomy, seed production and technology transfer components were organized. Several hundred of sorghum entries were screened and the hybrids D60 y D42, the line Wheatland (BTx399) and the maicillos criollos Peloton, Pespire I y San Bernardo IV, were selected with yields between 2 and 4 T/ha.

In 1976 commercial seed of Centa S-1 was produced for the first time. Emphasis at this time was to develop varieties and hybrids for dual purpose, grain and forage, photoinsensitive, and 2-3 dw. Disease resistance, good quality grain for human consumption, drought tolerant and good combining ability were considered. As a result of this work, CS3541 was identified as the most high yielding variety (4 T/ha). Later on, CS3541, underwent mass selection, originating Tortillero variety, named for its good grain quality for human consumption.

From 1980 to 1981 , in-service training was initiated with the collaboration of International Centers and foreign Universities (ICRISAT, TAMU, MSU, ICA). In 1980, a memorandum of agreement between SRN and INTSORMIL was signed, and a full time sorghum breeder was appointed to Honduras. Main objectives at this time were to rejuvenate the National Sorghum Improvement Program and provide the infrastructural base to sustain an efficient and scientifically based research program according to the farmer needs.

Due to the multidisciplinary character of INTSORMIL, disciplines such as nutrition, sociology, entomology and pathology were integrated. In 1983, seed production of two released cultivars, became important.

Agronomic researcn began late in the 70's. The complexity of the factors involved in the cropping systems with sorghum, retarded the agronomic research, nevertheless, these studies helped obtain a better understanding of these systems.

Research Accomplishments

Technical assistance provided by INTSORMIL to the National Sorghum Improvement Project has been fundamental in the achievements obtained. This support has consisted of:

1. Technical assistance
2. Germplasm exchange
3. Financial and logistic support
4. Training

Technical assistance - Appointing of a full time sorghum breeder with periodical visits of INTSORMIL scientists.

Germplasm exchange - Elite germplasm possessing high yield potential, resistance to biotic and abiotic stresses, has been introduced by INTSORMIL scientists. At the same time, maicillo germplasm has been distributed to other sorghum breeding programs.

Financial and logistic support - Financial support has been of great importance in strengthening and obtaining economic independence. Such support has been effective in the form of direct and indirect donations. Logistic support has included operational costs, agricultural equipment and computing systems.

Training - A Ph.D. has been trained in an INTSORMIL university and two B.S.s have been trained in service. Several M S. theses and Ph.D. Dissertations research problems have been conducted in collaboration with several INTSORMIL universities and the EAP, which has contributed to strengthening the multidisciplinary character of the National Sorghum Improvement Program.

As a result of this interaction, we can identify the following achievements:

1. Strength of the National Sorghum Improvement Program. Ongoing sorghum research is accomplished by INTSORMIL trained personnel. Honduras National Sorghum Improvement Project has gained creditability and leadership in the mesoamerican area.

2. Cultivars with higher yield potential are now available; Tortillero, Sureño y Catracho (4-7 T/ha range), in contrast with the local maicillos (0.9-2 T/ha).

3. Development of a broad base maicillo improved germplasm, represents a cornerstone for increasing sorghum yields and utilization under local conditions.

Constraints

1. Lack of a National development model which does not emphasize agricultural development policies nor the rational utilization of available natural resources.

2. Slow administrative paper work (PL480). In addition to the administration delay, funds are not available during the first four months every year.

3. Lack of good trained personnel. Personnel recruitment is not based on performance.

4. Instability of the administrative staff. High ranked officials at the Research Department are appointed based on political preferences.

5. Lack of understanding of INTSORMIL capabilities for cooperation and collaboration.

Because of the above mentioned constraints, PNS has not taken full advantage of the technical and scientific collaboration offered by INTSORMIL.

Goals

1. To consolidate and strengthen the National Improvement Program into a multidisciplinary scope.

a. Maintain personnel continuity.
b. To strengthen the collaborative efforts with INTSORMIL, ICRISAT and other public and private national and international organizations.
c. Hire qualified personnel.
d. Train young scientists and technicians in different agricultural disciplines such as: sorghum breeding, pathology, entomology, agronomy, physiology, cereal technology, economics, tropical soil management.

2. To increase sorghum productivity, consumption and utilization.

a. To promote a sorghum market based on the different products and by-products obtained. This is to be accomplished by developing technologies, such as cultivars and production procedures, for several utilization purposes.

b. To increase the yield plateau of 0.9 t/ha to 1.5 t/ha through improved sorghum technology transference to sorghum growers.

c. To alleviate food scarcity problems by promoting food type sorghums to be used for human consumption.

MALI

El Hadj Oumar Tall, Director General IER - Mali
Zana Sanogo, Head of Agronomic Research in IER, and
Moussa Traoré, IER - INTSORMIL Coordinator

Introduction

First of all, I would like to thank the Management Entity of INTSORMIL for having the collaborative countries participate in this important conference for international sorghum/millet research for the next ten years.

Located in West Africa, the Republic of Mali is a landlocked country of about 1,240,00 km^2. Mali is situated between latitudes of 10° north and 16° north, and between longitudes of 12° west and 4.15^o east. Rainfall in Mali varies from practically zero in the Sahara Desert, up to 1,400 mm (4.8") in the Guinean Zone, in the South. In between these two extremes, are the Sahelian Region with rainfall 200 mm (Timbuktu, Gao) to 700 mm (Ségou, Kayes), and the Soudanian Zone with 700 to 1000 mm rainfall (Bamako, Koutiala). About 90% of the Malian active population work in agriculture which constitutes the essence of the country's economy. Like in other Sahelian countries, here, a spectrum of drought has been hanging over the last 15-20 years. The worst droughts occurred in 1971-74, and 1980-85.

In the higher rainfall zones of Mali, the main crops are cotton (for local industry and export), and sorghum, maize and millet for food. Some groundnut is also grown for export, especially in the western half of the country. As rainfall decreases, and soils become sandier toward the north, more millet is grown, less sorghum, and even less or no maize and cotton. An important feature of sorghum and millet for the Sahelian Region is their ability to grow and produce under marginal land, climate and management conditions. In fact, sorghum and millet occupy most of the cropped land in Mali, and constitute the staple food for the populations. The land area under sorghum and millet has been increasing even more during the drought cycle, as more marginal lands were brought under cultivation. Differences in climate are largely dependent on the amount and distribution of rainfall, and the fragile equilibrium present between population, food production and environment has been disrupted several times because of the successive droughts, the process of desertification, and the rapid population increase.

The Five Year Development Plan (1987-1991)

The ongoing Malian Five Year Development Plan for the 1987-91 period, has set itself five priority objectives in order to reach the major goal of economic development. They are:

- Obtain food self-sufficiency.
- Fight against drought and desertification.
- Create jobs through development of new activities that can bring about economic growth.
- Make drinking water, education and health available to the entire population.
- Improve communications outside and within the country.

With a population of about 8 million people, Mali has a 2.85% population increase rate. Eighty per cent of the total population live in rural areas and has, essentially, agriculture as their economic activity. In addition, most of the little industry that exists is based upon agricultural products, thus making understandable that years of drought have severely slowed down economic growth in the Sahel in general, and in Mali in particular. The economy is strongly dependent on agricultural production, which in turn is highly influenced by the amount and distribution of rainfall. The main cash crops in Mali are cotton (first export product), and groundnut. Livestock (cattle and sheep), which also occupies a significant place in Malian economy, has equally been severely stricken by drought. Food grain self-sufficiency is almost reached in years of normal rainfall, in Mali. Large deficit years are, however, more frequent due to severe droughts. Thus, yield stability and grain security constitute the main objectives toward food self-sufficiency. Some examples of deficit years are 1978 (110,000 metric tons of deficit), 1984 (300,000 metric tons of deficit), 1985 (370,000 metric tons of deficit). To face the environmental constraints to crop production, agricultural research is to play a major role. To reach the production levels of 2,000,000 tons by 1991, and 2,500,000 tons by year 2,000, that are projected to cover the population increase, the Institute of Rural

Economy (IER) has been assigned to generate technology to increase and stabilize food production. Besides agricultural research, some political actions are scheduled to ease the adoption of improved technologies through supporting an economic interest for farmers to produce and invest more.

The second priority of the five year plan is to tackle drought and desertification:

- stabilize crop yields through drought resistance research and breeding for yield stability,
- protect and restore agricultural lands subject to erosion and soil degradation,
- use natural resources more efficiently and safely.

Present Status and Perspective of Sorghum/Millet Collaborative Research

Research in the area of sorghum and millet improvement in Mali, is carried out by a multidisciplinary team of researchers, and funded by different agencies collaborating with IER in a very well integrated research program. The collaborators are, among others: USAID, ICRISAT, CIBA GEIGY Foundation, CIRAD-IRAT, TROPSOILS, and INTSORMIL.

The INTSORMIL collaborative research program in Mali is concentrated on one of the major objectives of the development plan, that is to develop high and stable yields of sorghum and millet. INTSORMIL provided support to IER through consultancy, training, and funding of programs, in areas of breeding, food quality, and physiology. The IER sorghum breeding program has been supported by ICRISAT/Mali, and INTSORMIL. INTSORMIL breeders have provided several breeding lines to be tested and used in Mali. Many of the introductions are now being integrated into locals through crossing. The cereal technology laboratory at Sotuba is continuing to make progress in developing improved techniques to select sorghums and millets for tô quality. Sorghum lines in the breeding program are systematically evaluated for decortication characteristics, and tô properties. Grain molds and head bugs were found to cause significant damage to food quality, especially, of the improved varieties. Alternative uses of sorghums and millets have been investigated, and good progress has been made. The Sotuba technology laboratory has been and is being equipped with INTSORMIL funding, while the laboratory itself was built on USAID/ICRISAT/MALI funding. A screening technique for seedling stage drought resistance in sorghum and millet breeding material is conducted using the charcoal pit technique. A screening technique for post flowering drought resistance is being tested, and characteristics of local varieties that influence adaptation to the different locations are being studied. The Nebraska project NE-123 has provided significant support to INTSORMIL/Mali to help start a new program in the area of stress physiology. Several pieces of equipment were purchased and placed in Mali to carry out the physiology program, and two Malian students are being trained at the University of Nebraska on this project. Similar efforts are underway to start programs to study nitrogen use efficiency, with NE-114, and head bugs with TAM-125. The overall collaboration and support from INTSORMIL is very highly rated by the Government of Mali, as these programs contribute to reach food self-sufficiency, and fight drought and desertification, the two main objectives of the five year development plan of Mali.

To better tackle the problem of development, IER is preparing an ecogeographic organization of its programs. The need for well trained scientists will be greater, and more funds will be needed to adequately carry out the necessary research for the development of appropriate technologies. An even stronger interest of INTSORMIL Principal Investigators to the Mali program will be necessary to help train IER researchers, develop, with IER scientists, collaborative programs in the different disciplines, while keeping the strong integration between disciplines and also between funding sources, as a rule. For the near future, funding is needed to train two scientists for each of the following areas of research: Entomology, Pathology, Breeding, Food Technology, Physiology, Weed Science, and Soil Science. An extension of the IER/INTSORMIL collaboration to areas such as entomology, pathology, weed science and soil science is needed. Institution building in the IER research system, will be continued through the joint effort of the different collaborators: USAID, ICRISAT, INTSORMIL, TROPSOILS, CIRAD, etc. Support from INTSORMIL to build a physiology laboratory at the Cinzana station will be a very valuable investment. The Cinzana station was funded by the Ciba Geigy Foundation, USAID/ICRISAT, and the Government of Mali. Much of INTSORMIL/Mali activities are carried out at that station, including the stress physiology program.

This is a good occasion to express our appreciation for the help INTSORMIL has provided to Mali by training many scientists, and developing and funding a very efficient collaborative research program.

An even more intense collaboration will be desired by the Malian Program when the Government has finalized the indepth rest. ucturing of the national research service that is being implemented. Then, a long term research program will be developed with INTSORMIL, and adequate funding researched by the Institute of Rural Economy and its partners.

Finally, I would like to extend our appreciation to all U.S. collaborators who helped make the INTSORMIL/Mali program a very effective one. May we all make an even better use of the great potentials of the International Sorghum and Millet research in the Nineteen Nineties.

Niger Agriculture and INRAN-INTSORMIL Collaboration

Dr. Idrissa Soumana, Director General of the National Institute of Agronomic Research of Niger

Introduction

Before the 1968 drought, Niger produced a food crop of about 1.25 million metric tons, and was self-sufficient because this level of production could sustain the food needs of its 3.89 million people. In addition, the agricultural policy of the country during this first favorable decade after Niger's independence was based on the development of cash crops such as peanut, cotton, and onion which ensured currency acquisition.

Since 1968, drought has been becoming more and more frequent and severe, and has completely modified Niger's hopes and re-oriented the agricultural policy and strategy of Niger. Alimentary self-sufficiency has now become the priority of priorities; food deficiency has become a permanent problem for the country. As a result, all plans and all development programs since 1976 have aimed at satisfying the food needs of an increasing population, facing unstable and insufficient food production in an environment which is becoming more and more threatened by desertification.

I. Some Basic Data about the Niger Economy and Agriculture

Niger is a landlocked country spreading over 1.27 million km^2, 75% of which is desert, and 15% semi-arid with nomadic activities. Only the southern part of the country is arable; it receives an average annual rainfall greater than 350 mm with high variability; soils are mostly sandy in this region with some fertile and irrigated depressions (20,000 ha, maximum potential: 200,000 ha) along the Niger river and its valleys (Dallols, Bosso and Maouri, Goulbi Maradi, etc...).

Of Niger's estimated 1985 population of 6.5 million people, 85% live in rural areas, centered in the southern part, with higher densities around Niamey and the central frontier regions with Nigeria. Its annual population growth rate is 2.8% for the entire nation and 7% for urban areas.

The annual income per inhabitant was $300 in 1983. However, after regular increases from 1973 to 1983, income degraded because of the decrease in the international price of uranium (the principal national export), and the severe droughts of 1983 and 1984.

The Gross Agricultural Product (including forestry and fishery) represents presently 33% of the Gross National Product. From 1960 to 1986, it has increased at an average rate of 3.2% per year, due only to the increase in cultivated area. This increase, however, led to natural resource deterioration with reduced fallow, overgrazing, intense soil erosion, and an increased repartition between agriculture and grazing in agro-pastoral transitional zones.

Cereals occupy 90% of the cultivated areas. Pearl millet and sorghum, which are dryland crops, represent 75% and 20% respectively of the cereal production which remains very variable from year to year (for example, production was 0.9 and 1.7 million metric tons in 1984 and 1985 respectively, yet national requirements were estimated at 1.4 million metric tons); the remaining 5% of cereal acreage is devoted to irrigated rice and secondarily by corn. Groundnut and cowpea are the main cash crops. During the 1970s, the production of these legumes decreased perceptibly (from 260,000 to 96,000) compared to the latter (72,000 to 280,000 tons), mainly due to the market price changes.

Yields in general are low: 400 kg/ha for pearl millet, 460 for sorghum, 250 for cowpea, etc. For the last twenty years, yields have remained the same or have even decreased slightly.

Livestock is numerically important (in 1983 estimated head counts were: 3.5 million cattle, 3.5 million sheep, 7.5 million goats, and 0.4 million camels), but less productive. In spite of the high reduction recorded during the last 12 years of drought, there is an incremental increase in number of animals, particularly for small ruminants.

During a normal year, the average food consumption is 2400 calories per person per day of which 70% is furnished by cereals, 12% by legumes (cowpea and peanut), and 8% by animal products which play an important role in the diet of agro-pastoral and nomad populations.

International agricultural exchange, which operates essentially with Nigeria is slightly positive in normal years with surplus varying respectively from 15 to 60 and from 4 to 12 million dollars for animal production and crop production. (This data must be considered as not effec-

tively correct due to the insufficiency of statistical services and the uncontrolled ways of animal trades.)

From this short presentation, we can retain the following points, which are important for future analyses.

-The high variability of climatic conditions from one year to another, and from one locality to another, requires a greater continuity of research efforts. Also, the high variability calls for technical innovations capable of fitting changing conditions (instead of a simple innovation or complicated one i.e. "technological packets") proposed for average ecological and climatic conditions of the country.

-The relative low variability of soil types and the small number of nationally important products (even if certain products can have a great regional importance or local importance marked [peanut, voandzou, corn, sesame]) can justify a certain concentration of research efforts, however limited by the immensity of the country and distances (with bad road conditions).

-Finally, the high fluctuations of basic commodity prices, partly due to high climatic variability and thus production, and the lack of the State intervention to control the market. These fluctuations increase the risks caused by the adoption of new techniques, creating a context less favorable to the efforts that farmers can attempt to do in this area.

II. Advantages and Constraints of Niger Agriculture

Niger is a typical Sahelian Country, located between 12° and 23° North Latitude. It is essentially an agricultural country in spite of climatic constraints characterized by severe droughts which have marked the history of the country.

A. The Advantages of Agriculture

Here, the term agriculture has a restricted meaning. It means crop production destined to satisfy human food needs. In Niger, this type agriculture is blessed with three main advantages.

1. A Young Agricultural Population

In 1985, the agricultural population was 4,461,000 people which represents 70.3% of the total population. The population size structure is similar to that of the whole population but emphasized by its youth with 60% under 25 years old. This situation is an important factor in our favor, in light of a sector which must be developed and modernized.

2. Great Physical Potentialities

The arable land represents 24% of the national territory, almost 30 million hectares. Land under cultivation occupies 50% of the arable land, 15 million hectares, and the coefficient of growing-intensity of 25% leaves first of all, a fallow of almost 5 years with an occupation rate of 2 hectares for active agriculture.

Niger has the potential of irrigatable land estimated at 270,000 ha, 140,000 of which are located in the Niger river valley. Only 11,000 ha are under full irrigation management, and 30,000 to 40,000 ha are used with partial water monitoring.

3. Important Water Resources

In addition to the Niger river, which is the main water course, Niger has other rivers like the Komadougou, Yobé and some lakes, like Lake Chad. Niger also has numerous permanent and semi permanent water ponds, some seasonal rivers and some artificial water reservoirs.

The amount of underground water is estimated to be about 36 billion cubic meters while the present water consumption is about 250 million cubic meters. However, this underground water is of mostly fossil grainwater deeply distributed whose exploitation requires expensive wells.

B. Agricultural Constraints

1. Water Constraints

Presently, Nigerien agriculture is a dryland agriculture. 5,830,000 ha out of 5,908,000 cultivated in 1986 were dryland. This type agriculture is fundamentally characterized by high rainfall variability and irregular rainfall distribution in time and space. Niger's agricultural zone receives from 250 mm in the North to 850 mm in the South. These rains fall within 20 to 55 days in a very irregular manner. During the same season, the alternance of rainy and drought periods is frequent and creates favorable conditions for parasites and various plant enemies and unfavorable conditions for the development of crops. Since 1930, there has been an average of one dry year out of four.

2. Soil Degradation

Most Niger soils are ferruginous tropical soils also called dune sandy soils, and hydromorphous soils. The first type represent 80 to 85% of the agricultural land while the second type constitute only 15 to 20%. The dune sandy soils originated from the wind and are very poor in organic matter, phosphorous, and nitrogen. They also possess low water holding capacity. The hydromorphous soils are clay soils with medium to high fertility which can be irrigated to grow maize, cotton, and particularly onions. Under the desertification process which is now experienced by the country, these soils undergo wind and water erosion. Again, they experience high human and animal pressures and are exploited without restriction. Evidently, the decrease in soil fertility has some implications on their production.

3. The Limited Scope of Agronomic Research

Agronomic research should remove all the above constraints. However, because of the lack of human resources in quality and quantity, insufficient diffusion of agronomic results due to the formal relationship between research and extension service, today, the action of agronomic research is very weak.

Besides these constraints, one should recognize other problems relevant to the rapid population growth rate, such as cultural, social, economical, and financial problems.

C. Agriculture in the Five Year Plan 1987-1991

Elaborated to encourage Niger to overcome the new constraints for its long-term development, the 1987-1991 plan objective is to establish the components of sustained economic growth. Thus, growth will be the result of the vigorous rebirth of agriculture. The agricultural policy will be addressed, not only to consolidate and improve the self food sufficiency, but to diversify our commodities. Crop production should be the essential motor of social development during the period of the plan. Therefore, agriculture occupies not only a place of choice in the 1987-1991 plan, but should be the foundation of the economical and social development of Niger.

1. Long Term Orientations

One of the three major orientations retained for the sector of agriculture is the creation of an agriculture system with surplus production.

Although it occupies 70% of the population, crop production contributes only 25% of the Gross Domestic Product (GDP). This activity conserves a highly traditional nature which is characterized by the maintenance of the past cultural practices, low saving and investment capability, and a system of production largely oriented toward self-subsistence.

An agricultural system with surplus production is an agricultural system which strives to increase and diversify production. The creation of quantitative and qualitative surpluses will permit us to improve the income of the producer, which is uncertain today. The increase of surpluses which lead to an increase in farmers' income will have a boosting effect on the national economy by enhancing the saving and investment capacity of the producers. Finally, an agricultural system based on surplus production should also reduce extensive resource-depleting agriculture which damages a weak environment.

2. Objectives

The production objectives are determined according to three main preoccupations. (Tables 1 and 2.)

- A better satisfaction of domestic needs;
- A restriction to the increase of areas intended to dryland crops;
- The improvement of varieties to increase farmers' income.

For cereals, the increase of the production will be relatively low because of trade problems, the lack of price policies, and a relative yield decrease.

Table 1. Agricultural Productions - Objectives by 1991

	Objectives 1991			Average Annual growth rate 1987-1991		
Products	Area (1000 ha)	Yield (Kg/ha)	Production (1000T)	Area (%)	Yield (%)	Production (%)
Pearl Millet	3285.7	406	1334.0	1.1	0.0	1.1
Sorghum	1182.8	279	330.0	2.2	-2.0	0.1
Rice	22.8	3200	73.0	1.9	3.5	5.4
Corn	11.4	571	6.5	1.8	-1.0	0.6
Wheat	3.1	2320	7.3	3.7	2.6	7.1
Cowpea	1833.3	150	275.0	4.7	-1.5	3.0
Other Leguminous	13.4	1120	15.0	4.9	2.0	8.6
Cassava	23.3	8585	200.0	0.5	1.0	1.5
Sweet Potatoe	3.0	12500	37.9	1.9	1.0	3.0
Peanut	305.7	458	140.0	11.8	0.0	11.6
Sugarcane	2.9	12700	37.0	1.0	0.0	1.8
Fruits				56.0		10.0
Cotton	12.0	700	8.4	3.7	0.0	3.7
Other Crops	11.9	10500	125.0	2.2	3.0	5.5
Total	6712.0		2.6		2.9	

Source: Groupe Développement rural
*Base de départ moyenne 1980-85 décentrée sur 1985

Table 2. Agricultural resources: Excess and Shortage in 1991

Products	Necessary Production for satisfying National needs(*)	Production Objectives 1991 (1000 T)	Excess or Shortage in 1991 (1000T)
Pearl Millet	1334.0	1334.0	0.0
Sorghum	364.9	330.0	-34.9
Rice	82.5	72.9	-9.6
Corn	38.1	6.5	-31.6
Wheat	68.5	7.3	-61.2
Cowpea	241.2	275.0	33.8
Other Leguminous	15.0	15.0	0.0
Cassava	144.2	200.0	55.8
Sweet Potatoe	33.9	37.9	4.0
Potatoe	13.0	13.0	0.0
Peanut	214.6	140.0	-74.6
Sugar Cane	37.0	37.0	0.0
Fruits	56.0	56.0	0.0
Cotton	3.0	8.4	5.4
Other Crops	88.9	125.0	36.1

(*) Human Consumption + Seeds + Food Processing Source: Groupe de Développement Rural

3. Programs to be Executed

Three programs are concerned in the crop production sector.

- Desertification control and improvement of the food production system with the following objective; the reduction of the degradation of the agronomic and pedologic potential and of the cultivated soils, fertility, crops intensification by soils management, and the use of fertilizers.

  An essential component of this program is the extension of the positive results of Agronomic Research.

- Water control and the diversification of production in order to increase yields on irrigated lands, to valorize the irrigable land potential.

- The construction and the control of the economical channels in order to control imports.

III. INRAN-INTSORMIL Collaboration

INTSORMIL, the USAID CRSP responsible for the improvement of sorghum and millet, the two main crops in Niger, interests the National Institute of Agronomic Research of Niger (INRAN) for more than one good reason.

As shown by the collaboration program and the INRAN-INTSORMIL 1984-1987 plan, the constraints of these crops are:

Drought
Insects
Diseases
Weeds: *Striga* for instance
High soil temperature
Sandy winds
Low fertility and toxicity of soils

In addition to these physical and biological constraints, there are some socio-economic constraints such as the low income of farmers, the reduced price of products and their high fluctuation. The agronomic research in charge of solving those problems in order to increase quantitatively and qualitatively the production of these two crops and to valorize them, is also facing problems related to human and financial resources. In such a context, what should we obtain from our collaboration with INTSORMIL?

1. A Collaboration Concerned in Solving the Key Problems of Nigerien Agriculture

The conditions created by a young institution like INRAN, its characteristics, its needs, the multiplicity of its research structures, the requirement to solve some problems of Nigerien agriculture, etc., will impose on the institute to appeal to homologous institutions or to those interested in contributing to the research of adequate solutions for these problems. Today's inevitable reality and the necessity to master agronomic research in Niger, will incite us to seek the best possible use of assistance from institutions which would like to collaborate with us to improve Nigerien Agriculture.

1.1. An Innovative Collaboration

Today, assistance is required and used to provide INRAN with capabilities in areas where the institute has no specialist. Our lack of specialists makes it practically impossible to supervise the work done by the expatriate scientist who conducts his activities without any control from the institute. Obviously, when the expatriate researcher leaves the institute, his work leaves with him, and therefore can be considered practically lost. In order to achieve a better contribution, the expatriate scientist must be absolutely integrated into the INRAN program

and the research team. Considering this fact, the assistance team must recognize that criticism is necessary to break the isolation of both national and international researchers. The facilities of the international researcher and his management by a parallel structure independent from the institute do not facilitate at anytime his integration, and the institute with its infrastructures appear as just a transit area for him to reach his personal goals. This situation leads us to further question the importance of such a cooperation which definitely does not help INRAN and even blocks the INTSORMIL potential contribution destined to INRAN. The activity then, of research for the international researcher must be an integral part of the national program and a support to it. So, INTSORMIL must be aware of our national program and contribute to its reinforcement by helping in its formulation and identification.

1.2. Collaborative Training of Young Researchers

INRAN, a young institution with only 13 years of experience has a very young, well motivated but inexperienced research staff. INTSORMIL can and must play an essential role with its scientists who must be willing to educate these young researchers at all levels. As instructors, they have the ability to communicate through their field and laboratory visits. Their great field and lab expertise must motivate and stimulate our young researchers. A veritable partnership must be set up between them and INRAN researchers. We must even speak about the sponsorship to take charge in the education of young researchers.

2. *A Collaboration Leading to a Confident Inter-Institutional Relation*

INTSORMIL, as an executive agency of the Sorghum and Millet CRSP must be for INRAN a source of relations involving all universities. These relations must be confident without ulterior motives. This means the integration of scientists from both sides. So, the institution, must be regularly informed of the evolution of the common sector of interest. In the case of the presence of researchers, all communications should circulate following the normal procedures of circulation of information in the institution. This means according to the normal official channels which include the other responsible parties from the level of General Director down to other levels such as the departments, the leaders of research programs and research station scientists. To summarize, generally, the participant researchers are not integrated in the administrative structure nor in the research structures, from which they escape completely; partly because of INRAN deficiencies in human resources, but also because of the lack of precise instructions from INTSORMIL about the implantation of research and researchers into our structures. In the future, it is absolutely necessary to think about this insertion of researcher participants into the structures of the institute. The present conditions do not favour this integration. At the present time, the INTSORMIL researcher is unfamiliar with INRAN problems. In fact, INRAN is not fully aware of their instructions and field plans for their trials. We need improved program integration and collaborative planning.

3. *A Collaboration Concerned About the Role*

David Bell, quoted by S. Wortman and R.W. Cummings, Jr. said "le programme d'aide à l'étranger, c'est-à-dire en fait l'assistance doit être un Partenariat." This means that the International Aid, in fact assistance must be a partnership. He adds: "l'aide n'est pas quelque chose que le donnateur fait pour le bénéficiaire, mais beaucoup plus avec lui." This means that the beneficiary is more concerned about what he will learn from a giver than what he will be given. The conditions of an efficient collaboration is frankness and the respect of the well known interest of the partner. We must say that often our institutes are just considered as structures through which one must go and conduct his research, then accumulate results, products of which activity are transferred out of our control. In the present conditions of general weakness of INRAN, we consider the collaboration as assistance to reinforce the research capacities of INRAN in order to prepare it to be a partner on which we can count on in the achievement of all common research operations.

Conclusion

As written by PAPON, a developing and Sahelian country like Niger is facing three major problems:

-The satisfaction of its basic needs (mainly food);

-The improvement of the conditions of living standards;

-The protection of natural resources which may satisfy the present and the future needs.

The mission of INRAN is to contribute, through research, to remove the constraints to the agricultural development, and the collaboration with American Universities must help in its mission because, as written by R.W. Cummings, Jr. "Les Universites Americaines reconnaissent les sérieux besoins des pays en voie de

développement, elles reconnaissent que les membres de leurs staffs peuvent aider à réduire les problèmes de la faim et peuvent bénéficier du point de vue professionnel de leur expérience à l'étranger et elles reconnaissent que quelques leçons apprises ailleurs peuvent être pertinentes chez elles. S'il en est ainsi alors la politique de collaboration, de coopération scientifique prend toute son importance. Il s'agit maintenant qu'elle soit assurée de façon équitable à la satisfaction des deux parties et qu'elle serve au mieux les intérêts du partenaire le plus faible".

This quotation means that American Universities recognize the serious needs of developing countries, that their staffs can help to reduce hunger problems and can benefit from the international and professional experience, and they recognize that sometimes, lessons learned elsewhere can be relevant to them. As such, the policy of collaboration, of scientific cooperation becomes more important. This policy must be secured for the equal satisfaction of both partners but better serves the interest of the weakest partner.

Sudan

Dr. El Hilu Omer
INTSORMIL/ARC Coordinator
Gezira Agricultural Research Station

Introduction

Sudan is a vast country occupying an area approximately 2.5 million sq. Km. The potential cultivable land is about 74 million ha, whereas the total cropped area is estimated at 10 million ha. The remaining represents grazing land, forests or uncultivated area.

Sorghum and millet are the main cereal food crops of the population. Grain sorghum occupies about 40% of the total cropped area. It is mostly grown under rain and only 7% of the sorghum area is irrigated. The mechanized farming contributes about 62% of grain sorghum produce, 23% is harvested from the traditional sector and the irrigated schemes yield about 15%.

Millet comes next to sorghum in area (1.6 million ha). It is mainly produced in west Sudan (90-95% of the total area) Table 1 summarizes the areas occupied by the two cereals, total production and average yield in relation to wheat during the seasons 1985-86).

Table 1. Grain area, production and average yield (1985-86).

	Area (000 ha)	Production (000 MT)	Yield (kg/ha)
Sorghum	5184(74.5%)	3403(86.5%)	656
Millet	1639(23.6%)	351 (8.9%)	214
Wheat	134 (1.9%)	178 (4.5%)	1328
Total	6957	3932	

Research policies shall continue oriented towards agricultural sector objectives and overall development and national goals. These goals aim for:

1. Securing self-sufficiency in grain food.

2. Maintaining strategic food reserve to offset the effects of instability in food production.

3. Increase the country's foreign earning.

4. Generate employment for the rural community.

5. Contribute to equal distribution of wealth between different regions.

6. Maintain, conserve and develop natural resources.

In broad terms, the mandates of Sudan agricultural research are no different from mandates of any national or regional research organization and essentially aim for the realization of national goals. These can be summarized as follows:

1. To identify constraints to agricultural development.

2. To devise means of alleviating these constraints through technological advances.

3. To assist in the transfer of technology to the farmer through cooperation with other institutions and national and international research organizations.

4. To participate and advise the government in drawing its agricultural development policy.

Sorghum/Millet Research

Constraints affecting sorghum/millet production are numerous.

Prioritizing them is not an easy task, but some of these constraints mentioned here are over-riding problems. ARC program in the next five years shall continue addressing these constraints.

1. Drought Resistance

The successive drought years that have affected Sudan, among a number of African countries, greatly reduced production, resulted in famine, caused decertification and inappropriated producer prices.

The effect of drought is exemplified by examining yield data of seasons 1984 and 1985 (Table 2). The former was a drought season, whereas the latter is considered a normal season.

Table 2. Sorghum/Millet production (1984 and 1985).

	Area (000 ha)	Production (000 M.T)	Yield (kg/ha)
		Sorghum	
1984 (Drought)	3010	661	209
1985 (Normal)	4897	2864	587
% increase	63	333	181
		Millet	
1984	1280	161	122
1985	1720	417	238
% increase	34	159	95

B
ased on data in current Agric. Statistics, Statistics Section, Dept. of Agric. Economics, Ministry of Agric. (1988).

Our collaborative effort is giving the drought program due attention and the lines that succeeded in making a crop under the harsh conditions of the 1987 season in Gadambali hold promise that we may succeed in the next five years in narrowing the gap between a drought season and an average season.

2. Striga Research

This is a most challenging area of research. The acreage claimed by *Striga* is increasing from one season to the other. In badly affected areas yield deficit may be as high as 70-100%. A contributing factor to this increase is the agricultural system adopted by farmers in the country. Whether in mechanized farming or the traditional sector, sorghum is cultivated after sorghum.

In spite of the voluminous research published on *Striga*, an easy solution to the problem is not within reach. We need to know more about the biology of the parasite, devise better means of chemical and cultural control and improve host plant resistance.

Our country program, with the help of INTSORMIL and IDRC, is adopting an integrated control approach in farmers fields where researcher-managed trials proved the superiority of using a resistant cultivar (SRN-39) or (IS-9830), nitrogen in the form of urea (192 kg/ha) as post-emergence.

The effects of crop precursors, intercropping and mixed cropping are ongoing activities of the program. We hope through more in depth investigation in collaboration with INTSORMIL scientists and other interested organizations, we accumulate more better understanding to the solution of this problem.

3. Millet Improvement

Millet in the Sudan is a poor man's crop. The cultivars grown in the country are low yielders. Millet research in the country is still very deficient in many respects. We need to strengthen the millet improvement program through strengthening the research capabilities particularly with regard to research manpower.

Future research objectives should address improving yields and prescribe the best cultural practices to suit the harsh conditions of the west.

4. Pests and Diseases

The most prominent pests affecting sorghum are the stem borers and the central shoot fly. Aphids usually come late during the season and may become a problem earlier in drier seasons. American bollworms may occasionally reach a worrying level.

Besides chemical control, the program aims at screening germplasm against pests.

Charcoal rot resistance, legitimately, is well connected with breeding for drought resistance. Selection for drought tolerance should be based on a number of desirable traits including resistance to charcoal rot. Smut diseases are still a priority in our disease control strategy. This shall included promotion of effective chemicals and disease resistance research. Leaf diseases are a problem in high rain-fall areas. A disease resistance program needs to be initiated to meet our need in these locations. Downy mildew and leaf diseases of millet need to be surveyed and their damage be assessed. The appropriate disease control program can then be initiated.

5. Agronomic Research

The recommended three-course rotation (Sorghum-sesame/cotton-fallow) for the mechanized farming is not adhered to by most farmers because sesame harvesting is labor intensive and cotton requires expensive inputs. The tendency is for continuous sorghum monoculture. Land preparation is carried out by wide-level disk when the land receives 120-150 mm rainfall. The number of diskings varies from one to three depending on weed density. During the last disking operation, planting is done with a seeder box. The only subsequent cultural practice is a light hand weeding. Fertilizer is not applied. Plant

population is usually less than optimum and sorghum is hand harvested but threshed with a stationary thresher or combine harvester.

Future research plan should address the following

1. Improved method of land preparation for maximum moisture utilization

2. Adoption of herbicides for weed control in rainfed areas

3. Row planting compared to broadcasting

4. Optimum plant population for the different rainfall areas

5. Nutritional requirements of the crop in the mechanized farm

6. The best rotation for the rainfed crop

6. Socio-Economic Studies

The success of agricultural research program is judged by the acceptance and the rate of adoption of the technology generated by the producer. This is where socio-economic research is most needed. Socio-economic research is a recent addition to our collaborative activity.

The coming five year plan should witness more in depth survey of target areas, identify favorable factors and constraints to the adoption of new technologies and verify the economic profitability of new packages.

7. Food Research

Previously, the input of the food scientists was considered a late activity of the evaluation process. Now, ARC policy is to encourage the integration of the food technologist in all food research programs as early as possible.

The program will continue addressing problems related to baking and nutritional qualities of breeder material.

Human Resource

Training is the priority of priorities in research. Admittedly, Sudan ARC, compared to other African countries may be considered among those having the highest number of qualified personnel, but ARC is the sole organization in the country officially responsible for conducting research on field crops, horticultural crops, forestry, fish, animal game and food research. The country is vast with many stations to meet the needs of the agricultural development in the different regions. Furthermore, ARC is annually losing a big number of its qualified personnel because of low salaries and attraction from neighboring rich countries.

If we consider the two crops, sorghum and millet, we find there is great need for more scientists. The greatest emphasis on sorghum is handled by Gezira Research Station. Apart from the two breeders in sorghum, all other research workers have obligations towards other crops and/or administration. The situation in El Obeid, where millet research is handled, is no better than GRS.

We would like in our next five year plan to train more scientists to fulfill our need in the different stations. In-service training for both scientists and supporting staff is of utmost importance. Exposure of our scientists to experience, techniques and achievements of U.S. scientists is vital to solving our own problems. Although government policy is strongly for training, financial resources are usually insufficient to meet the needs of the country. We hope that USAID and INTSORMIL give this due consideration.

Our priorities in training for the next five years are:-

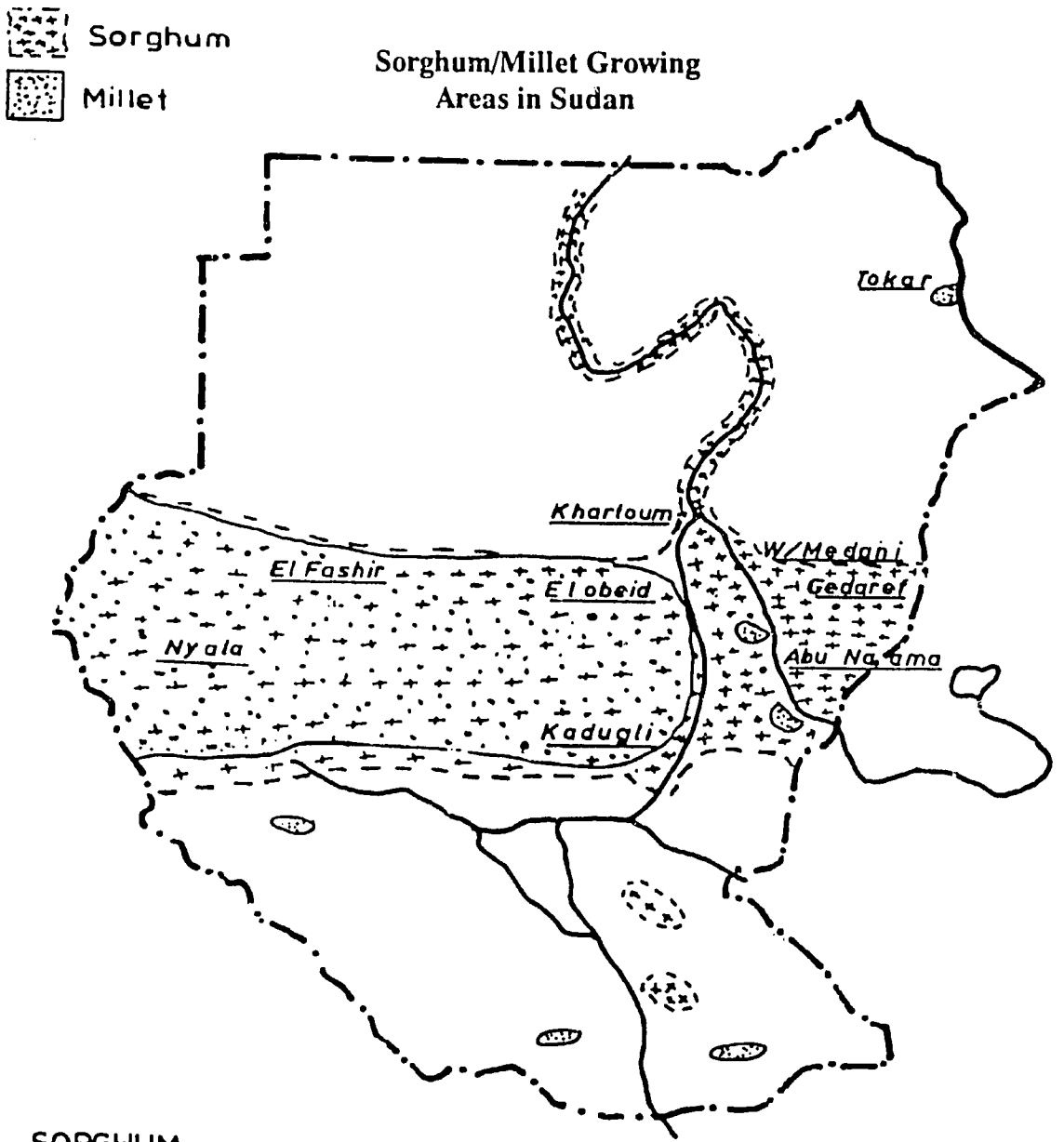
Discipline	No. of Scientists (Ph.D.)
Breeding	3
Agronomy and Crop Physiology	2
Entomology	2
Pathology	2
Mechanization	1
Economics	1
Striga (Biology)	1

Our Relation With INTSORMIL

I am particularly happy with the way our program has been conceived and successfully developed as a model of collaboration between INTSORMIL and our national scientists. The scientist to scientist multidisciplinary approach which INTSORMIL adopts, in my judgement, would reflect itself in the years ahead in a significant impact of the results on improving sorghum and millet production.

Mr. Chairman, I would like to take this opportunity to thank the organization, its former director, Dr. Glen Vollmar, the present director, Dr. John Yohe and the collaborating scientists for their continued help. We thank Dr. Allen Kirleis, the country coordinator who, throughout our association with INTSORMIL, responded with a great sense of dedication. The promptness and efficiency of Katy Ibrahim and the staff of USAID Mission of Khartoum deserves our praise.

Mr. Chairman, our presence here today in this important meeting is an indication that INTSORMIL is determined to continue its global mission in improving sorghum and millet production. We in the Sudan feel that INTSORMIL scientists shared with us our responsibility and provided invaluable services to our country during the 1980's. We do look forward for continued strengthening of our national capabilities in the decade ahead.



SORGHUM

Total area - 4 million ha
(40% cropped area)

Mechanized farming	62 %	Produce
Traditional area	23 %	"
Irrigated schemes	15 %	"
	(7 % of crop area)	

MILLET

West Sudan	90-95 %
Tokar	>5 %

Session III: Sustainable Technical Strategies for the 1990s by Prime Site

Session Chair: Dr. Jerry Maranville

Speakers:
Dr. Richard Vanderlip
Dr. Lynn Gourley
Dr. Darrell Rosenow
Dr. Lloyd Rooney
Dr. John Axtell
Dr. Gebisa Ejeta

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Southern Africa: Botswana

Dr. R.L. Vanderlip
Kansas State University

Botswana was designated as the prime site in the Southern Africa ecogeographic zone in the INTSORMIL global plan (INTSORMIL, 1985). Sorghum and pearl millet producing areas in southern Africa are geographically removed from those in the east and west Africa and generally are characterized by extremely wide variation in annual rainfall and patterns of annual rainfall. Choice of Botswana as a prime site complements the SADCC/ICRISAT Center at Bulawayo in Zimbabwe. The two locations are close enough together and accessible for continued interaction but diverse enough to allow a range of environmental conditions to be encompassed.

Norman et al. (1987) have described the farming systems in Botswana. Table 1 shows selected characteristics of agriculture in the Mahalapye area. Sorghum and millet production is on an extensive system in which the crop is broadcast and plowed in with multiple plantings to reduce the risk of crop failure because of the extremely variable rainfall patterns. Earlier work has suggested that..."the chance effects of the weather tend to be predominant over those of soil and technology, and the potential of a site at planting may quite literally be anything between 0 and 2 T/ha more depending upon subsequent weather" (DLFRS, 1978).

Table 1. Botswana agriculture, Mahalapye (from Norman et al. 1987).

Climate
Rainfall - 470 mm/yr
Rainfall >.5 pet - 0 months
Farm size
Cultivated land - 5 ha
Total land - 17 ha
Residences
Village
Lands area
Cattle post
Cropping System
Crops - sorghum, millet, cowpea, melons
Sorghum yield - 74 kg/ha
Power - animal
Planting system - broadcast and plow in
Peak labor - weeding, harvesting

Major constraints to sorghum and millet production in Botswana are identified in the Global Plan (INTSORMIL 1985) and include limited moisture, stand establishment, insects, diseases and price policies. I think it is obvious why the constraints to production list limited moisture as the first constraint. I would suggest that we should add to this list trained personnel. This training needs to be both at the B.S. and postgraduate levels. Initiation of the agricultural program at the University of Botswana should help in this regard, however, this will take some time before the impact is felt in the research and extension programs.

Collaboration in this region is excellent with a very supportive AID mission in Botswana, the Southern African Center for Cooperation and Agricultural Research (SACCAR) being in Botswana and the SADCC/ICRISAT Center at Bulawayo, Zimbabwe complementing the Department of Agricultural Research at Botswana and the INTSORMIL program. Collaborative work in Botswana is carried out in two very different but complementary ways. First, there are two INTSORMIL employees stationed in Botswana, the first, Dr. Doug Carter, being stationed there as a complement to the Agricultural Technology Improvement Project (ATIP) and the other PI, Dr. Naraine Persaud, being added to provide assistance in the area of soil-water relations. Objectives for the INTSORMIL PIs are 1) provide interim personnel while DAR personnel are away for training, 2) determine effects of mulch and manure on sorghum yields and 3) determine feasibility of water harversting. The second type of collaboration is through U.S. based PI projects conducted in Botswana in collaboration with DAR scientists. Areas of research are sorghum and millet breeding, entomology, plant pathology and stand establishment.

Major accomplishments resulting from the total INTSORMIL effort in Botswana are as follows:

- Wayne Youngquist replaced Lucas Gakale while he was completing a Ph.D. at the University of Nebraska.

- Use of mulch produced mixed results, ranging from decreased yields to increased yields.

- Use of manure increased yields, with increases becoming greater as yield levels increased. Annual applications are not necessary.

- Both macro- and microwatershed water harvesting can increase yields. Other considerations such as flooding and nutrient availability must be considered.

- Close collaboration between Louis Mazhani, DAR sorghum breeder, and David Andrews, University of Nebraska. Louis is presently completing a Ph.D. at the University of Nebraska.

- Chris Manthe, Ph.D. student at Texas A&M, in collaboration with George Teetes, has identified resistance to the sugarcane aphid and collected local predators.

- Baikabile Motalaote, plant pathologist, completed M.S. at Texas A&M and continues to collaborate with Gary Odvody.

- Miranda Mortlock, Ph.D. student at Kansas State University, conducted stand establishment studies on seed quality effects in collaboration with the ATIP and ADNP Farming Systems projects in Botswana. She now is teaching at the University of Botswana.

Future plans for the Botswana/US collaboration anticipate the continued presence of in-country collaborators as well as Botswana/US scientists-to-scientists collaboration. In addition, a greater effort should be made to train the DAR scientific staff and better coordination with SADCC/ICRISAT and SACCAR should be pursued. Because the in-country collaboration is tied by Memorandum of Understanding to the ATIP project which will terminate in 1990, it is imperative that the future of in-country collaboration be evaluated and jointly planned by DAR, AID/Botswana and INTSORMIL.

Sorghum and millet production in Botswana is under extremely severe climatic conditions. Sorghum yields in Botswana frequently average less than 500 kg/ha, even though rainfall in eastern Botswana should be sufficient to allow production of 2,000 kg/ha in most years (Lightfoot, 1979; Thompson, 1988). Botswana has the resources and the historical record of using these in agricultural schemes if practices for increasing production could be developed. INTSORMIL, thus, has the potential for making significant impacts on food production in Botswana if significant alleviations to the constraints can be identified.

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CIAT/South America: Colombia

Dr. Lynn M. Gourley
Mississippi State University

Background

Located in the northwest corner of South America, Colombia is bordered by Venezuela, Brazil, Peru, Ecuador, and Panama. It is the continent's fourth largest country with 114 million hectares land of which only 5% is cultivated. Colombia, with 26.5 million people, is expected to surpass Argentina by 1990 to become the third most populous nation in Latin American after Brazil and Mexico. About 30% of the total population lives in rural areas, which represents a work force of about 8.8% of the total population.

Gross domestic product of Colombia was $32.0 billion in 1985 of which agriculture contributed 21.9%. Major agricultural products include coffee, bananas, cut flowers, cotton, sugarcane, livestock, rice, corn, tobacco, potatoes, soybeans, and sorghum. Per capita income is slightly more than $1200.

Coffee is the main stay of Colombia's export sector, representing 46% of the 4.03 billion dollars of total export earnings. Overall, agricultural exports contribute over 70% of Colombia's foreign exchange earnings. The United States received 43% of Colombia's exports in 1985 and supplied 35% of her imports.

Colombia has three main topographical regions: flat coastal areas, central highlands, and eastern plains or Llanos. The climate varies from hot and humid on the coast and the Llanos to cool weather with frequent light rains in the highlands. The highlands experience two dry seasons, from December to February and from June to August. The Llanos at Villavicencio has an average annual precipitation of 2614 mm with a pronounced dry season from December through March.

The nine eastern departments (states) and territories, constituting about 54% of Colombia's area, have less than 3% of the population and a density of fewer than one person per square kilometer. This is the target zone of Colombia for expanding the area planted to sorghum and pearl millet.

Production Constraints

The most important constraint to increased sorghum and pearl millet area of production in Colombia and generally throughout South America is soil acidity. South America has the largest area of acid soils 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. Subsoil acidity, with subsoil being defined as those layers of soil immediately below the layer disturbed by cultivation, is really what is being addressed in estimates of the extent of acid soil. This subsoil acidity is important because it limits the depth of rooting of Al-sensitive cultivars, thereby, reducing both the amount of available water during rainless periods and the subsoil nutrient uptake. It has not been possible to apply traditional agricultural practices successfully in these areas because of limiting factors including: lack of access to capital; inadequate transportation and marketing systems; and the high cost and inequitable supply of production inputs for resource-poor farmers. To initiate sustainable agriculture, a technology based on low-inputs of soil amendments is required.

The second most important constraint to 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. The north coast of Colombia is the most consistent drought prone area of this prime site during normal production periods.

Other production constraints include plant diseases, insects, and birds. A lack of adapted germplasm, possessing stress tolerant characteristics, has also been a production constraint. As previously mentioned, the low population density in the Llanos can be considered a production constraint because of limited roads, markets, and other infrastructure.

Collaboration

Collaborative research in the Prime Site of Colombia operates under two formal agreements. In 1981, a Memorandum of Intention was signed by the Directors of INTSORMIL, ICRISAT, and CIAT. 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. CIAT invited INTSORMIL to conduct sorghum and millet research at their facilities after the question of mandated crop species had been cleared with ICRISAT. CIAT has provided infrastructure, a core of professional staff researching production problems of other crop species on acid soil, research supply import and finance privileges, equipment, various research laboratories and substations. CIAT's outreach programs throughout South America have saved INTSORMIL time and money in the pursuit of research objectives. CIAT is an ideal base of operations, but ICA is the primary collaborating institution. ICRISAT has supported INTSORMIL's research objectives in Latin America, both from ICRISAT Center and from its outreach program at CIMMYT, financially in the case of workshops and with sorghum and pearl millet germplasm. ICRISAT has requested that INTSORMIL continue breeding sorghum for tolerance to acid soil constraints and to take the lead in this research in Africa as well as Latin America.

Colombia does not have a USAID Mission, only a representative. Funding for this Prime Site is from the INTSORMIL MS-111 budget and funds allocated by ICA. The acid soils research initiated at this Prime Site has attracted outside funding to INTSORMIL by several organizations. The El Alcaravan Foundation along with commercial seed company financial support will assist future collaborative research of ICA and INTSORMIL in Colombia. The production and extension oriented organization, FENALCE, has also provided funds in the area of drought tolerant research. INTSORMIL is collaborating with the National Agriculture Universities at Palmira and Villavicencio by assisting Colombian students, working for their B.S. degrees, with their thesis research in sorghum. This helps INTSORMIL and ICA to conduct sorghum research at a very reasonable cost.

Collaboration with the TROPSOILS CRSP and the International Board for Soil Research and Management (IBSRAM) has been initiated, but not formalized. Networking through these international organizations and the Colombian Prime Site, INTSORMIL has established collaborative research linkages with EMBRAPA-Brazil, FONAIAP-Venezuela, and INIIPA-Peru in the major acid soils areas in South America. Within INTSORMIL institutions, most plant breeders have had plant germplasm evaluated in Colombia through germplasm exchange. Specific long-range research goals in Colombia now include pearl millet (NE-118 and KS-101), drought tolerance (TAM-122), pathology (TAM-124), and grain quality (TAM-126 and PRF-103B) investigations. Some entomology input is also provided by MS-105.

Objectives

The specific research objectives of the Prime Site project (MS-111) are as follows: (1) To establish a regional program for the development of sorghum and pearl millet germplasm with tolerance to low pH tropical soils with phytotoxic levels of Al; (2) To screen and evaluate a portion of the world sorghum and pearl millet collections for tolerance to Al and Mn toxicities, and low P availability; (3) To incorporate sources of tolerance to Al and Mn toxicities, and low P availability into elite U.S. and tropical sorghum genotypes; (4) To develop minimum-input technology strategies for the evaluation of Al-tolerant sorghum lines grown on tropical savanna soils; (5) To distribute sorghum and pearl millet germplasm developed from INTSORMIL and ICRISAT projects to national programs in Latin America and Africa; (6) To train and assist Latin American and African scientists in the use of effective breeding and screening methods for the adaptation of sorghum and pearl millet to acid soils; and (7) To assist other INTSORMIL projects in the accomplishment of their Colombian Prime Site objectives. General regional objectives are to develop sorghum and pearl millet research networks throughout South America, conduct research and other training activities, distribute germplasm, consult on problems and opportunities, and to transfer any technology developed by INTSORMIL, ICRISAT, CIAT, or INTSORMIL Universities.

Accomplishments

The list of accomplishments for the six years INTSORMIL has been involved at the Colombian Prime Site is impressive. In outline form, some of the major accomplishments of the research conducted in Colombia are as follows:

1. Germplasm released or near release includes 11 pairs of brown midrib (low lignin) A and B-lines, three pairs of Al-tolerant A and B-lines, two random-mating Al-tolerant (B-line and R-line) populations, and seven photoperiod sensitive tropically adapted R-lines, and three photoperiod insensitive temperate zone adapted Al-tolerant R-lines.

2. A reliable and repeatable field screening technique for Al toxicity as represented in the humid tropics has been developed.

3. About 400 Al-tolerant lines from the Sorghum World Collection have been identified.

4. A few manganese-tolerant lines from the Sorghum World Collection have been identified.

5. An International Acid Soil Workshop, funded by ICRISAT, INTSORMIL, and CIAT, was conducted in Colombia and helped to establish a network of scientists working with the problems of acid soils in Latin America.

6. The proceedings of the above workshop were published in English and will soon be published in Spanish. The first printing of the English edition of 600 copies has sold out.

7. INTSORMIL introduced pearl millet and finger millet into Colombia as acid soil tolerant species.

8. We have screened about one-half of the 5000 entry Ethiopian sorghum collection for tolerance to Al toxicity.

9. INTSORMIL and ICA are presented evaluating Al-tolerant by tolerant sorghum hybrids in Colombia.

10. Two books, nine chapters in books, and 23 refereed journal articles have been published by staff in this project. Project personnel have been invited to make 15 formal presentations and have presented 12 additional papers at professional meetings.

11. The acid soil research conducted under this project has attracted outside funding to INTSORMIL and ICA. The El Alcaravan Foundation, a consortium of petroleum companies in Colombia, has agreed to provide funds for five years to conduct sorghum and pearl millet breeding and evaluation research in the Northeastern Territory of Arauca.

12. Eleven graduate students have received advanced degrees with INTSORMIL projects associated with the Colombian Prime Site. Nine graduate students are currently being trained at INTSORMIL Universities. Dr. Guillermo Munoz (Ph.D., MSU, 1988) is currently the INTSORMIL Prime Site Coordinator. Mr. Cesar Ruiz (M.S., MSU, 1987) has returned to Colombia as ICA's sorghum breeder at the La Libertad station. The INTSORMIL Colombian Prime Site Project is using INTSORMIL and outside funds to aid ten Colombian students working toward their B.S. degrees with their thesis research in sorghum.

The Future

Are the Prime Site objectives still valid? Changes have been made as the need became apparent during the last six years. Pearl millet has been added to the list of acid soils species. Pearl millet will exceed sorghum yields at higher Al saturation levels and requires less fertilizer than sorghum. Finger millet is a very acid soil tolerant species which will be evaluated in the future. An additional change in the sorghum breeding research is the progression from the short and mid-term goals of screening and evaluating Al-tolerant genotypes as varieties to the long-term and ultimate goal of developing Al-tolerant high yielding grain sorghum hybrids.

The reduction of INTSORMIL funds required the discontinuation of the evaluation site in the deep Llanos at Carimagua, Colombia. Outside funding from the El Alcaravan Foundation has allowed INTSORMIL and ICA to evaluate sorghum and pearl millet at several locations in Arauca. The results of INTSORMIL's collaborative research effort with ICA has attracted this outside source of funding.

The answer to the question raised in the first part of this section is no. ICA's long-range goals involve all INTSORMIL disciplines. Original objectives were concerned only with the breeding discipline to solve the production constraints of acid soils.

New strategies have been developed to help INTSORMIL accomplish collaborative objectives. When you have budget cuts you are forced to focus and prioritize. Annual in-country planning sessions with most host country organizations (commercial seed companies have not been invited to participate) and INTSORMIL have made the whole collaborative effort more efficient. Specific research problems are first prioritized and then assigned to the in-country research organization with the beset capability of solving this problem.

Another new strategy is to use the expertise found in INTSORMIL to attract outside funding. Host country organizations other than the National Program, for example FENALCE, will pay transportation and per diem costs of INTSORMIL PI's to go to Colombia to help with specific problems. Foundations involved with agriculture such as the El Alcaravan can help fund INTSORMIL and ICA research and training goals. Mr. Luis Fernando Angulo, El Alcaravan representative, has provided funds to obtain equipment and to train National University students in sorghum research in Arauca. He has also agreed to help INTSORMIL obtain the funds to conduct a sorghum and millet workshop in South America.

Another untapped source of outside funding is the multi-national commercial companies in the host country. INTSORMIL is developing plans to involve the commer-

cial seed companies in Colombia to help evaluate the products of our collaborative research. They are willing to provide funds to INTSORMIL and ICA for the privilege of being involved at an early stage in this process. If the commercial seed companies are not involved in the process of getting this material to the farmers, the implementation of this new technology will be delayed. If the commercial companies are convinced that there is a saleable product, their demonstration plots at field days will help sell this technology to the farmers.

As the National Program becomes more acquainted with the research programs and capability that INTSORMIL has to offer and as INTSORMIL becomes more acquainted with national program long-range goals and production constraints within the country, collaboration improves. INTSORMIL has provided advanced training opportunities for not only ICA personnel, but also INTSORMIL personnel. The last two in-country INTSORMIL PI's have been trained in INTSORMIL projects. INTSORMIL linkages are strengthened by maintaining contact with National Program staff trained at INTSORMIL universities. This is perhaps the most long lasting contribution that INTSORMIL can make to the host country. New linkages have been established with the El Alcaravan Foundation and the commercial seed companies in Colombia. Many of the production constraints in Colombia are also found in Venezuela, Brazil, Peru, and Bolivia. The regional network of sorghum and millet research scientists needs to be maintained and strengthened.

INTSORMIL's collaborative research effort in Colombia has a high potential payoff for the USAID dollars invested. The Colombian Prime Site can make valuable contributions to the goals of INTSORMIL in the 1990's.

Central America: Honduras

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Background

Honduras serves as INTSORMIL's Prime Site for its collaborative activities in the Central America-Mexico-Caribbean Ecogeographic Zone. Sorghum is an important drought tolerant, risk-aversion crop in Honduras as well as other countries of the region. Sorghum is important as both a food and feed crop. The proportion going into human food varies with the supply of maize, but can be high in years of a poor maize crop. The major food use is as tortillas.

There are two distinctly different types of sorghum grown in the area. One is photoperiod insensitive combine height hybrids or improved varieties which are used primarily by larger mechanized farmers in Central America and over all of Mexico. The other type is called maicillo criollos and these constitute the majority of the sorghum in Central America. These are tall, highly photoperiod sensitive sorghum varieties grown primarily in intercropping systems with maize on small, hillside, often steeply sloping farms on the Pacific side of Central America. The area extends from Southeast Guatemala to Lake Nicaragua, with the heaviest concentrations in El Salvador and Southern Honduras. In Honduras, approximately 56,000 ha are planted annually to maicillo criollos out of a total of 62,000 ha for all sorghums. In all of Central America, out of 330,000 ha of total sorghum planted annually, 235,000 ha are of the maicillo criollos type. The maicillo criollos are planted at the beginning of the long, but often very erratic, rainy season in May, with harvest during the dry season in late December or January.

Production and Utilization Constraints

Many of the constraints to sorghum production and utilization in Honduras are related to the fact that most sorghum is grown by small, resource poor, subsistence farmers on steep hillsides. Major specific constraints are: (1) Low yield potential of the Maicillos Criollos; (2) Insects (fall armyworm, seed and seedling pests, stem borers, midge) (3) Diseases (downy mildew, grain mold, acremonium wilt, foliar diseases; (4) Food grain quality; (5) Drought; (6) Soil, topography and related problems; and (7) Availability of seed of improved types.

Collaboration

The major collaboration of INTSORMIL in Honduras is with the National Sorghum Program in the SRN (Secretary of Natural Resources), and is covered by a MOU signed in 1982. In 1988, a MOU with the Panamerican Agricultural School (EAP) was signed to formalize the officing of Dr. Dan Meckenstock at the school, collaborative activities involving INTSORMIL graduate students and EAP/USAID/SRN collaboration and research activities supported by USAID. The Honduras USAID Mission has made major contributions in local currency to INTSORMIL/SRN/EAP collaborative sorghum research activities. Major collaboration and networking activities has existed between INTSORMIL and the ICRISAT/CIMMYT program in this area as well as with countries in the region. This includes co-sponsoring regional workshops and the annual CLAIS (Central American Sorghum Workers) meetings, participation in regional CLAIS trials, seed and germplasm exchange, and scientist travel. Major networking activities exist with El Salvador (CENTA and UES) and Guatemala (ICTA and INCAP), as well as with Mexico.

Objectives

Overall objectives of the program in Honduras are:

A. Reduce yield loss and increase sorghum production and utilization thru breeding, agronomy, entomology, pathology, and cereal technology.

B. Support sorghum research programs in the region thru:

1. Planning and coordinating research
2. Developing and distributing germplasm
3. Developing and releasing improved varieties and hybrids
4. Joint workshops
5. Graduate study and research
6. On job training

C.Enhance technology transfer thru on-farm trials and seed production.

The program in Honduras is multi-disciplinary and multi-institutional. Specific scientists, institutions, and research activities in Honduras to carry out the collaborative program include:

Breeding

1. F. Gomez - breeder at Choluteca with SRN-all breeding aspects plus the major host-country collaborator.

2. D. Meckenstock - INTSORMIL/SRN/EAP/TAMU breeder at EAP-all breeding aspects plus overall coordination in Honduras and networking in region.

3. D. Rosenow - TAMU disease resistance, drought, germplasm.

4. G. Peterson - TAMU - midge resistance.

5. F. Miller - TAMU - food type varieties and hybrids - F. Gomez (Ph.D.)

Pathology

1. R. Frederiksen - TAMU - downy mildew - other diseases - G. Wall (Ph.D.).

Entomology

1. H. Pitre - MSU - seed, seedling, and foliage pests - M. Castro (M.S. and Ph.D.) and C. Trabanino (M.S.).

2. F. Gilstrap - TAMU - biological control - R.Sequeira (M.S.).

Grain Quality

1. L. Rooney - TAMU - food, tortilla quality - C. Choto (deceased).

Socio - Economic

1. B. and K. DeWalt - UK, 1981-83 - farming systems, sociology, -anthropology, nutrition.

2. M. Futrell - MSU, 1981-82-sociology, nutrition.

3. J. Sanders - PU-agricultural economics, technology transfer.

Agronomy

1. E. Oviedo - intercropping.

2. D. Meckenstock and F. Gomez - on farm trials-extension trials.

Accomplishments

INTSORMIL activities in Honduras began in October, 1981 with the placement of Dr. Dan Meckenstock, INTSORMIL/TAMU sorghum breeder, at Choluteca in southern Honduras. He renovated the La Lujosa Experiment Station near Choluteca, and rejuvenated the Honduran National Sorghum Program.

A landmark study of the sorghum-maize intercropping farming systems in the subsistence farm, hillside agricultural area of southern Honduras was completed and found sorghum to be an important risk-aversion, multipurpose crop. The major constraints to production and utilization were identified.

Sociological and nutritional field research studies in three localities in southern Honduras determined that with the use of sorghum in the diet, it is possible to grow enough maize, sorghum, and beans to meet energy and protein requirements.

Three releases of photoperiod insensitive improved sorghums have resulted from the SRN/INTSORMIL collaborative program. The variety Tortillero was released in 1982, the hybrid Catracho was released in 1984, and the variety Sureño was released in 1985. All are white seeded, food type sorghums that produce good quality tortillas. Sureño is a dual purpose variety with good disease resistance, and grain with resistance to the maize weevil, grain mold, and weathering.

Major emphasis in the breeding program is to improve the traditional maicillos criollos. Improved photoperiod sensitive maicillos breeding lines have been developed and are under intensive station and on-farm testing in Honduras as well as in El Salvador and Guatemala. Some lines appear very promising and should be released soon. Objectives are to improve yield potential, disease resistance, and grain quality.

Hybrid maicillos have shown a tremendous yield advantage over local maicillos criollos varieties. Breeding for hybrid maicillos has become a priority breeding objective. Some B-line improved maicillos have been identified and are being sterilized.

Numerous on-farm trials have been established in cooperation with Extension and USAID to evaluate improved varieties and management.

Seed production has been encouraged and enhanced with an estimated 245,000 pounds produced in 1987 for planting in 1988, of which 151,000 pounds were of the INTSORMIL/SRN developed variety, Sureño.

Breeding for sorghum sudan hybrid forages has been initiated with emphasis on downy mildew resistance.

Grain quality research indicates that sorghum grain with certain traits can produce tortillas of comparable quality to those of maize. Important traits were found to be white grain with an absence of pigment or staining, grain with little or no grain mold or weathering, grain with a thick pericarp to facilitate pericarp removal, and grain which retains a light color in the presence of alkali. Tan plant color and tan or straw colored glumes are also desirable. Quick quality tests and cooking trials have been developed to screen breeding material for these traits.

Diseases of sorghum in Honduras have been identified, and their importance determined through incidence, severity, and loss assessment studies. Diseases of major importance are downy mildew, MDM, grain mold, acremonium wilt, and foliar diseases such as gray leaf spot, rust, zonate, and oval leaf spot. Local and introduced germplasm has been screened for resistance, and resistance sources have been incorporated into the breeding program. Acremonium wilt, a new disease of sorghum, was identified as a potentially serious disease in Honduras.

Downy mildew has been identified as a serious disease in several areas in Honduras. A new, virulent pathotype (P5) was identified in 1986 at Comayagua which attacks most of the commonly used sources of resistance in the U.S. New sources of resistance have been identified. A downy mildew screening nursery has been established at Comayagua.

Studies on biological control of the fall armyworm and stem borers have been completed, and an exotic parasite effective in controlling stem borers was mass reared and released in Honduras and El Salvador and apparently has become established in both countries, but at low numbers.

The complex of insect pests, especially seed and seedling pests, on intercropped sorghum and corn in southern Honduras has been identified, studied, and control strategies developed. Important seed and seedling pests include several soil inhabiting arthropods: white grubs, wireworms, rootworms, ants, and millipedes. The "Longosta", a lepidopterous larval pest complex which ravages young sorghum and maize plants in Southern Honduras in May and June, was identified to include southern armyworm, fall armyworm, and two grass loopers. A sorghum line, AF28, TAM 428, and several maicillos criollos were identified as possessing a good level of resistance (antibiosis) to the fall armyworm. Midge resistant sorghums from the U.S. also show good resistance in Honduras.

Over 200 native maicillos criollos (local sorghums) have been collected from Honduras and neighboring countries. Over 75 have been introduced into the U.S. and 44 have been entered into the cooperative TAES/USDA-ARS Sorghum Conversion Program.

A close networking of sorghum researchers has developed in the Central America, Mexico, Caribbean area as a result of the INTSORMIL activities. In late 1987, a major regional workshop emphasizing research on the maicillos criollos was held in Honduras, cosponsored by INTSORMIL, SRN, and ICRISAT/CLAIS.

Several Honduran and Central American students have been trained, with several conducting their research in Honduras. Francisco Gomez (Honduran) received his Ph.D. in plant breeding at Texas A&M University and INTSORMIL assisted in his placement as a sorghum breeder with the Honduran government (SRN). He now serves as Head of the Honduran National Sorghum Program. Carlos Trabanino (Honduras) received a M.S. in entomology at MSU and is now on the faculty at the Panamerican Agricultural School (EAP) at Zamarano. Other students include: Marco Castro (Honduras) - M.S. and Ph.D. in entomology at MSU - currently working on Ph.D. in entomology; Ronaldo Sequeira (Nicaraqua) - M.S. in entomology at TAMU; and George Wall (El Salvador) - Ph.D. in pathology at TAMU. U.S. students receiving advanced degrees involving research in Honduras include: Miriam Fordham (M.S.), Karen Thompson (M.S.), and Susan Duda (Ph.D.) in sociology/anthropology from UK; Robert Jones (Ph.D.) and Eunice McCullock (Ph.D.) in sociology from MSU; and Robert Jones (M.S.) in entomology from TAMU. Several Central American researchers have been involved in short term training missions to the U.S.

Current graduate students include Miguel Lopez,in Ag. Economics with Sanders (Ph.D.), Hector Portillo and Julio Lopez in Entomology with Pitre (M.S.), and Lorena Lastres in Entomology with Gilstrap (M.S.).

The Future

The overall objectives of INTSORMIL in Honduras and the region remain valid, but shifts in emphasis will occur. Research on the improved maicillos will continue to be the major thrust of the program. Work on hybrid maicillos will increase as will the on-farm testing and agronomy programs. A potential Honduran student has been identified to work on agronomy with Dr. Clegg at Nebraska.

In addition to specific research needs, special emphasis is needed in several areas: (1) Strengthen SRN in research capability and number of collaborators; (2) Strengthen SRN/EAP collaboration; (3) Develop collaboration with the USAID/H LUPE Project; (4) Strengthen regional networking; (5) Improve student identification and training; (6) Enhancing the role of private industry in sorghum improvement and seed production; (7) Develop appropriate seed policies to permit and encourage private seed industry; and (8) Continue to procure USAID/H local currency support. The political and economic crisis in Central America is a powerful force in the region and will continue to impact future INTSORMIL activities.

West Africa: Mali

Dr. L.W. Rooney
Texas A&M University
and
Dr. Moussa Traore
Institute Economic Rurale, Bamako, Mali

Production and Utilization Constraints

Yield stability in sorghum/millet production is of major importance in Mali where food production is marginal relative to population. Low soil fertility, drought, diseases and insects are major contributors to yield instability. Grain is consumed as thick porridge (to) or couscous. Milling properties are critically important. Head bugs and molds adversely affect grain quality, sometimes rendering it unfit for human food. Food quality is critically important for acceptance of new varieties in Mali and in W. Africa because producers consume sorghum or millet at every meal.

Drought resistance and tolerance are affected by low soil fertility. Due to a lack of nutrients, principally N and P, usable water is left in the soil profile even by native range plants in the Malian Sahel. Thus, work continues on the relationship between soil nutrients and water use efficiency in sorghum and millets grown at various fertility levels. To make the best possible progress in grain production in Mali, the development of an effective knowledge of soil properties and management is required. Hence, the strong interaction between TROPSOILS and INTSORMIL has been developed from the inception of the Malian program.

The local sorghums are tall, have extremely loose heads, long black glumes that cover much of the kernel and the stalks bend over at maturity. The kernels often have thick pericarp with a hard kernel. These locals produce low but consistent yields of grain with good seed viability and good food quality. In contrast, the higher yielding improved types are affected by head bugs, grain molds and weathering which together reduce yields or markedly lower planting seed as well as food quality. Then the poor seed quality gives poor stand establishment and low grain yields from the improved types. Stand establishment is a critically important constraint exacerbated by poor seed quality.

Diseases are critical constraints in Mali. Long smut is present in western Mali, anthracnose in southern Mali, and various other foliar diseases. *Striga* is an important constraint and downy mildew of millet is critically important.

Sorghum/millet utilization is an important constraint in good crop years when surplus production significantly reduces grain prices. Transformation of the grain into shelf stable more acceptable food products would provide local employment, reduce importation of cereals and stabilize grain prices. The poor image and tedious labor required for daily processing of sorghum and millet are significant constraints for all sorghum/millet areas in the world.

Collaboration

Institutions/Agencies Involved:

Institute of Rural Economy (IER), Bamako, Mali
Texas A&M University, College Station, Texas
University of Nebraska, Lincoln, Nebraska
TROPSOILS CRSP, Texas A&M University, College Station, Texas
ICRISAT - Mali
ICRISAT
USAID - Mali

The Ciba-Geigy Foundation has financially supported the development of the CINZANA station since 1979. The IDRC donated critically important milling equipment to the laboratory early in its development. The program in Mali is an integrated effort among INTSORMIL, TROPSOILS, ICRISAT-Mali and the IER. The effort is so totally integrated that it is difficult to separate the programs into specific sections supported by any one agency. This vital collaboration among INTSORMIL, TROPSOILS and ICRISAT-Mali continues to provide efficient use of limited resources.

In Mali, each Malian scientist develops research plans cooperatively with their INTSORMIL counterpart which provides for effective research planning, communications and coordination. Major INTSORMIL collaborators

travel to Mali annually during the critical period of the crop year to consult, conduct research and review progress with their counterparts in Mali. Most Malian scientists have been to the U.S. to interact with their counterparts.

INTSORMIL has been in Mali informally since November 1979. An initial Memorandum of Agreement was signed in 1981 with a formal research contract for sorghum and millet production and soil management studies completed in 1984. The program has always interacted closely with ICRISAT-Mali, TROPSOILS and IER. USAID-Mali has strongly supported the efforts morally and financially through additional small allocation for funds to sponsor various activities, i.e., english training for students, short term training/consultants and equipment.

Objectives

1. Introduce new germplasm and evaluate their disease, insect, drought and general adaptation and food quality under Malian conditions.

2. Identify breeding lines for various types of drought and other stress resistance, study the underlying physiological mechanisms through which such resistance is obtained, and utilize the information gained in breeding adapted high yielding varieties.

3. Determine the interaction between soil fertility and efficient water use with different sorghum and millet genotypes.

4. Define factors affecting desirable quality of sorghum/millet and how to select for them in breeding programs.

5. Transform sorghum and millet into shelf stable products with enhanced value and acceptability as food.

Accomplishments

Training

INTSORMIL has provided short term and graduate training for several key Malian scientists. Short term trainee subjects include Physiology, Breeding and Food Technology. The INTSORMIL coordinator, Dr. M. Traore, completed a Ph.D. degree in physiology at the University of Nebraska. Scientists trained in Food Technology, Pathology and Agronomy have returned to Mali and collaborate in the program. Eight graduate students are training in INTSORMIL universities to provide personnel to continue the programs. They include Agronomy, Breeding, Physiology, Soil Fertility and Soil Chemistry.

Technical assistance to develop the Cinzana station, to map the soils and obtain detailed physical and chemical analysis of the soil profiles has been provided jointly with TROPSOILS.

Equipment and short term consultants were supplied to establish and install sprinkler systems and screening procedures for drought tolerance research at Cinzana.

Germplasm from U.S. breeders and the sorghum conversion program has been incorporated into the Malian breeding programs.

Sorghum and millet postharvest technology systems in Mali were documented in 1979 and strategies for evaluating the quality of cereals, especially sorghum, for thick porridge (tô) were devised. Mini tests for testing milling and tô properties were developed and currently are used to evaluate breeding materials.

Sorghum dehulling properties were defined by combined village trials in Mali and laboratory work in the U.S. Sorghum with hard endosperm and thick pericarps was definitely preferred for traditional hand pounding.

Equipment for the new food technology laboratory was provided and personnel were provided short term training programs in the U.S. Some key milling equipment was provided by I.D.R.C. of Canada during the early stages of the program.

Pearl millet quality is affected most by variation in dehulling characteristics. The size and shape of pearl millet affects dehulling properties significantly. Souna pearl millets in general have reduced yields of decorticated grain. The tô does not vary in quality among millet cultivars as much as among sorghums.

The importance of head bugs on food quality of many introduced sorghums was first recognized in Mali. Head bugs are critically important factors affecting sorghum yields and reducing food quality significantly in West Africa. Malisor-84-7 appears to have some resistance to head bugs perhaps because of its hardness.

A strong program in Agro-physiology has been developed in Mali under the direction of Dr. Moussa Traore in collaboration with Dr. Sullivan (NE-115). IN-

TSORMIL financing is supplemented by a USAID-PSTC grant to Dr. Traore as P.I.

Accomplishments to date are:

1. A screening technique using charcoal pits for seedling stage drought resistance is used on all breeding materials including locals, introductions, new varieties and crosses.

2. Abscisic acid (ABA) seed treatment improves the seedling survival rate of some sorghum genotypes. Sorghums responding to ABA treatment generally have poor seedling survival rates. Thus response to ABA may be a useful screening test. Work continues in this area.

3. A potential new technique for determining post flowering drought resistance in the off season is being developed.

4. Differences in planting seed quality exist in Mali. Seed viability differences significantly confound the results of performance trials etc. Seeds should be produced in the off season or at a location where seed quality is likely to be good, i.e., Bema. Seed quality of improved types is a major constraint.

5. In general, local varieties and well adapted sorghums outyield others through higher plant densities. Seed quality in relation to stand establishment is critically important especially in harsh environments. Head bugs and molds significantly affect seed quality as well as food quality.

Progress has been made to determine factors affecting the "soils problems" in Mali through joint INTSORMIL/TROPSOILS collaboration. Some "dune varieties" originating in Niger appear tolerant.

Soil nutrient water relationships are critically important. Lack of nutrients severely limits the ability of plants to use available soil moisture. Phosphorous and nitrogen are critical.

Seven improved sorghum lines from the Malian program have been released. These Malisor lines 84-1 to 84-7 have different maturities and characteristics for use in specific regions of Mali. Malisor 84-7 has shown some advantages in multiple cropping systems and is very hard with some tolerance to head bugs. It has outstanding milling and tô quality. Others better adapted to northern Mali are more useful for couscous, the major food system in that area.

Some Malisor varieties are grown by farmers under different names especially in western Mali.

An effective interdisciplinary team of Malian scientists now exists in Mali. A spirit of cooperation exists among the key scientists involved which will lead to many more significant accomplishments in the immediate future. Ten years ago that was not the case.

These accomplishments are the results of the combined efforts of INTSORMIL, IER, ICRISAT-Mali and TROPSOILS. It has truly been an integrated effort involving multidisciplines. Especially in the early stages, key leadership was provided by ICRISAT-Mali.

The Future-Building on Accomplishments and linkages

Objectives

The current objectives are still valid; but they can be refined to focus on more specific opportunities that can be attacked because of additional strengths in Malian IER personnel. For example, work on pathology is currently being expanded because Mr. Diourte, IER pathologist, returned to Mali after M.S. training. He worked closely with the breeding program this past crop year and interacted with long smut research being done in Niger. Interaction with INTSORMIL pathologists is planned.

Research on the head bug grain mold complex will be expanded by an integrated approach of entomologists, pathologists, breeders and food technologists. It includes IER, INTSORMIL and ICRISAT. Head bugs are a critically important constraint limiting sorghum improvement in Niger, Burkina and other areas of W. Africa. Mr. Doumbia IER entomologist is available to collaborate with Dr. Teetes.

Millet breeding will be strengthened by interaction of Andrews through Mr. Karim Traore who is working on a M.S. at the University of Nebraska.

New Strategies

The USAID-PSTC grant terminated in 1988 and the ICRISAT/Mali bilateral program terminates in 1990 which will cause considerable change in operations and more demands on an INTSORMIL budget that is inadequate to meet current demands. Continued funding of an AID supported program beyond 1990 is essential to harvest the fruits and basic infra structure of the previous ten years of effort.

We believe it is necessary to design the next program (Phase II) to capitalize on strengths. It is clear that the ICRISAT Sorghum Center for the subhumid tropics located at Samako near Bamako will not adequately support the National IER program during this critical Phase II development. Perhaps, a program combining INTSORMIL, TROPSOILS and ICRISAT could be designed to build on the existing infrastructure including the farming systems project.

The next program could focus on the transformation of sorghum and millet into new food products based on low level village scale processing technologies. The evaluation and testing of SORI and MILRI acceptability is an example. If the products prove acceptable, after additional laboratory and village trials the economics and marketing aspects will require evaluation. To be successful, an adequate, consistent supply of grain of the right quality would be required. Thus, the need for improved food quality varieties and inputs to produce adequate supplies of grain would require continuation of essential parts of the current program objectives. A constant supply of grain would be the basis for expanding the poultry feeding industry.

Training Requirements

There is a significant need for additional trained personnel in Mali. After evaluation of existing personnel and current trainees, the following areas for training were identified: Food Technology (1), Physiology (1), Soil Science (1) Agronomy (1), Breeding (2), Cereal Quality (2), Entomology (2), Weed Control (2) and Pathology (2). The Food Technology program will urgently need more trained personnel with skills in chemistry and processing technology if progress on utilization is expected.

Equipment

The current INTSORMIL vehicle will need replacing in 1989 or 90. The laboratory will require significantly more equipment. Priority should be given to processing equipment and to develop chemical analyses in conjunction with other laboratories. A need exists for a physiology laboratory at the Cinzana station.

Networking

Malian personnel have interacted with the Burkinan Sorghum/Millet and Corn research program through Nursery Field Days in Burkina. Dr. Da, leader, Burkinan Cereals Research, spent a week in Mali in 1988.

Dr. Da has 15 scientists in his interdisciplinary teams located at three locations in Burkina. The headquarters at Bobo Dioulasso is relatively close to Bamako. His team contains entomologists, pathologists, agronomists, breeders and a food technologist. The problems in Burkina are nearly the same as those in Mali. Over the long term, the needs and advantages of cooperation coupled with personnel who like and respect each other encourages collaboration. A modest amount of funds from international agencies could greatly facilitate this cooperation.

The key to continued success in Mali is continued training of key personnel and support for them when they return to Mali. The INTSORMIL program had provided continuing scientific support and modest financial support to catalyze efficient use of existing funds in Mali.

West Africa: Niger

Dr. John Axtell
Purdue University

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 1989/90.

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 tô 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 re-

search information exchanges have taken place through INTSORMIL scientist visits to Niger.

Continual dialogue between INTSORMIL and INRAN scientists must continue over several years in the designated research areas. Joint research planning and joint nursery visits in both the host country and U.S. are essential.

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 in 1989 as in the past. We are hopeful INRAN will appoint an INRAN scientist in 1989 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 exotic 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 just 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 known, we will be able to alter the time of cowpea planting and hence shading level, to increase overall production of the intercropping systems.

East Africa: Sudan

Dr. Allen W. Kirleis and Dr. Gebisa Ejeta
Purdue University

Background Information

Sudan is the largest country in Africa with about 2.5 million square km of land. It covers regions of vast ecological variation ranging from a typical desert climate in the North with little or no precipitation to tropical forest zones of the South region where precipitation up to 1500 mm is often recorded. With a significant portion of Sahelian Africa occupying Sudan, efforts to produce food for the poorest of the poor in semi-arid tropics is of major importance.

Sorghum is grown throughout the country where it is possible to raise a crop; it is produced in all provinces of the country, from the arid region of the North to the high rainfall climate of the Southern region. However, the bulk of the crop is grown mainly in the Central Clay Plains which include the provinces of Kassala, Gezira, Blue Nile, White Nile and Southern Kordofan. This area which is essentially the sorghum-belt of the country accounts for over 65% of the total sorghum production in the country. Over 90% of the total sorghum acreage is under rainfed conditions and most of that is mechanized.

Millet is the second most important cereal to sorghum and is mainly produced in Western Sudan under rainfed conditions. In the western provinces of Darfur and Kordofan about 1.6 million ha is devoted to millet with an average yield of 656 kg/ha.

The first sorghum improvement program in Sudan came into existence in 1952 with the establishment of the Central Rainland Research Station at Tozi. The national responsibility to undertake research on all aspects of sorghum and millet improvement today, resides with the Agricultural Research Corporation (ARC). The ARC is a semi-autonomous organization which comes directly under The Ministry of Agriculture. It deals with all research pertaining to plant and animal production and utilization. Several research stations, research centers, and sub-stations, spread throughout the country, are directly administered by the corporation headquarters at Wad Medani. The Gezira (Wad Medani) and Abu Naama Research Stations (on the western side of the Blue Nile about 200 miles south of Wad Medani) conduct research on sorghum. Where as stations at El Obeid and Kadugli (located in Western Sudan) conduct research on sorghum as well as millet.

Major Constraints of Sorghum and Millet Production in Sudan

The major constraints of sorghum and millet production were previously covered in a presentation by Dr. Hilu. These constraints will, therefore, only be listed in outline form here.

A. Lack of good drought tolerant sorghum and millet cultivars to meet the need in low rainfall areas of Sudan.

B. Lack of available sorghum and millet cultivars tolerant to *Striga*,diseases, insects, and bird pests.

C. Agronomic constraints.

- Lack of improved methods of land preparation for maximum moisture utilization.
- Lack an understanding of the nutritional requirements of sorghum in the mechanized farming region.
- 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.

D. Lack of cooperatives and credit facilities to small sorghum and millet growers.

E. Lack of combinable high yielding sorghum cultivars with excellent food qualities.

Linkage and Coordination with Non-ARC Research Program

The ARC has a close association with the two Sudanese Universities offering degrees in Agriculture. The Faculty of Agriculture of the University of Khartoum at Shambat is the oldest of all institutions giving formal training in agriculture. Most of ARC scientists are graduates of that institution. A number of ARC scientists have contributed in joint feasibility studies with University members. The University relies heavily on ARC in assessing and modifying its curriculum. In addition research workers are often invited to teach courses and act as external examiners. Other ARC scientists assume a more active role as co-supervisors to graduate students.

The University of Gezira, located in Wad Medani was established in 1976. The Faculty of Agricultural Sciences at the beginning was, almost entirely made up of ARC scientists working at the University either on secondment or as part-timers. In fact ARC scientists are, officially recognized as teaching faculty for some graduate courses. In addition graduate students conduct their thesis research at the GRS under the direction of an ARC scientist. Some of these students are working on sorghum and Striga related problems.

Linkages With Other National Agricultural Research Projects in Sudan

German Agency for Technical Cooperation (GTZ). GTZ functioned in Nuba Mountains area (1980-85) and the main emphasis of this Agency has been on seed bed preparation and rotation. The GTZ program is headquartered in Kadugli. This agency normally produces a final report and distributes it to scientists in ARC.

The Canadian Farm Mechanization Project. The Project works with the Mechanized Crop Production Corporation conducting adaptive research on rainfed sorghum production.

The Agricultural Services Department, Adaptive Research Division of Hunting Technical Services Limited. This firm started functioning in 1981 to serve the Jebel Marra area in West Sudan with headquarters at Zalingi. Adaptive research of Hunting covers a diversity of activities on field crops, horticultural crops, forestry, credit and marketing, cultivation system and processing. Hunting scientists are concerned with sorghum and millet as well as a number of other crops. Their studies on sorghum and millet involved variety tests, national variety trials, agronomic studies, pests and weed control in addition to testing entries obtained from international organizations for a variety of traits. The major emphasis is devoted to extension with more than 30 active subcentres working directly with farmers.

Linkages With Other International Agencies

The ARC has a long history of linkages with regional and international agricultural research organizations. Prior to 1972 the ARC received international variety trials from the Food and Agriculture Organization and Purdue University but the Arid Lands Agricultural Development (ALAD) was the first international organization functioning in the Sudan. ALAD initiated a large introduction of a wide range of sorghum germplasm with good yield potential and good grain quality characteristics. The program also promoted increased interaction and exchange of germplasm with other groups - the Ethiopia Sorghum Improvement Program, Purdue University and Texas A&M.

In addition to their research programs, scientists from ALAD trained some of the ARC technical staff from the breeding section both in country and at the Centre in Beirut. A number of ARC scientists also received advanced graduate training in the U.S. on Ford Foundation scholarships through ALAD.

The International Crop Research Institute for the Semi Arid Tropics (ICRISAT), financed by the United Nations Development Program, established a cooperative program for sorghum and millet improvement in the Sudan in 1977. The Institute had two resident scientists; a sorghum breeder stationed at Wad Medani and a millet breeder stationed at El Obeid in Western Sudan. The assistance received from ICRISAT terminated in 1985. A number of significant achievements were accomplished from the cooperative program.

- Through the ICRISAT program buildings, equipments, transport and operating costs were furnished for the ARC breeding section. Moreover, the program was, in part providing financial support to the plant breeding section and other cooperating scientists.

- The organization sponsored workshops and attendance of Sudanese inside and outside the country. Furthermore, field days were annual events of ICRISAT staff at the station.

- The ICRISAT sorghum breeder introduced a popular hybrid sorghum (HD-1) and developed

advanced breeding lines while working in Sudan.

- ICRISAT has helped train Sudanese personnel at various levels.

- ICRISAT sorghum breeders collaborated with IDRC Sudanese workers on *Striga* and identified genotypes with good levels of *Striga* resistance.

The International Development Research Centre (IDRC). IDRC funded a joint *Striga* research program between ARC and the University of Khartoum Faculty of Agriculture. The *Striga* program was active from 1978-1985. The IDRC program was a multidisciplinary effort involving breeders, biochemists, botanists, agronomists, and biologists. The program included both research and training components. Research accomplishments from the project are listed below.

- Selection of *Striga* tolerant sorghum and millet cultivars.

- Cultural practices for controlling *Striga*, e.g., fertilization, rotation, watering and population density.

- Chemical *Striga* control using herbicides, ethylene and other germination stimulants.

- Studies on the biological control of *Striga* insects.

The International Sorghum Millet Collaborative Research Support Program (INTSORMIL). A memorandum of agreement between INTSORMIL and the Sudan was signed in 1980. Since then exchange visits of U.S. and ARC scientists has taken place. Activity of the program include breeding, weed research, plant diseases and physiology at the GRS. The Food Research Centre which is part of ARC is also involved in the INTSORMIL program. The program functions on collaborative basis involving U.S. and Sudanese scientists for the common goal of improving the productivity of sorghum and millet in the country. Thus far, the Sudan program has been mainly confined to sorghum. During its short active period in Sudan INTSORMIL has made significant contributions to the ARC sorghum and millet research program. Specific contributions are listed in a late section of this paper.

General Objectives of INTSORMIL/ARC Programs:

The INTSORMIL/ARC Sudan cooperative program for sorghum and millet improvement and utilization was established in 1980 with the overall objective of cooperating with and assisting in the strengthening of the national research efforts in the development and utilization of improved cultivars of sorghum and millets. The program has been guided by the following specific project objectives.

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 (longsmut, 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 recurrent 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.

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 response to moderate nutrient supply and/or soil moisture conservation.

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.

Plant Pathology

- Screening sorghum cultivars for charcoal rot tolerance under imposed stress and in drought areas.
- Screening cultivars for anthracnose 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.

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 controlling *Striga* on sorghum.

Entomology

- Identify chemical insecticides with outstanding performances to alternate with Sevin, the only chemical currently recommended against sorghum stem borers.
- Identify sorghum lines with resistance to stem borers.

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.

Economics

- Evaluate the potential impact of Hageen Dura-1 and other new technologies (new cultivars, fertilization, crop rotation, etc.) to increase sorghum production.

Library Improvement

- To provide ARC libraries with current sorghum and millet reference material.

Major Accomplishments in Sudan 1980-1987

INTSORMIL activities in Sudan began in November 1980, with the signing of a Memorandum of Understanding with the Agricultural Research Corporation (ARC) and the University of Khartoum, Faculty of Agriculture. This agreement led to the placement of Edward B. Reeves and Timothy Frankenberger (University of Kentucky Economic Anthropologist) in El Obeid from July 1981 through August 1982. These social scientists carried out farming and marketing system studies in 15 villages located within 50 km of El Obeid to collect baseline data for the Western Sudan Agriculture Research Project, Kordofan Regional Ministry of Agriculture, and INTSORMIL. They identified wind erosion, pests and diseases, low soil fertility and inadequate rainfall as the most important natural constraints limiting crop production in the region. To combat inadequate rainfall, they recommended the introduction of early-maturing drought-resistant varieties of present crops as well as new drought-resistant crops.

In March 1982, scientists and research administrators associated with ARC were interviewed and documentary data on research plans were collected by Larry Bush and William Lacy (University of Kentucky). They found that the ARC scientific community is well trained. The research conducted by ARC scientists is generally of an applied nature. They also found that while ARC scientists consider financial support and operating supplies and

material the most important resources for their work, these same resources were also generally regarded either as the least adequate or often inadequate. Many of the findings from this study were used to develop the ARC/INTSORMIL cooperative scientist to scientist research program.

During the 1982 through 1984 cropping seasons Tareke Berhe (Kansas State University) carried out agronomic research in the El Obeid area of North Kordofan. This agronomic work targeted many of the natural constraints identified by Reeves and Frankenberger. Major accomplishments of the research work included; (1) identification of an early maturing millet variety (Ugandi, developed by ICRISAT/Sudan program) having good yield potential with limited rainfall, and bristles rendering protection from the birds, mice and grasshoppers and (2) establishment of an on-farm sorghum/millet testing program in cooperation with the Kordofan Regional Ministry of Agriculture. This on-farm testing program continues to be used by the Regional Ministry today as a measure of introducing new crop varieties and technologies to farms.

In collaboration with scientists at ARC and INTSORMIL, ICRISAT's Sudan cooperative breeding program released the first sorghum hybrid (Hageen Dura-1) in January 1983. Hageen Dura-1 (HD-1) is a superior hybrid with yields of over 150% of those of improved local varieties under irrigated and rainfed conditions. HD-1 possesses several important attributes including high yields, drought tolerance, and good grain quality characteristics that helped its rapid spread and wide acceptance by farmers.

The Food Research Centre has since demonstrated that HD-1 grain is easily decorticated. Thus, it produces a high yield of white sorghum flour suitable for making good quality bread with a composite flour containing up to 40% HD-1 decorticated flour.

INTSORMIL sponsored a workshop on hybrid sorghum seed at Wad Medani in November 1983. Detailed discussions at the workshop, involving scientists, administrators, policy makers and interested private entrepreneurs, focused on effective marketing and government policy considerations that would encourage seed industry development in the Sudan. Concrete recommendations for developing a seed industry were submitted to the Government of Sudan.

A study of the communication of agricultural information in Sudanese villages was done by C. Milton Coughenour (University of Kentucky) and Saadi M. Nazhat (graduate student) around El Obeid in 1984. They found that INTSORMIL's farm trials conducted by Tareke Berhe provided an excellent means of informing farmers about the characteristics of new sorghum/millet varieties. They also learned that information about an innovation spreads among Sudanese farmers much like that found in more developed communities (an S-shaped growth curve over time).

The ARC/INTSORMIL research program at the Gezira Research Station has been designed to strengthen ARC sorghum/millet research and training activities. These have been combined to facilitate attainment of the long-term ARC objectives. Although the program started in 1980, INTSORMIL funds were not transferred to ARC until 1984. The primary disciplines involved in ARC/INTSORMIL collaboration are breeding, stress physiology, plant pathology, entomology, *Striga*, cereal quality and agricultural economics. Some of the major accomplishments from the ARC/INTSORMIL program are listed below.

Cooperative ARC/INTSORMIL crop physiology and breeding work on drought tolerance of sorghum has led to a better understanding of crop adaptation to stress. Sorghum lines with pre-flowering stress tolerance were found to accumulate significantly higher concentration of certain metabolic osmolytes than drought susceptible cultivars. Sudan is an excellent location for screening for drought stress. Some of the best new sources of drought tolerance for use in the ARC and U.S. sorghum improvement programs have come from screening INTSORMIL germplasm in Sudan.

In 1981/82 over forty Sudan sorghum varieties were collected in the Kadugli and El Obeid area and introduced in the U.S. for conversion and breeding lines. In addition, a number of elite Sudanese breeding lines have been selected and transported to the U.S. for the same purpose. These lines should be very useful in broadening the sorghum germplasm base available in the U.S., and as sources of desirable grain quality traits.

An inoculation technique for long smut has been developed in Sudan. This long smut inoculation technique provides sorghum improvement programs with a method of evaluating germplasm for host resistance and is the first of its kind in the world. The inoculation technology was extended to Niger during the 1987 crop year. Work in Sudan on the histology of the infection has shown that long smut is not a seed born pathogen and can only infect sorghum flowers.

Work on the food quality of sorghum by ARC/INTSORMIL has shown that a fermentation process, commonly used to prepare most Sudanese sorghum foods, improves the protein digestibility of cooked sorghum products. This work has led to a better understanding of the factors that influence sorghum protein digestibility and work is now in progress to apply this new knowledge to improve the digestibility of sorghum when used as an animal feed in the U.S.

The Future

New Strategies To Accomplish Objectives

INTSORMIL must continue to develop a multidisciplinary sorghum research team in Sudan. In collaboration with ARC scientists, INTSORMIL must strive to develop an integrated, multidisciplinary research team addressing sorghum improvement and utilization activities in the areas of breeding, pathology, entomology, agronomy, *Striga*, food quality, and economics. In addition INTSORMIL must participate and encourage the development of inter-institutional cooperation involving other agencies, e.g., IDRC, USAID/Khartoum, etc.

INTSORMIL should expand the millet improvement and utilization activities in the SUDAN. A cooperative ARC/INTSORMIL millet breeding project was established in 1988 at the El Obeid Research Station. However, increased efforts on the part of ARC and INTSORMIL are required to accelerate the breeding research activities and expand the millet work into areas of entomology, agronomy, *Striga*, and food quality. This is needed as there is considerable potential for increasing millet production in Western Sudan through development of better cultural and pest management practices and identification of higher yielding drought tolerant millet varieties with good food quality.

Additional funding will be necessary just to continue the present level of INTSORMIL activity in Sudan. The INTSORMIL Sudan budget has remained the same since 1984/85. Thus, substantial funding increases will be needed to expand future INTSORMIL activities in Sudan. One possibility for additional funds is from the INTSORMIL core budget. A second possibility currently under consideration for securing additional funds for INTSORMIL/ARC Sudan activities exists through a USAID/Khartoum buyin program. The mission buyin program remains a good possibility provided INTSORMIL continues to align their sorghum/millet research objectives to conform with USAID Khartoum Strategic Objectives for its agricultural project, which are:

- Raise income of the rural poor farmers by improving productivity of the cultivated crop particularly the rain-fed traditional sector in Western Sudan.

- Improve food security by improving food grain productivity of the rain-fed traditional and rain-fed mechanized system through improved technology, improving selected parts of the road network and by encouraging better post-harvest storage at village level.

- Protecting natural resources by developing improved technology and management system to encourage farmers, particularly in the rain-fed sector, to maintain a sustained agricultural system.

Session IV: Training, the Foundation of Institutions and Collaborative Research

- INTSORMIL Accomplishments
- Training Strategies

Session Chair: Dr. Gebisa Ejeta

Speakers: Dr. Tim Schilling
Dr. Lee House

INTSORMIL Student Training: Accomplishments

Dr. Timothy T. Schilling
Associate INTSORMIL Program Director

As you know, and have probably already heard several times during this conference: The major thrust of any CRSP is the generation of solutions to priority problems through research. However, this goal is not really all that different than that of the IARCs, nor many of the AID Mission projects or other foreign funded agricultural development projects. What makes the CRSPs unique is our concomitant objective to enhance national research system capabilities in our prime sites through long-term, collaborative US to Host Country Institutional linkage. Although we generally refer to this linkage as being "Inter-Institution" it is in fact, a relationship among people: scientists from American Universities and scientists from host country national research institutions. When we talk about "Institution-Building", what we really mean is "People-Building"; After all, rarely can we pin the success of a research endeavor solely on the presence of glamorous laboratories. Rather, our successes are attributable to the concerted effort among people.

It is evident that over the past nine years, a very positive and natural change has occurred within INTSORMIL. It has allowed us to achieve a greater level of success than other similar programs. The change I am referring to is the gradual establishment of strong professional and personal relationships between our American University scientists and their Host Country Counterparts. Nowhere is this relationship stronger and more productive than when initially established through an INTSORMIL graduate student training program.

One such relationship of which I am familiar, although there are many, is that between Dr. Charles Sullivan, Physiologist at Nebraska, and his former student, Dr. Moussa Traore, Physiologist at IER in Mali. Upon completion of Moussa's training at Nebraska, he went back to Mali and headed up the Sorghum Agronomy/Physiology section at IER. He continues to work in this capacity and has also assumed additional responsibilities as INTSORMIL's Mali Coordinator.

On a professional level, the accomplishments of this joint Nebraska-Mali/Physiology project are both numerous and outstanding. These accomplishments are attributable to the interaction which continues between these two scientists. These relations and others like it have played and will continue to play a key role in the success of INTSORMIL and the enhancement of NARS.

The two basic elements that make a relationship like this productive and effective are:

1) A Continuous Dialogue - These two scientists communicate frequently, on a monthly and sometimes even weekly basis by Electronic Mail and International Post. Because of this dialogue, they are able to avoid typical problems due to great gaps in communication.

2) Peer equality - Both scientists feel as if they are working together on a priority problem of mutual interest. There is no Genius-to-Idiot quality or stigma in their relationship. Professional or Personal.

These two scientists and all others who have made such a valiant effort to collaborate are to be commended. This is what makes a CRSP work like no other Agricultural Development Program can.

Not surprisingly, as I said earlier: the best relationships are almost without exception, those established initially through a graduate training program. I think this is true simply because it allows both people a considerable amount of time (2-4 years) to get to know each other.

Because of this, INTSORMIL's graduate training program is extremely important to the success of the CRSP and to our mutual benefit in sorghum and millet research.

I would now like to dissect our training program and look at what we have done; to whom, where, and how.

Table 1 shows a total of 527 students or participants have been trained since the beginning of INTSORMIL in 1979.

Table 1. INTSORMIL Student Training by Origin and Gender.

	Men	Women	Total
U.S. Students	107	59	166
Non-U.S.	289	72	361
Total	396	131	527

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361 of those were international students and the remaining 166 were from the US. It is therefore evident that INTSORMIL places a priority on training students from other countries.

Table 2 shows that about half of our training is to the Ph.D. level and the other half to the M.S. level.

Table 2. INTSORMIL Student Training by Degree

Degree/Type	Number
Ph.D.	226
M.S.	208
B.S.	21
Short Term Technical	44
Post Doctoral	20
Visiting Scientist	8
Total	527

Short term technical training has often been designed specifically for enhancing particular skills like learning an inoculation technique, breeding method, etc. A total of 20 post-doctorates have been funded and a few visiting scientists have been provided U.S. tours of agricultural research in sorghum and millet.

Not all these training participants, however, are funded by INTSORMIL.

Table 3 presents the statistics on training funding sources.

Table 3. INTSORMIL Student Training by Funding Source

Source of Funding	Number of Students
INTSORMIL	242
SADCC	43
Other	242
Total	527

About one half the total, or 242 students, over the last 10 years were funded by INTSORMIL which means project funds were utilized to provide assistantships.

Forty-three students were funded by the SADCC program which began in 1985: Dr. Lee House will be talking more about this program shortly, but basically INTSORMIL has an agreement with ICRISAT to organize and manage the advanced degree program for the regional project. At the end of the first phase, INTSORMIL successfully placed 43 SADCC students in appropriate universities for advanced long-term training

The other half, or 242, students were funded through other sources. These have traditionally been students from other AID Mission programs, foundation scholarships, and private sources. These students work on INTSORMIL projects but come from countries where INTSORMIL does not have an active program. However, it is a very beneficial program for them because they become acquainted with INTSORMIL and links are sometimes formed which blossom into collaborative programs.

Also some of these students are American and it gives them an opportunity to become acquainted with international agriculture and programs like INTSORMIL.

Now, lets look at our budget by line item and see what it tells (Table 4).

Table 4. INTSORMIL Budget by Line Item

Expense	% Total
Equipment	5.0
Fringe Benefits	4.9
Graduate Students	12.4
Other Direct Costs	5.1
Other Salaries	6.9
Overhead	23.4
Post Doctorates	8.0
Staff Benefits	2.0
Supplies	6.9
Travel	12.7
University Staff	12.6

As you see, we spend more money on student training through assistantships than practically any other single budget item. 12.4% of our total budget in Fiscal 1987 was spent on graduate training and these figures are almost identical for Fiscal 1988. These figures represent the cost of assistantships and not the other related costs such as transportation, research equipment, conferences, etc. In effect, 12% is a conservative estimate, its really more on the order of 15-17%. In any case, the figures show that we view student training as a very important, necessary investment.

While observing the cost of our student training program, I should point out that since the beginning of the program in 1979, INTSORMIL has spent 6 million to train about 242 students. For those of you familiar with student training, some quick arithmetic should tell you that these figures are extremely cost effective: For

USAID to train the same number of students through OIT or through USDA it would cost about 15 million. That's almost three times what it cost us, not including management fees. In addition, INTSORMIL provides a level of high quality, personal training which is almost non-existent in most training programs.

If we look at where our priorities have been concerning our training efforts by discipline we see that of the 527 INTSORMIL related students (Table 5) most of our participants have been trained in breeding and agronomy followed by food science, plant pathology and entomology.

Table 5. INTSORMIL Budget by Discipline vs Students Trained by Discipline

Discipline	% Total Budget	%Total Students
Agronomy	17.7	25.5
Breeding	40.7	25.6
Economics	3.3	2.1
Entomology	8.0	9.7
Food Science	11.4	20.3
Plant Pathology	5.6	11.2
Other	5.9	1.0

You will note however, that we are very deficient, in our training in the social sciences. Only, 2% or 6 students have been trained in agricultural economics; this is very slim considering the importance of agricultural economics in farming systems research and marketing. Also, sociology represents a very small piece of the pie considering its importance when introducing new technologies into vastly different cultures. We, therefore need to make greater efforts in identifying and recruiting students interested in these fields.

However, the way we are currently structured, we cannot expect to train individuals in certain disciplines, like ag economics and sociology if those disciplines are not being sufficiently supported from AID Washington. In order to train students in these areas, projects must be adequately funded.

Note that in Table 5, those disciplines which are so severely undertrained are not, surprisingly, those which are shown to take the least of the budget pie.

We see that for most practical purposes there is a direct correlation between % Students Trained by Discipline and % Total Budget a Discipline commands. The exceptions to this trend are agronomy and food science which devote on an average a greater relative proportion of their budget to training. Breeding, on the other hand devotes on an average relatively less of their budget to training.

Finally, INTSORMIL's training efforts are probably best summarized by the following world maps. Note that in Illustration 1, each dot represents a student trained between 1979 and 1984.

We can therefore quickly observe that most of our training effort during the first five years of INTSORMIL was concentrated in Mexico, Colombia, East Africa, Botswana, India and the Philippines. Secondly, we can easily see that training among the disciplines of breeding, agronomy and food science were equal at about 60-70 students each. In addition, you will note that our training effort also reflects the importance of sorghum and millet throughout the world.

In comparison, Illustration 2 shows all INTSORMIL related students trained between 1979 and 1989. Now you will note that a significant change has occurred: A much higher proportion of African students are now being trained. Especially in West and Southern Africa. This trend reflects AID's response to the urgent need for training in these important sorghum/millet areas of Africa which were brought to the attention of a greater audience in 1984 due to the drought. Also a higher proportion of students from Latin America are being trained duringthe second five year phase. On the other hand, training in India and the Philippines has almost been terminated due to the absence of projects in those countries after the budget cuts of 1984 and 1985.

In conclusion, I hope that I have presented you with a clear picture on 1) how important student training is to our broader program objectives 2) how extensive the INTSORMIL program is and 3) how successful the program has been.

The only area which warrants some improvement in the 1990s is the orchestration of our training efforts through a dedicated and defined system. A system which allows INTSORMIL to fit into the larger Manpower Development Schemes in the countries and regions where we work.

In the near future we should formulate a strategy, in concert with USAID Missions and their plans, and Host country research institutions and their needs to ensure the highest quality of training without duplication. I look forward to working with our Board, EZC and TC on the development of this system.

Illustration 1. INTSORMIL Student Training

1979 - 1984

Illustration 2. INTSORMIL Student Training

1979 - 1989

Strategies for Manpower Development in Sorghum and Millet Improvement in the SADCC Region

Dr. L.R. House
Executive Director for ICRISAT in Southern Africa

Introduction

As I look back at my stay in India during the 1960's, two significant events took place in their agriculture. One was the introduction and exploitation of germplasm in an array of important crops. This has contributed in moving the country from a deficit situation to one of sufficiency and export. The second, and in the long term possibly the more important, was the development of an educational program that brought one or more agricultural universities to each of the states of the country. This has contributed a creative scientific capability that sustains their agricultural development.

The focus of the SADCC/ICRISAT program for the improvement of sorghum and millets has as it's primary objective the strengthening of national research capability. There are three strategies to approach this objective: research, education and training, and service type activities (strengthening experiment stations, off-season nursery, etc.).

The education training component of the program is substantial. It's contribution in the SADCC Region is appreciated.

Objective of the Education/Training Program

For the sorghum and millet improvement program for SADCC, the objective of the education program was to have, after ten years, the relevant team of scientists in each national program. Numbers to be educated were twice the required number accepting attrition along the way. The general objective was clearly stated and serves as a useful guide.

To begin to implement the educational program Drs. Panagides and Eriesen came to the region and developed a strategy in consultation with national programs. There was some modification and approval by the then Coordination Technical Committee (CTC) with two stipulations: that they would not hold exactly to either the distribution of education across disciplines or to the timetable. They were recognizing both changes in their needs for trained manpower and the availability of people at a particular time in a particular discipline. In short, flexibility was deemed desirable. Significantly, the program of education was developed with national authority and carried their approval.

The education/training component of the program is substantial. The first five years of the sub contract with INTSORMIL for education has involved 40 people at a cost of 2.7 million dollars. It is anticipated that 46 people will go for degree studies during the second five year period at a cost in the neighborhood of six million dollars. Accomplishment to date is reflected in Tables 1 and 2.

Table 1. SADCC Training by Discipline

Discipline	BSc	MSc	PhD	Total
Ag Economics	0	1	0	1
Agronomy Physiology	7	6	1	14
Entomology	0	1	2	3
Food Technology	0	1	0	1
Breeding	0	6	4	10
Pathology	0	3	3	6
Rural Extension	0	0	1	1
Seed Technology	0	0	1	1
Soil Fertility	0	1	0	1
Total	7	19	12	38

Thirty-eight students are involved in B.Sc., M.Sc. and Ph.D. programs across the array of relevant disciplines: breeding, agronomy, crop protection, crop utilization, economics, seed production, and extension. This is a broader array of disciplines than originally anticipated.

Table 2. Current Status of SADCC Training Component by Country and Degree as of September 1988.

Country	BSc	MSc	PhD	ET	Total
Angola	0	2	0	0	2
Botswana	1	1	1	0	3
Lesotho	2	3	1	0	6
Malawi	0	3	6	0	9
Mozambique	0	1	0	0	1
Swaziland	0	1	1	0	2
Tanzania	2	3	1	1	7
Zambia	2	4	0	1	7
Zimbabwe	0	2	1	0	3
Total	7	20	11	2	40

The strategy for education in the various SADCC countries was designed anticipating the needs of each country. The distributions presented in Tables 1 and 2 deviates some from the original plan. Students from Mozambique and Angola are recently participating.

The program implementation has basically been limited by the availability of people. I might add several points. Initially we received USAID authorization to include candidates for the B.Sc. This has now pretty much changed so that all B.Sc. training should, in as much as possible, be undertaken in the region. There has also been the question of the adequacy of the M.Sc. vs the Ph.D. A look at our future strategy would indicate that we are supporting education to the Ph.D. to bring regional scientists better into the international community of scientific knowledge and interaction. Improving SADCC Regional opportunity for education is occurring. There is a gradual rising interest in local opportunity for students from the region studying elsewhere to do their thesis research in the region. This interest will increase as newly qualified scientists gain stature.

We are in the beginning stages of our second five year period. INTSORMIL has contributed a strategy for education in keeping with original objectives. Our four year review felt that developments during the first phase dictated a slight shift in strategy - primarily in the areas of food technology and economics - and that the strategy should be reevaluated in consultation with people in the region. We anticipate that this will be undertaken by INTSORMIL during the year and we will be happy to collaborate. A general outline of numbers of individuals to be educated from each SADCC country during the next five years is estimated to be 35 to the Ph.D. and 16 to the M.Sc. (Table 3)

Again, I feel it worthwhile to point to our established strategy, developed in consultation with concerned authority in the region, that is flexible and responding to change. The fact that INTSORMIL has the capability to effectively assist with strategy and contribute appropriate education makes the effort possible and effective.

Training

We visualize two components to our manpower development program - education and training. We have discussed the education program, implemented by INTSORMIL, and leading to a degree. The other component is training which has been undertaken at both the ICRISAT Center and at our Regional Center at Matopos in Zimbabwe. I would like to include discussion of this training component because I feel that INTSORMIL has been involved but could be much more involved.

Table 3. SMIP Phase II (1 May 1989 thru 30 April 1994) Training Program - Schedule.

Components	1989 (9 Mths)	1990	1991	1992	1993	1994	1995	Total No. of Students MSc	Phd
INTSORMIL Students									
Angola	1	2	1	1	1	1	1	2	1
Botswana	1	3	3	2	3	2	2	4	2
Lesotho	1	2	2	2	1	1	-	3	-
Malawi	2	4	3	2	1	1	1	4	1
Mozambique	1	2	3	3	3	3	1	2	5
Swaziland	1	-	1	-	1	-	-	2	1
Tanzania	2	5	5	5	6	4	4	9	2
Zambia	2	3	3	4	3	2	-	5	1
Zimbabwe	2	4	3	3	3	2	1	4	3
Students per Year									
PhD	4	13	19	20	20	15	10	35	16
MSc	9	12	5	2	2	1	-		
Total Students	13	25	24	22	22	16	10		

Our accomplishment in training during Phase I is presented in Table 4.

Table 4. Training of SADCC technicians during the first phase (1985-1988) of the regional program.

	1986	1987	1988	Total
ICRISAT Center	4	9	4	17
Regional Center	9	7		16
Station Superintendents at Regional Center		16	15	31
				54

The focus was on a practical training for technicians and two training sessions were added for experiment station superintendents. We were limited in numbers because of manpower availability. The availability of technicians was additionally complicated because so many scientists were away for education. We want to organize to do much more training during the off season.

Our anticipated training program for Phase II is presented in Table 5.

Three additional areas of manpower development are being added in Phase II. We are anticipating a post doctoral program. Dr. Monyo, from Purdue, is currently with us and we anticipate increasing interest in this opportunity. We are also planning for a Research Associate Program where countries can send their staff for a six month to two year period to the Regional Program. Research Associates will be supported by the Regional Program and work across the SADCC Region. We have been requested and plan that returning students spend one to three months with the Regional Program shortly after they return. We feel that these opportunities will broaden individual awareness of sorghum and millets in the region, enhance appreciation of research capability within different SADCC countries, and build personal relationships among scientists in the region.

Table 5. Sorghum and Millet Improvement Program Phase II (1 May 1989 thru 30 April 1994) Training Programs.

Description Course	Duration	Number of Trainees in a year
1. Foundation course in Experiment Station Management, Development and Operations at ICRISAT Center	6 Months	4
2. Orientation/refresher course on Experiment Station Management Development and Operations	6 Weeks	15
3. Orientation/refresher course for Research Technicians	6 Weeks	10
4. In-service training for SADCC/ICRISAT Research Technicians	6 Months	2
5. Vacation training for University Students	3 Months	14
6. In-Service training for Scientists in SADCC Region	4 Months	10
7. In-Service training for Research Technicians at ICRISAT Center	6 Months	6
8. Orientation/refresher Course on crop utilization	6 Weeks	8 (from 1990)
9. Orientation course on Experimental Design	2 Weeks	10 (twice in 5 years)
10. Orientation course on forage research	2 Weeks	5 (from 1990)

The training programs in station development and management and in design are directed toward improving the quality of research results. The program was reviewed after it's first eighteen months and it was recommended that students studying in the USA either avail of short courses there in station management and/or gain familiarity of the management of the university station and the interaction between station managers and user scientists. Station development and management is of keen interest in the SADCC region. Generally, station managers and directors are drawn from their scientific pool. Their educational experience does not include conceptualization of the organization and management of experiment stations. I would encourage INTSORMIL to look at this issue, and evolve a series of seminars, opportunities for students to participate as observers in planning meetings within the various departments, or even organize a short course that would expose students in all disciplines to this issue and create both awareness of and methods for experiment station organization and management.

Participation of INTSORMIL staff in training programs in the region on experimental design to improve the quality of results would be welcome and we can interact with INTSORMIL on time and curriculum. They would be most welcome to participate in such training. The same is true of our training in food technology and forages. INTSORMIL has participated with ICRISAT and CIMMYT in training programs for Central America. We are thinking about a somewhat different type of training involving few people, for more time, and in more detail.

Periodically, we have scientists from the region at Matopos to work individually with one of our scientists. As scientists return from their educational experiences we want to work closely with them. An example, is the return of Mr. Kaula, a pathologist in Zambia. There is a problem of sooty stripe and we have contacted Dr. Odvody to spend some time with us in Zambia to better orient our research. We expect that the opportunity for this type of interaction will expand.

Availability of seed is a problem of serious concern in the SADCC Region and DENAGRO with DANIDA funding has recently concluded an exhaustive study of the situation. Training and consultation figures with prominence in their report. We are currently working with SACCAR to enhance this activity possibly through a project on seed production. Again, recalling recommendations of the 18 month review that an effort be made to expose SADCC students to the seed industry so that they conceptualize quality control, production, and marketing and their inter-relationships. This is generally not part of academic training, but a number of these students will be moved into positions where they will be confronted by these issues. An exposure, conceptualization, while students could be of great value later on. I would encourage INTSORMIL to explore various avenues in which SADCC students, possibly others, could gain a reasonable insight into the seed industry in the USA.

INTSORMIL should be concerned about follow up of their efforts to educate. This is not only in response to interaction with returned students but on opportunities for educated people. At a recent SADCC Conference a comment was made that more educated people were not required because all government positions were full. The rationalization of educated people in the community of agricultural activities could be a rewarding sharing of experiences with our national colleagues.

The integration of research, education, and extension is a topic of current concern in the SADCC Region. In many countries these are in separate departments or agencies and inter-relationships are informal and at times strained. The Land Grant System is one recognized way of closely associating these functions and student understanding of this relationship would be valuable. India, during the 1960's made major changes to develop a system similar in many ways to the Land Grant Systems and a sharing of experiences was of value.

Conclusion

INTSORMIL has and continues to be involved with education. In southern Africa they have contributed to a strategy of education against a defined goal of having the relevant team of scientists in each SADCC country in a ten year period. INTSORMIL continues to participate in the educational program and in the future needs to assist in modifying the strategy in the light of recent developments. There is regional concern, that as local capability increases, that the opportunity also expand to undertake thesis research in the region.

Recognizing that many students rapidly advance in position when they return home and face issues not included in formal education. INTSORMIL could provide additional service by providing exposure, training, to SADCC students (others as well) in such areas as station management and seed production. They might also be aware of opportunities for educated people to uplift agriculture in their home countries, and the effective integration of research, education, and extension by sharing experiences.

Session V: Major Issues Relevant to the CRSP Mode of Operation

- S&T Bureau Strategy
- The American Seed Industry
- The Basic Ordering Agreement
- Other Funding Sources
- Applied vs Basic Research
- The American Farmer
- AID Mission Relations

Session Chairs: Dr. Charles Sullivan
Dr. Frank Gilstrap

Speakers: Dr. Robert Schaffert
Dr. Bruce Maunder
Dr. Fred Johnson
Dr. John Yohe
Dr. Darrell Nelson
Dr. John Abernathy
Mr. Flynn Fuller

Strategy for the CRSP's in the 1990's

Robert E. Schaffert
Senior Agronomist AID/S&T/AGR/AP

I am not here today to tell you what should be in the INTSORMIL project portfolio. The Agency for International Development looks to the CRSP's as a knowledgeable resource base of expertise. The Technical Committee of each CRSP is the one that should be advising the Agency regarding the course of action that should be taken during the next decade and beyond. However, I would like to share with you today some of my personal thoughts about the CRSP's and especially about INTSORMIL.

A.I.D. Focus

A.I.D.'s agriculture focus statement has three interrelated parts; 1) increase the income of the poor majority, 2) increase food consumption and availability, and 3) maintaining or enhancing the natural resource base. The objectives of the Office of Agriculture of the Bureau for Science and Technology is to implement this focus as efficiently as possible with the limited amount of resources available. The CRSP model, a result of Title XII of the Foreign Assistance Act of 1975 to provide for "long-term collaborative research on food production, distribution, storage, marketing, and consumption", involves Land-grant Universities using their expertise to contribute to the development process of developing countries. The CRSP model is considered by many as being very effective and one that may be improved upon and duplicated for other commodities and services where universities have a comparative advantage.

Population Growth

The world population continues to expand by about two percent a year and the population of the world is expected to reach six billion before the end of this century. Much of this growth, of which about 90% is in developing countries, is occurring in urban areas. The income of the people in the developing countries is also expected to increase, furthering the demand for food as well as changing the pattern of food demands, i.e., more demand for fruits, vegetables and animal products.

Integrated Production System

In recent years, a trend has been evolving where A.I.D. and other donors are including in their objectives cash crops and income, generating projects involving the transformation of agriculture raw materials into higher value products. Today, forages is an acceptable topic in the corridors of a development agency, it has been realized that we need a whole package for the farmer, even the small farmer; a farming system or as some prefer today, integrated livestock and cropping systems. In the future there will need to be a significant increase in the production of agriculture commodities as well as an increase in the personal income of the poor so that they can purchase the food and agriculture products they need.

Environment

There is much concern today, about the preservation of the environment. The recent flooding in Asia highlights the urgency of this aspect of development. The pressures of an expanding population on the environment is ever present, usually involving the destruction of the forests for firewood, and in the unproductive tilling and eventual loss of extremely fragile lands in an attempt to produce enough to eat. A major thrust of agriculture development today is sustainable production.

Technology Generation

In the words of Dr. John Mellor, Director of IFPRI "There are two fronts of development to resolve these environmental problems. The first is to increase the agricultural productivity on the most productive lands in order to lower the demands or pressure on the marginal or nonproductive lands. The second is to transform nonproductive areas into productive areas". The first we know is done by generating and using new technology, that what you all have been doing throughout your professional careers. The second is not quite so easy, we're not talking about massive inputs to alter the environment, but something like what INTSORMIL has had as part of its objectives since its inception, transforming the plant to produce over a series of abiotic and biotic stresses and developing appropriate production systems for these stress conditions. I feel that this is one of the KEY research areas for the 1990's and beyond.

Research and Development

We are talking about "high-tech", "low-input", reduced cost, sustainable production. More research, both basic and applied, is needed in the area of abiotic stress physiology including that at the molecular level. Biotechnology tools to develop screening and selection methodology for use in genetic improvement of crop cultivars are also needed. With the development of acid tolerant - aluminum toxic cultivars we have also seen an improved efficiency in the use of soil and fertilizer phosphorous, why not then develop more efficient genotypes in the use of nitrogen, potassium and other limiting plant nutrients to lower the amount of fertilizer necessary and the cost of production.

RFLP (restricted fragment length polymorphism) is a genetic data-base system that needs to be developed to make the genetic improvement program more efficient. This system together with the new knowledge of abiotic stresses, improved plant nutrient efficiencies, "yield genes", tolerance to plant diseases, insect resistance, resistance to other pests (*Striga* and birds), improved biological value traits, etc. will all be key factors in developing crop cultivars for the marginal and previously unproductive lands.

Another area of great potential is the development of biological control of insects for use in integrated pest management programs. A number on natural enemies and diseases have recently been found in the tropics for a growing list of damaging insects in a wide range of crops. These need to be developed into usable systems for the control of damaging pests. In many cases lower production costs are a result as well as less damage to the environment.

A maintenance program for genetic resistance and tolerance to diseases is an important factor for both highly productive and stressed environments.

Agronomic practices frequently can be modified to give greater security of production, higher yields, more efficient use of labor, greater benefit for the next crop, greater protection of the environment, etc. Some old time practices have actually been rediscovered.

A 10 or 20 percent gain in the biological value of the final product is as important, actually superior to a 10 or 20 percent gain in production. It took 25 years from the discovery of an improved quality maize protein (opaque-2) until the development of QPM a product that appears equal to normal maize, but with improved levels of lysine and tryptophan. It seems logical that the same progress could now be made with sorghum in a much reduced time frame. This to me is tremendously important for sorghum as it has one of the poorest quality proteins of all the cereals. The evidence strongly suggests genetic variation exists for this in sorghum.

Market development is extremely important with crops like sorghum and millet. These cereals have a low value per volume ratio and are costly to transport for long distances. Market development is extremely important in areas where there is a comparative advantage for sorghum or millet production and a great production potential. The transformation of these cereals into higher value animal products is income generating and results in a relatively lower transportation cost for domestic urban consumption or export.

CRSPs and the Future

In recent years we have seen a declining trend in the proportion of funds coming from the United States for development work in the poorer developing countries. This has not been an actual reduction in dollars, but a larger share of the costs being taken up by other donors. The U.S. domestic monetary policy is to reduce its spending deficit and balance the budget. The incoming administration has said it will not increase taxes to arrive at a balanced budget, but reduce spending. The "wise" people of Washington tell me this all leads to at the most optimistic level of projection, no or at the best, little new or additional resources. In other words we'll be lucky to hold our own. In general it appears that old programs will need to be terminated before new programs can be set in place.

The CRSP model is one that has and is receiving good reviews, one that is producing remarkable results with fairly small investments. It has been designed to yield returns for the American farmer, and several positive examples can be cited from the last 10 years, since the first CRSPs were structured. Also, within the Regional Bureaus of A.I.D. some missions are much better integrated with the CRSPs than others. We need to continue working with the missions to improve working relationships and to improve the developmental process. The missions frequently have the same objectives as the CRSPs and the developmental process could be enhanced through mission "buy-ins" of a CRSP program. A good relationship with a host country is through the mission, therefore good communications are a necessity. Cable clearance is important before traveling, always

check-in with the mission when you arrive and check out again when you leave a country.

An area of concern within the Agency is if the technology being generated is really getting down to the final user, the farmer. Many feel that the extension process is not working. The CRSP model was developed principally to generate new technology, but technology transfer and extension can't be divorced completely from the technology generation process. One of the basic ideas of Title XII was to use the expertise of the land grant universities in the developmental process. It seems logical that research in the technology transfer mechanisms and processes could be a part of the CRSP program. There is a growing concern in the Bureau for Science and Technology that the technology being generated gets into use. I would like to see the Technical Committee address this as INTSORMIL prepares for its grant renewal. I am sure it will receive attention within the S&T Bureau.

Another concern is if the CRSP scientists and directors are effectively demonstrating their results. Have you been informing your congressmen and senators as to the benefits of the foreign assistance funds you are using, for US agriculture or more specifically for Texas agriculture, or Nebraska agriculture etc. It seems as though this professional courtesy would be in line.

There has been concern that the CRSPs could be more effective in the technology development and transfer process if there was more interaction and/or cooperation between the CRSPs. A general consensus is that it should be productive, but exactly how this might be accomplished is still being debated. There is definitely an interaction between the CRSP commodities and services. I think this is another area that the technical committees of the various CRSPs could make a contribution. A think tank approach might be a productive way to look at this. The new "Science & Technology Agriculture Reporter" or "STAR" of the Office of Agriculture of the Bureau for Science and Technology is a vehicle that was developed for this use and I hope that you will use it.

I've been asked by some of you if there will be additional resources for new projects during the coming years. That is a very difficult question to respond to. I think the proper process would be for the technical committee, with the recommendations of the external evaluation committee set the agenda and priorities for the INTSORMIL program in the 1990's. If you, INTSORMIL, feel that there are gaps in the program make the appropriate recommendations and project alterations together with the necessary justifications. I think it would be good to keep in mind that each project, either continuing or new, produce a tangible product. That is the driving force behind future funding. New projects need to address, preferably directly or indirectly, the concepts; sustainable agriculture, enhancement of the natural resources and generate income for the poor, the principal concerns in agricultural development today.

INTSORMIL and the Seed Industry

Dr. Bruce Maunder
Vice President, Agronomic Research
DeKalb-Pfizer Genetics

The relationship of INTSORMIL and the seed industry, whether on a domestic or international basis, benefits from mutual respect and support. The topic was considered by five research leaders, representing four multi-national seed organizations, with the following an attempt to summarize their comments and to illustrate mutual opportunities.

Domestic Relationship

Generally, industry has benefitted from the increased availability of germplasm which more importantly has in-country descriptors. As we all know, working world collection material is all too often a random activity with little or no information associated with the PI. I would urge, however, that more effort needs to be initiated regarding the role of INTSORMIL in regards to germplasm.

This brings up name recognition (public relations) which, as might be expected, suggests ICRISAT to have more recognition than INTSORMIL but to a lesser degree on the domestic scene. Obviously, the evaluation of such awareness will be determined by the scope and success of your activities as well as duration of the program. The impact of the training component should also contribute significantly.

Responses suggest the seed trade supports the concept of INTSORMIL with restrictions. There is agreement that the philosophy of passing funds through U.S. institutions is more effective than less controlled overseas "give-a-ways". Support was given to the training program, assuming the scientists return to their home country, although one response favored international centers for this activity. Concern was expressed as to the high proportion of the budget related to overseas travel by U.S. scientists as well as the dilution of research activities affecting U.S. producers. Since U.S. research locations involved with INTSORMIL do not necessarily relate environmentally to situations, overseas training should best be done on basic concepts. If a scientist wants to make a significant research contribution which is product oriented he really needs to live in the third world site where research can best be directed toward product development.

International Relationship

The multi-nationals, at least through their international department, have contacts with overseas collaborators of INTSORMIL. Additionally, these collaborators may visit industry research operations in the U.S. as a part of their training or during planning visits with PI's. Certainly, schedules permitting, the seed industry welcomes these opportunities to exchange ideas on germplasm and breeding methods.

There seems to be general agreement, within the seed trade, that overseas efforts by the Principal Investigators have in fact diluted their support of the domestic sorghum industry, possible more on the short term. To the contrary, companies with overseas activity are likely, or soon should, benefit from materials developed through collaborative research which fit the needs of LDC's such as the taller, food types. The industry has concern for continued state/federal support of domestic programs where obviously much of the research is internationally oriented. Will not the same criticisms be raised in this regard that surfaced in pre-CRSP days concerning internationally oriented support for Land Grant institutions and heavy emphasis on foreign student graduate training?

In general, the seed trade on a national level, is relatively new or non-existent in many third world countries, but will allow a means of production, conditioning, and distribution. This service is often not available within national programs where cultivars have long been maintained on a family or community basis. At times this same developing industry may recruit research and management staff from your trainees, a less frequent and serious loss perhaps than the all too often elevation of these people into administrative positions.

Mutual Opportunities for INTSORMIL and the Seed Industry

Both INTSORMIL and the seed industry developed considerably within host countries over the past nine plus years. While neither has progressed as well as would seem desirable during this time-frame both will benefit and make greater progress towards increasing production

and improving quality by working together. Some of these opportunities would be:

1. Collection, characterization, and introduction of elite "exotic" germplasm from around the world. Release of useful germplasm on a regular basis rather than the delayed release of finished inbred lines would be a real contribution. Obviously, a weakness of INTSORMIL continues to be any sort of organized germplasm system.

2. Much joint product evaluation would be possible through cooperative testing, a necessary but expensive activity. This would improve the likelihood of a new release being adapted to the varying stresses which may occur.

3. Recognition of the PI's and collaborators as well as their many contributions needs to go beyond the ME, Board, and EEP. Presentations on INTSORMIL activities/accomplishments should be explained at meetings such as the Biennial Sorghum Conference (GSPA, SICNA), ASA meetings, and wherever the opportunity exists overseas. Publications can be circulated to appropriate organizations. Field Days discussing INTSORMIL activities should be held both domestically as well as overseas. In brief, more public relations will benefit INTSORMIL.

4. Countries lacking an infrastructure to effectively or efficiently condition and distribute seed may often find the seed trade their best alternative. In a similar manner an organization with people in daily contact with producers can serve as an "extension service" to introduce new methods and products.

5. The transition from varieties to hybrids may be a time for transition from public to private seed operations depending on market size, complexity and cost of conditioning, and ease as well as type of distribution.

6. Training will be an opportunity with dual inputs. An established seed industry will be willing to train scientists from LDC's that intend to operate their own seed industry as a public function just as INTSORMIL will train people who may choose to make their career in the private sector.

While many more opportunities could, and perhaps should, be listed this brief discussion would be remiss in not encouraging both public and private input as the most effective way to carry out the mandate of INTSORMIL and achieve the goals of the host country. Only when the producer and consumer benefit have either INTSORMIL or the Seed Trade made any measurable progress.

Basic Ordering Agreement

Dr. Wm. Fred Johnson
BIFAD

The Basic Ordering Agreement (BOA) is an agreement between an agency of the United States Government and a U.S. Land Grant University. In this case, the agency is the Agency for International Development and the University is one of the universities which serves as the Management Entity for a Collaborative Research Support Program (CRSP). The BOA provides the framework and sets forth the terms and conditions under which "delivery orders" may be developed for all A.I.D. Missions or office to request a CRSP university to provide technical assistance or applied research services, related to the CRSP research.

The BOA is not a contract. Rather it is a legal agreement similar to a "Memorandum of Understanding" used between a CRSP and a host government, or a "cooperative agreement" between AID and a university. A BOA can be signed between AID and a CRSP Management Entity of any of the eight CRSPs.

BOA's have existed for some time for such programs as the Mississippi State University seed technology assistance and training program, and the Kansas State University grain storage research and technical assistance program. The use of the BOA has recently been extended to include the University of Idaho's post harvest preservation and storage program for fruit and vegetables, and the University of Hawaii's International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT).

It has taken several years of effort to resolve legal issues to apply the BOA to CRSP universities. The development of the BOA mechanism was conceived as a solution to the buy-in problems. The last hurdle to be overcome was a market survey which was conducted by AID's Contract Office. This was done through a notice published in the Commerce and Business Daily, advising that A.I.D. was proposing to sign BOAs with CRSP Management Entities for applying "delivery orders" to U.S. CRSP institutions for providing applied research and technical assistance services to AID Missions. This would be done by waiving class competition. The notice invited expressions of interest and objections to the class waiver of competition. A fixed period of time was allowed for response. Only one response was received and this was not relevant to the areas of research of the eight CRSPs. Therefore, the Contract Office concluded that it was appropriate for that office to grant a class waiver to competition for CRSP institutions to provide the applied research and technical services to AID Missions in areas related to the research of the respective CRSPs.

Once AID and a CRSP Management Entity signs a BOA, the stage is set for signing delivery orders under that particular CRSP. In order to extend the authority of a BOA, the ME must sign a sub-BOA with each interested U.S. institutions participating in the CRSP. However, no services are provided until a delivery order is requested and signed. An individual delivery order is required for each requesting entity, be that an AID Mission or a regional office of AID, or a regional or central bureau of AID-Washington.

The delivery order is a legal contract. The ME signs the delivery order and sub-delivery or orders with each interested U.S. institution whose services are requested. However, participation by a CRSP institution is not obligatory, even though the ME may have signed a BOA and delivery order, and the CRSP institution may also have signed the sub-BOA. Such institution has the option to decline the request and not enter into a contract.

It is important to understand that the delivery order is a legal contract, and although it is associated with the grant document, the rules of a contract apply. AID is requesting a specific service which is to be provided for a given, limited time. Performance is based on the service being provided within the given time frame which might run up to two years.

After the BOA is signed between AID and the ME of a CRSP, and the ME has executed sub-BOA's with each U.S. CRSP institution, the availability of the services is made known to missions and AID offices.

An interested AID Mission, regional, or central office of AID may write a P10-T requesting the service. The P10-T is submitted to the CRSP Project Officer in the Bureau for Science and Technology's Office of Agriculture (or Nutrition Office for Nutrition CRSP) who submits the P10-T to the Contract Office. The latter and the Project Officer decide on the relevance of the P10-T request to the CRSP Program. If the decision is positive, the Contract Office requests a proposal from the AID Mis-

sion or office which issued the P10-T. The proposal must include a cost estimate, a scope of work, a budget, and the general terms of the contract. Once there is agreement, a delivery order is signed by the ME and a sub-delivery order or orders are signed by the CRSP institution, or institutions, by the AID Project Officer, and the requesting AID Mission or office. The delivery order is comprised of two to three pages. The prime delivery order constitutes a contract as does each sub-delivery order.

The duration of the term of services is spelled out in the delivery order and sub-delivery order. However, the term relates to the term of the grant document and cannot extend beyond the grant termination date by more than 120 days.

There is a limit to the accumulated value of delivery orders or sub-delivery orders under each CRSP. The amount cannot exceed the value of the CRSP during the life of the program. The limit estimated on the Sorghum and Millet CRSP by the Contract Office of AID is $5.5 million for the current life estimate for the CRSP. There is also a fixed limit to allowable overhead payable to the ME on a "delivery order". The MEs overhead rate would be applicable to the first cumulative $25,000 of "sub-delivery orders" with each participating institution. That is, each sub-BOA would constitute a sub-contract, according to the Contract Office. This interpretation was made as a means of encouraging mission use of this method of buy-ins. Payment of overhead on the first $25,000 to each sub-delivery order could become very expensive, which could be a dis-incentive to missions to use this method, the Contract Office maintains. To offset this rule, the cost to the ME and to the sub-contractor for administering the program, and the overhead cost would be factored into the buy-in costs. Such costs, if not paid, could be counted as university match required in the grant.

This method of buy-ins is provided for U.S. universities. Sub-BOAs and sub-delivery orders also can be signed with international agricultural research centers (IARCs). For this purpose, such centers have been defined in legislation to be of U.S. nationality. Non-U.S. nationals of IARCs retained by U.S. universities would be classified as Third Country Nationals or Cooperating Country Nationals.

The method of payment would be by advance letter of credit if the Mission or AID office requesting the services is using grant funds. However, if the funds are bi-lateral loan funds, as might occasionally be true, payment would have to be made on a reimbursement basis. This is because interest is accrued on loan funds.

Provisions are made in the BOA for the use by Missions of local currency to pay for logistic support that might be provided in lieu of "in-kind" for the visiting scientists and other university members. Disbursement of local currency would be made by the Mission directly to the visitors for purchase of the logistic support.

No overruns are allowable in delivery orders unless prior written approval is requested of the Contract Office and the AID-Washington Project Officer. The Mission cannot authorize an overrun.

Other Sources of Funding

Dr. John M. Yohe
INTSORMIL Program Director

The INTSORMIL ME Office frequently receives inquiries from INTSORMIL scientists about potential new sources of funds to accomplish specific research tasks or for new funds to augment their on going research. This presentation will outline four different programs which are competitive in nature but which are available to all INTSORMIL scientists.

AID Program in Science and Technology Cooperation (PSTC)

The PSTC program seeks to stimulate new and innovative scientific research on problems which confront developing countries. The program is administered by the Office of the Science Advisor (AID/SCI), and provides highly competitive research grants which are subject to external scientific peer review.

The PSTC program gives highest priority to submissions from scientists in those developing countries which receive USAID development assistance. Cooperation with U.S. scientists is strongly recommended but not required. The grants competition is also open to U.S. investigators and scientists from middle income countries, such as Brazil, Colombia, Mexico, Nigeria, or Malaysia, when the research is particularly relevant, unusually innovative and there is strong scientific collaboration with developing country investigators. The PSTC does not support research in other developed countries.

The PSTC seeks new research ideas in the natural sciences, such as chemistry and biology and in engineering. Innovative ideas that will eventually lead to solutions to serious developing country problems are accorded highest priority. The PSTC program presently accepts proposals under six modules:

- Biotechnology/Immunology in Human and/or Animal Systems.
- Plant Biotechnology
- Chemistry for World Needs
- Biomass Resources and Conversion Technology
- Biological Control
- Diversity of Biological Resources.

Contact the INTSORMIL ME regarding procedures for submitting proposals to this program.

The International Foundation for Science (IFS)

The IFS supports developing country scientists of outstanding merit for their research efforts in agricultural and biological sciences and related technology.

IFS support is primarily financial and in the form of research grants normally not more than U.S. $10,000 per granting period and renewable up to three more times. IFS funds are to be used to purchase the basic tools of research: equipment, expendable supplies, and literature.

IFS granting criteria require that a applicant shall be:

- native to a developing country
- in possession of an academic degree or equivalent
- currently employed at a university or research institution in a developing country
- young or at the beginning of his or her career

Research proposed by the applicant shall be:

- conducted in a developing country
- relevant to the needs of a developing country
- on a specific project which falls within the IFS research areas:

  Aquaculture
  Natural Products
  Animal Production
  Rural Technology
  Food Crops
  Afforestation and Mycorrhiza
  Fermentation and Applied Microbiology

Contact the ME about procedures for applying to this program.

African Dissertation Internship Awards

The Rockefeller Foundation announced a program in 1977 which enables African graduate students enrolled in United States universities to undertake supervised dissertation research in Africa.

The primary aim of the program is to increase the quality and relevance of overseas advanced training for outstanding African scholars and, thereby, to facilitate their transition into a productive scientific career when they return to Africa. The scope of the program is for Rockefeller to support approximately 25 young African men and women who are enrolled in U.S. universities to return to Africa for a period of 12-18 months to carry out doctoral research either in their home countries or in another country where a local university or research institute can provide adequate supervision in the student's field.

These awards are open to citizens of sub-Saharan African countries studying in the United States who are about to embark on dissertation research in the fields of agricultural sciences health and life sciences, related social sciences and history. Research projects must require field observation or use of primary sources only available in Africa.

The ME can provide copies of the guidelines for application or interested students can contact:

African Dissertation Internships
The Rockefeller Foundation
1133 Avenue of the Americas
New York, New York 10036

AID/Science and Technology (S&T) Bureau Small Activities Program

The S&T Bureau has a limited amount of resources to fund activities of special interest which contribute to the furtherance of research goals and objectives of the Bureau. Activities which can be considered for funding are:

- Workshops/Conferences
- Innovative Research Ideas
- Other

In all cases, a proposal with supporting budgets is required for requesting support from this source of funds. For all INTSORMIL related activities, requests from this source should be coordinated through the INTSORMIL S&T/AGR Project Manager, Dr. Robert Schaffert.

The Management Entity can help with guidance for proposal preparation from this source of funds.

The Role of Basic Research in Development

Dr. Darrell W. Nelson
Dean and Director, Agricultural Research Division
University of Nebraska-Lincoln

Most effort in INTSORMIL has been directed at applied research to solve production and utilization problems for sorghum and millet in selected developing countries. Increasing emphasis was placed on applied research as budgets were reduced, as efforts were concentrated on prime site countries, and as USAID policy became more focused on problem solving approaches. The INTSORMIL Board of Directors has long recognized the imbalance in the basic-applied research components of the program and have become increasingly concerned about the future of the program in 5-10 years from now when much of the current sorghum-millet technology has been exploited and little new technology has been generated. This paper attempts to provide a framework for including basic research as a part of an agricultural development program.

The Research Continuum

Research is conducted over a wide continuum that spans from basic research to maintenance research (Figure 1). There are not sharp divisions between the different types of research or between the types of agricultural scientists conducting the research. For example, both "basic research scientists" and "applied research scientists" carry out developmental research, depending upon the problem and the interest of the scientist.

Don Holt[1] has defined basic, developmental, and adaptive research in the context of the agricultural research and development system as:

Basic Research - Research conducted to better understand the physical, chemical, biological, and economic principles which govern agricultural systems. Basic research generates ideas for new products and practices.

Developmental Research - Research conducted to evolve a product or practice from an idea. Developmental research will optimize performance of the product or practice and establish its usefulness in defined situations.

Adaptive Research - Research conducted to test, compare, and integrate new products or practices into operational systems tailored to the specific soil, environmental, and socioeconomic situations that make up agriculture. Site- and situation-specific information is developed for farmers.

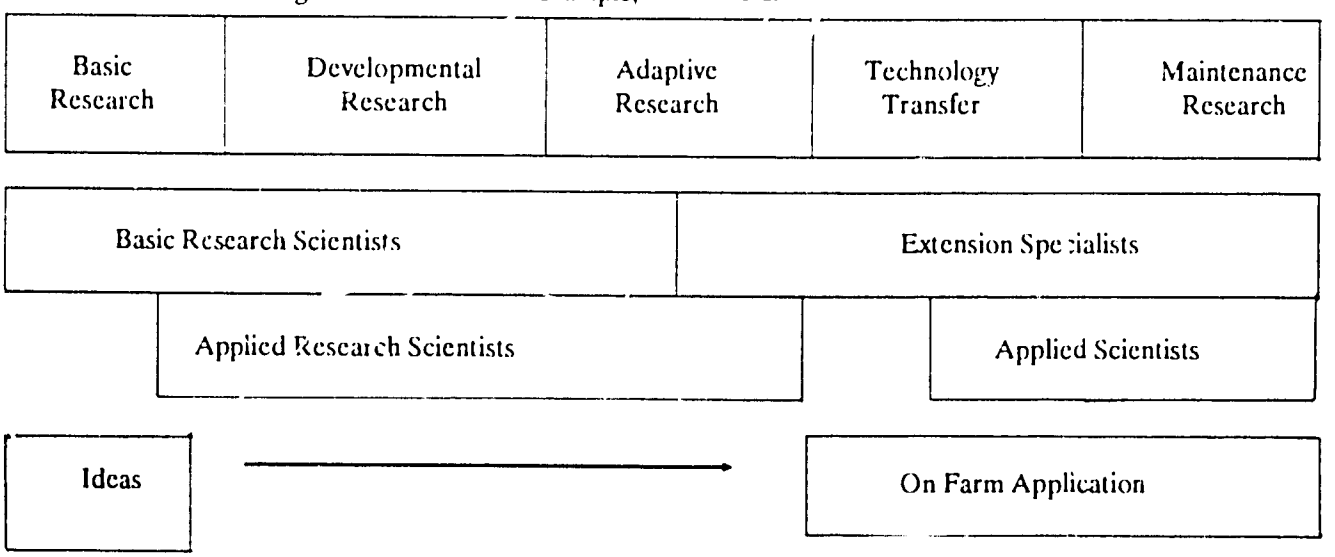

Figure 1. A model for agricultural research.

[1]Don Holt, 1987. Where will agricultural production efficiency research come from in the future? Address to the 1987 Annual Meeting of the North Central Branch of the American Society of Agronomy.

Many biological scientists now assume that the only basic research in plant and animal sciences is that dealing with subcellular processes. Dr. Holt's definition is much broader and can include research with whole organisms. The broad definition of basic research is used in this paper. Technology transfer and maintenance research can be defined as follows:

Technology Transfer - The transfer of information on new products or practices to users, either directly or indirectly, through agricultural extension or other educational programs.

Maintenance Research - Research conducted to determine why a new product or practice is not performing as expected on a farm or within a region. Additional research is conducted to modify the use of the product or practice to ensure satisfactory performance under farm situations.

It is clear that INTSORMIL scientists have a strong record in carrying out developmental and adaptive research on many aspects of grain sorghum and pearl millet production and utilization. INTSORMIL collaborating scientists in prime site countries have been actively engaged in developmental research, adaptive research, technology transfer, and maintenance research. The INTSORMIL research program has been highly successful to date because of the storehouse of basic research information developed over the past twenty years and the expertise and dedication of all scientists participating in the program.

The Role of Basic Research in INTSORMIL

The Board of Directors has become increasingly concerned about the future of INTSORMIL programs 5-10 years from now when much of our current technology has been exploited. There is relatively little basic research currently under way on grain sorghum or pearl millet by public or private research organizations. There are no indications that significant increases in federal or state investments in basic research on these two crops is planned. Therefore, the Board of Directors is faced with answering the following questions:

Should INTSORMIL scientists undertake basic research projects?

Should INTSORMIL funds be used to support basic research?

I believe that INTSORMIL must have a basic research component if we are to have the knowledge base to solve the difficult production and utilization problems that will be faced by the organization in the next decade. INTSORMIL scientists and other scientists with special research skills should undertake focused basic research on grain sorghum and pearl millet. A basic research component should be built into the base budget (perhaps 10% of the total budget) and funds should be awarded on a competitive basis to conduct research on priority topics. Projects to be undertaken are those providing essential information that can be used to eventually solve difficult practical problems, e.g., biology of *Striga*, pest resistance mechanisms, mechanisms for tolerance to drought or acid soils, and principles underlying the digestibility and nutritive value of sorghum and millet grain.

INTSORMIL basic research should be directed at those critical projects that are unlikely to be funded by national competitive grant programs or by regular federal and state appropriations for agricultural research. Strong linkages must be developed between basic and applied scientists to ensure that basic research is used at the earliest possible time in problem solving research.

"Mainstreaming" Basic Research in INTSORMIL

Building a significant basic research capacity within INTSORMIL will represent a change in program orientation. A number of activities must be accomplished before a basic research component can be fully integrated into the INTSORMIL Plan of Work. The Technical Committee and the Board of Directors must agree that the development of a basic research component is important for the continued success of INTSORMIL. We must also convince USAID and other federal agencies to support critical basic research projects because INTSORMIL funds will always be inadequate for attacking even the highest priority problems. Specific actions that are needed to implement a basic research component in INTSORMIL include:

1. Preparation of a "white" paper on the role of basic research in solving food production problems. The "white" paper must emphasize the advantages to the CRSPs of involvement in basic research.

2. A far reaching discussion of basic research needs and expected outcomes at a CRSP Council meeting.

3. Regular input to USAID administrators on the advantages resulting from incorporating basic research components into CRSPs.

4. Testimony and informal input of Congressional Committees which deal with USAID funding and programs. The objective should be to increase the appropriations from CRSPs and to establish a competitive basic research grant program at USAID.

5. Meetings with appropriate commodity organizations to explain how investments in basic research will benefit United States agriculture.

This is not a complete list of appropriate actions, but the list serves as a starting point. We need to begin the process of "mainstreaming" basic research into the INTSORMIL program. All of us will need to work diligently and in concert to accomplish this goal.

INTSORMIL and the American Farmer

Dr. John R. Abernathy
Texas Agricultural Experiment Station
Lubbock, Texas

The support from INTSORMIL has enabled U.S. scientists to make significant advances and contributions for sorghum and millet production/utilization in the United States as well as for LDC's. There are many developments and contributions that can be traced directly to the activities of INTSORMIL which are beneficial for the American farmer. For purposes of this presentation, I shall try to discuss some of these contributions by the respective INTSORMIL disciplines.

The respective research disciplines of INTSORMIL are:

- Agronomy/Physiology
- Plant Breeding
- Entomology
- Food Quality and Nutrition
- Pathology
- Socioeconomics

These respective disciplines have received economic support directly to the participating universities in the United States, including Purdue, Kansas State, Nebraska, Mississippi State, Texas A&M and the University of Kentucky. INTSORMIL activities have enabled these support dollars to target and coordinate the best scientists in the United States that conduct sorghum and millet research. As U.S. scientists have worked in many of the targeted countries, they have obtained a glimpse and window of future problems for U.S. agricultural sorghum and millet production/utilization. By addressing these problems, U.S. scientists have in turn benefited the American farmer.

Specifically, in the agronomic/physiology area, significant results have been obtained in crop rotation studies with sorghum/millet and soybean/millet rotations. These have economic implications for the U.S. farmer as he deals with water, fertility, row spacings, microbial dynamics of soils and of lower input/improved profitability. Rotations also have implications for significant contributions from an environmental standpoint, that is, specifically maximizing the use of nitrate fertilizers and impact on groundwater. Rotations and genetically improved drought tolerance have increased sorghum profitability under semi-arid climates.

Considerable contributions have also resulted in improvement of the stand establishment of sorghums and millets. One of the major problems facing American farmers in production of these crops is the early season stand establishment.

In plant breeding, major contributions have occurred with U.S. breeders being able to tap the germplasms of the world and incorporate that germplasm into U.S. sorghum production. Sorghum is not native of the United States; therefore, the scientist must go to those countries where it is native to find the diverse sorghum germplasm pool. Contributions from this area include the development of sorghums with resistance to many diseases, insects, to aluminum and iron toxicities in the soil, resistance to drought, and yield enhancement. This genetic diversity has also provided the basis for food quality grain development by selecting high quality low tannin sorghums.

Major contributions also from the entomological area go hand in hand with the breeding effort in developing the sorghums and incorporating the germplasm identified by entomologists on a world basis to the key insect pests, whether those pests are in the LDCs or whether they pose a problem for entrance into U.S. agriculture. The ability to predict these problems internationally and to incorporate resistance probably has saved the American farmer millions of dollars in terms of pest control measures within U.S. sorghum production.

In the area of food quality and nutrition, significant advances in analytical procedures have been developed by U.S. scientists that serve the U.S. food and feed industry. Many of the analytical tools for determining tannins, phenols, and starch and proteins in sorghums and millets came directly from involvement of INTSORMIL activities by U.S. scientists. These analytical tools have set the standards for the industry. The entire area of human and animal nutrition involves sorghum and millet quality

and the development of sorghums that have higher quality nutrition levels. The programs are also linked back to the respective breeding programs to increase food quality on a worldwide basis. As American farmers continue to produce sorghum, the market demand will increase for better quality sorghums.

The discipline of pathology has also been heavily involved in identifying new disease organisms around the world and in the United States and to provide the background information to genetically and biologically manipulate sorghums and millets to be disease resistant. Pathologists have developed disease strategies for major U.S. and International diseases.

The area of socioeconomics has developed technology, knowledge, and models which have direct benefit to U.S. farmers as they seek international markets.

Throughout all the disciplines, a key advantage is the ability of U.S. institutions to train scientists on a worldwide basis. These scientists as they come to the United States provide manpower to work on U.S. problems also. They then return home to countries that do not compete with the United States to help develop their own food supply.

These are a few of the major contributions to the U.S. farmer from INTSORMIL/CRSP as reflected by the respective principal investigators that deal in the INTSORMIL arena. It is important that we all try to develop better cooperation within our commodity leaderships, universities and U.S. AID programs and to be able to articulate the benefits of CRSP's to the American farmer.

Mission Relations and Protocols

Mr. Flynn Fuller
Agricultural Development Officer
USAID, Niamey, Niger

As your program states, I'm here to talk to you regarding Mission relations and protocols as they relate to CRSP management. However, I will be confining my comments to "How We at USAID/Niger Perceive the Role of the Mission in CRSP Management from Our Experiences Working with CRSP's" and I'll also add a few personal comments of my own that I hope might help both the CRSP and host country governments to better understand each other and AID and thus be better prepared as you collaborate to address your research priorities.

USAID/Niger has substantial experience working with CRSP's by being fortunate to have three active CRSP's in Niger for some time now, including:

1.) The Peanut CRSP - mainly providing seed for varietal trials by INRAN and some collaborative work with ICRISAT;

2.) TROPSOILS - addressing soil and water conservation, crop residue management, fertility management, soil variability, windbreaks and climatology; and of course,

3.) INTSORMIL - who is working on various aspects of breeding, entomology, stress physiology, agronomy, cereal quality and plant pathology.

With each CRSP, we've had differing experiences - mostly positive, but from time to time management headaches of concern to the Mission do occur.

USAID/Niger sees its role in CRSP management, mainly as one of facilitator and advisor, particularly in support of the host country government and as AID's representative in the field looking after AID's investment and helping to integrate the CRSP's into the national research program. AID/Washington has delegated management responsibility of the CRSP's to the lead universities and holds them responsible for the programs and accountable for AID funds. There is also a project manager in Washington designated to monitor the global programs. Within our role there are times that, if problems arise, the Mission may have to step in and play a more active part in helping to resolve issues. We don't like to play the heavy, but the Mission does represent USAID's interests in the host country, and if the Mission feels those interests are threatened due to issues that have arisen within any USAID sponsored program, the Mission will step in with directives appropriate to the situation to resolve that threat. Even then we see ourselves as advisors to the two parties (host country government and the CRSP institution), and as an information link with Washington.

It is vitally important that if the Mission is to fulfill its part (again as advisor, as broker, as facilitator) we must be kept within the communication loop between the host country government and the CRSP institution, so that when issues do arise, no matter how minor or how severe, we are better equipped to assist in resolving them. Or better yet, we may be able to foresee a problem developing and be able to help resolve it before it actually becomes an issue.

Again in the case of Niger, each of the three CRSP's have a memo of understanding that was developed and negotiated between the CRSP entity and the host country government. During this negotiation phase the Mission is very active in advising both parties to assure that an amicable and workable agreement is reached. We have found that the key factor the CRSP's must keep in mind (and we do have to remind them from time to time, especially during this negotiation stage and during and updates), is that their major purpose for being in Niger is to address Niger priority research objectives as determined in consultation with the National Research Institute (INRAN). Developing countries cannot afford to devote their limited resources to address non-priority research topics. On the other hand, INRAN needs to be fully aware that the CRSP's do have global and zonal plans, with global and zonal goals and objectives and that research activities agreed upon will, in most cases, necessarily be those that can transcend national boundaries. The trick therefore, is to be able to identify and agree upon research activities that address both - the host country priorities, as well as the more global priorities.

Something else that I personally think should be explained to the host country government at the beginning, but I'm afraid is often ignored, is that the U.S. institution is not involved for purely selfless reasons. CRSP's have a dual goal of improving agriculture in the developing countries and in the United States. In fact, participating

U.S. institutions agree to contribute at least 25% of the cost of the CRSP, justified on the basis of benefits that can accrue to their state's agriculture and their institution. In other words, it is envisioned that results obtained through addressing research priorities in developing countries, will also have a positive impact at home.

Another aspect that, if not clarified in the beginning, may create hard feelings later, is the topic of publishing of research results. For example, does the host country have the right to edit a document and grant concurrence on content prior to publication? Remember the research was conducted in the host country, using host country collaborators and other host country resources. If the answer is yes, all relevant personnel should be informed accordingly.

It has been our experience that the best CRSP relationships evolve when CRSP activities and administration can be facilitated through close association with an established Mission bilateral program being implemented with assistance from a member CRSP institution (i.e., INTSORMIL with in-country assistance from Purdue University). This also fits in well with the Africa Bureau's plan for supporting agricultural research in Africa by integrating CRSP's into the national research programs, which is also a priority of our mission. In this particular case, it is often difficult to distinguish between INRAN/INTSORMIL activities and INRAN activities supported by our bilateral program. This kind of arrangement also reduces substantially, the administrative burden on the host country government, the USAID/Mission, as well as the CRSP institution.

Our experience also shows that if such a relationship like the INTSORMIL/Purdue/INRAN relationship is not feasible, yet the CRSP activity warrants an in-country presence by institutional personnel, the activity should be adequately funded to support both the scientific as well as the administrative aspects of the in-country program. In other words, the scientist is there to do research and should not be expected to deal with all of the day to day administrative (both domestic and work related) difficulties one faces in an obviously unfamiliar third world environment. Such tasks take an inordinate amount of time, which results in scientific work being unduly neglected, and at no fault of the scientist. So we would urge you to select your people well, and then give them the support required to do their job. If not, you may find yourself losing support from key players (such as the USAID mission) and thus find it hard to justify a continued presence.

In closing, I would like to say that I personally have really appreciated the professional and personal manner in which INTSORMIL operates, and to say that the mission looks forward to a continued profitable and long lasting working relationship between INRAN, INTSORMIL and USAID/Niger.

Session VI: Advances in INTSORMIL Research - Highlights

- Millet Research
- Striga Research
- Water Stress Research
- Food Quality and Utilization Research

Session Chair: Dr. Fred Miller

Speakers: Prof. David Andrews
Dr. Larry Butler
Dr. Darrell Rosenow
Dr. Lloyd Rooney

Advances in INTSORMIL Pearl Millet Research

Professor David J. Andrews
University of Nebraska

INTSORMIL has conducted research on pearl millet (*Pennisetum glaucum* (L.) R and Br.; USDA, 1986 and IBPGR, 1987) in the areas of agronomy, entomology, pathology, food quality, socio-economics, and genetic improvement. Collaborative research on pearl millet has involved Botswana, Burkina Faso, Colombia, India, Mali, Niger, Senegal, and the Sudan. Thirty-five scientists have/are receiving post-graduate training in pearl millet from Botswana, India, Lesotho, Malawi, Mali, Niger, Senegal, Sudan, Tanzania, Zambia, Zimbabwe, and the U.S.

INTSORMIL's collaborative research focus on pearl millet has mainly been on Africa, where pearl millet is the traditional staple food crop in hot dry zones with uncertain rainfall and sandy soils. These zones, where soil and agroclimatic conditions are too stressful for sorghum to be the major cereal, are among the most fragile environments for arable cultivation. Recent droughts, accompanied by increasing human and animal populations and deforestation have produced situations where research on sustainable agriculture has become an urgent primary need. The research topics investigated by INTSORMIL in different countries/regions are decided in relation to existing national research needs, and international research activities, particularly those of ICRISAT, with whom several international workshops have been jointly sponsored.

Almost as much pearl millet is planted on the Indian subcontinent (12 m/ha) as in Africa, and here genetic and agronomic research coupled with strong markets have contributed to increased production. Because of budget constraints, INTSORMIL's collaboration in Asia is presently confined to germplasm exchange and workshops; however, sources of regional funds are being sought for pathology and stress research.

Pearl millet, with an inherently more nutritious grain than sorghum and a high growth rate, also has the potential to be a feed grain crop in the Americas (and elsewhere). Research in this direction in INTSORMIL is facilitated by the Title XII legislation requiring that research in the CRSP's should also benefit U.S. agriculture. Pearl millet is grown for forage in the southern U.S., but the plant type required for grain production is entirely different. Pearl millet is in a somewhat analogous position to soybeans 30 years ago, which were entirely too late, tall, and low yielding for cultivation in the Midwest and without a local market. As we shall see, considerable progress has been made towards developing high yielding combine grain types in pearl millet. It should be noted that the development of yield potential per se as needed in the U.S.A. is a major requirement for useful genetic contributions in collaborative research in environments where yield is limited by stress.

Review of research (see Table 1).

This brief review has been compiled from project reports and personal communications with scientists in collaborating countries and INTSORMIL P.I.'s who conducted the research; for more details see INTSORMIL Annual Reports.

Agronomy

Seed size and millet agronomy (KSU 101-106). Effects of seed size and density, mesocotyl and coleoptile length were studied in Kansas and Botswana. Seed of medium size was better able to germinate at higher temperatures; however, evaluation of seed characteristics in Botswana showed no advantage from physical separation of seed. Genetic differences in mesocotyl and coleoptile lengths also did not result in significant effects in the field. Mortlock and Vanderlip, 1988.

Agronomy trials in western Sudan, where rainfall has declined steadily over the last twenty years, have shown the need (and farmers' preference for) for earlier maturing millet varieties such as 'Ugandi'. Rotations with legume intercrops with new cowpea or other varieties of legumes which are also earlier maturing than traditional types, may help in stabilizing crop production in conditions where fertilizer application is risky because of unreliable moisture regimes. Berhe and Jain, 1986.

Adaptation of pearl millet to acid soils (MSU-111). A range of pearl millet genotypes were tested against acid tolerant sorghum cultivar checks on acid soils (53-60% Al saturation) in eastern Colombia. All pearl millet genotypes grew faster, were earlier to bloom, and produced higher forage and grain yields than the sorghum. Pearl millet grain yields averaged 2700 to 3500

Table 1. INTSORMIL collaborative research in pearl millet improvement.

Project Number	Country	Discipline	Topic
KSU-106	Botswana	Agronomy/Physiology	Seed quality
KSU-101-1*	Sudan	Agronomy/Physiology	Production agronomy
NU-113	Botswana	Agronomy/Physiology	Millet vs. sorghum
	Niger	Agronomy/Physiology	Millet legume rotation
NU-114	Niger	Agronomy/Physiology	Nutrient utilization
NU-116	Niger	Agronomy/Physiology	Water-use efficiency in millet intercrops Residue management
MSU-111	Colombia	Agronomy/Physiology	Acid soil tolerance
AZ-101*	U.S.A.	Agronomy/Physiology	Drought resistance
TAM-125	Niger	Entomology	Millet stemborer and head girdler
KSU-108	Nigeria	Pathology	Bacterial diseases
	Niger	Pathology	
TAM-128	Botswana	Pathology	Charcoal rot
KY-101*	Sudan	Socioeconomics	Technology diffusion
PRF-105	Niger	Socioeconomics	Constraints to technology adoption
	Sudan	Socioeconomics	
NU-119*	Senegal	Food Quality	Mechanization of food products
TAM-126	Mali	Food Quality	Grain quality characteristics
KSU-101	India	Plant Breeding	Yield breeding/ germplasm exchange
	Kenya	Plant Breeding	
	Senegal	Plant Breeding	
	Zimbabwe	Plant Breeding	
PRF-103A	U.S.A.	Plant Breeding	Forage quality
NU-118	Botswana	Plant Breeding	Yield/germplasm exchange and selection techniques
	India	Plant Breeding	
	Mali	Plant Breeding	
	Senegal	Plant Breeding	
	Sudan	Plant Breeding	

*Project discontinued in last budget reduction.

kg/ha, sorghum 1200 to 1600. Pearl millet appears to be able to tolerate higher levels of Si, Ca, and Mg in leaf tissue than sorghum. It is evident that pearl millet has potential as a feed grain (or fodder) crop on acid soils in South America. Tolerance to acid soils is probably a traditional adaptation factor for pearl millet on the leached sandy soils in west and particularly southern Africa.

Millet vs. sorghum at low rainfall levels (NU-113). Adapted sorghum and millet cultivars were compared in Botswana at different fertility levels and planting dates. At rainfall levels of less than 350 mm, millet was a higher yielding crop and produced more stover. Youngquist, 1988.

Cereal/legume effects (NU-113). At Mead, NE, yields of millet grown after a legume (soyabean) benefited to the equivalent of the addition of 45 kg/ha N fertilizer. Similar longer term trials with sorghum indicated similar benefits and a gradual increase of yields indicating a sustainable improved production environment. In areas of low fertility, cereal/legume rotations should be emphasized. Gakale and Clegg, 1987.

Pearl millet intercropping and fertilizer effects (NU-113). Grain yields increased from 700 to 1190 kg/ha and stover yields from 2800 to 3840 kg/ha as N rates were increased from 0 to 150 kg/ha in Niger. Increasing plant densities increased yields in millet/cowpea intercrops and 100 kg N further increased millet grain yields by 100 to 390 kg/ha.

Mineral uptake and utilization (NU-114). Millet and cowpea cropping is being examined in Niger for N & P fertilizer responses in relation to light interception, biomass production and yield. The nitrogen use efficiency for a) biomass production (NE_1), and b) grain yield (NE_2), were compared in Lincoln between millet cultivars and sorghum. Under N stress, millet NE_1 values were generally lower than sorghum but higher for NE_2. Alagarswamy, et al., 1988.

Water-use eficiency in pearl millet/cowpea intercrops (NU-116). Earlier planting of higher yielding short season dual purpose cowpeas is recommended in pearl millet/cowpea intercrops in Niger where moisture often limits production. Using various degrees of shading and determining water-use efficiency (WUE = photosynthesis:transpiration) of millet and cowpea canopies, it was found that light intensity was the major component limiting cowpea production in the currently recommended millet/cowpea intercropping system. Altering the cowpea row arrangement and spacing between hills allowed more light on the cowpea canopy and increased cowpea grain and total dry matter yields by 15 and 24%, respectively. Reducing millet shading effects (without reducing millet yields) through the use of shorter varieties would also be beneficial. The direct and residual effects of cowpeas on intercropped millet yields are also being investigated. Leaving crop residues on the soil surface had dramatic effects on the millet crop in the following year in Niger. Two t/ha of residue increased grain yields from 200 to 1060 kg/ha and total dry matter from 740 to 3320 kg/ha. Eastin and Verma, 1988.

Water-stress effects (AZ-101). Using a Kansas hybrid and its two parents under line source irrigation in Arizona, it was shown that leaf water or crop water stress indices, based on canopy or leaf temperatures were better indicators of photosynthesis and yield than other measures. Osman, 1987.

Entomology

Millet stalkborer and millet head girdler (TAM-125). Work was conducted in Niger on the biology of these two common pests of millet to establish a basis for control. *Haimbiacha* (= *Acigona*) *ignefusalis* was the most important species of stemborer on pearl millet and was more frequent in earlier plantings in 1986 when populations were high. Lower populations in 1987 did not show the same pattern. In contrast, attack by the millet head girdler *Raghuva* (= *Heiliochielus*) *albipunctella* was higher on early plantings that were earlier to flower. Though parasites attack the borer in millet and in non-crop plants, natural parasites/predators do not give effective control, indicating that exotic parasites might be better. A naturally occurring parasite (*Bracon hebetor*) had good potential to reduce millet head girdler populations and methods to increase numbers of this parasite could provide good control. Crop and non-crop refuse management can reduce the diapause larvae populations and maximize effects of parasites.

Pathology

Causal agents of bacterial diseases in pearl millet (KSU-108). Bacterial stripe of pearl millet, common in West Africa, was found to be caused by *Pseudomonas avenae* which can also affect maize, sorghum, and sugarcane (different from *P. rubrilineans*). Bacterial leaf streak, found in Niger and Nigeria, is caused by *Xanthomonas campestris* var. *pennamericanum*. Claflin, Ramundo, Leach and Erinle, 1987.

Charcoal rot on pearl millet (TAM-128). Charcoal rot was found associated with several crop species in

Botswana including pearl millet; however, pycnidia formation was not observed in pearl millet. Strong variety differences were tabulated. Diourte, 1987.

Socio-economics

Constraints to communication and adoption of new technologies (KY 101-102). In a study in N. Kordofan, Sudan, information about sorghum and millet technology spread more rapidly via male farmers and the market place was the most important source of information. Field demonstrations and extension programs on market days would be effective. Coughenour, Reeves, and Bidegaray, 1987.

Economic evaluation of new technologies (PRF-105). Based on modeling activities in Niger and Burkina Faso, the riskiness of fertilizer use in millet production was evident. The reduction in subsidies, lack of credit and low cereal market prices have further depressed the little use of fertilizer there was. Modeling studies in Niger show new varieties increasing incomes 10% but a fertilizer/variety/plant density package increased incomes 27%. It is apparent that the development of new cultivars can be made more rapid if low moisture and nutrient stress effects can be reduced by agronomic interventions. However, the instability of cereal markets discourages the adoption of even low cost technologies. If the new technologies and (for the good years) a price floor of 50 CFA/kg were combined, then farmers' incomes would be increased by 42%. Adesina and Brorsen, 1987; Habash, 1987; Nagy, Sanders, and Ohm, 1987 and 1988.

Grain Quality

Evaluating pearl millet germplasm for good quality (NU-119). In conjunction with the Institut de Technologie Alimentaire Dakar, Senegal, making millet arraw was successfully mechanized using a 'V' blender. A taste panel could not detect substantial differences between arraw made from 4 pearl millet varieties grown in the U.S. All were rated acceptable. Analysis of millet cultivars grown in Nebraska and Kansas showed bushel weights between 57-61 lb./bu, crude protein 9.7-15.7%, and fatty acids from 4.7 to 7.7%.

Food nutritional quality of sorghum and millet (TAM-126). The microstructure of pearl millet kernels has been investigated by light, fluorescence and scanning electron microscopy. Spherical kernels generally decorticate more easily. Poor decortication has a stronger adverse effect on Tô (thick porridge) quality than do variety differences. Research in Mali found that Sanio (late maturing) millets generally mill better than Souna (early maturing) varieties and produce better couscous.

In continuing research on producing shelf-stable millet products, parboiling appears promising. The decortication process is easier and less wasteful after parboiling. The product can be quickly cooked, like rice. Storage tests continue.

The composition of pearl millet grain suggests it has potential as a feed grain. The "in vitro" protein digestibility of pearl millet is higher than that of sorghum and maize.

Plant Breeding

Pearl millet breeding (KSU-101). The KSU pearl millet breeding program was started by Dr. A. J. Casady in 1969 at Manhattan. The Fort Hays program started in 1971. USAID strengthening grant, obtained in 1978, was phased into the INTSORMIL program in 1979-80. Collaboration with ICRISAT personnel and Senegal, Zimbabwe, Botswana, Kenya, and India have resulted in exchanges of germplasm. KSU materials derived from crosses between elite Kansas lines and improved importations are selected for desirable plant type, large seed size, and improved stand establishment capability, lodging resistance, yield potential, and food quality. Materials are returned to collaborators as F_2 families, advanced inbred lines and as components of populations. KSU materials reselected by ICRISAT are being used in nearly all Indian breeding programs and at least one KSU-101 A-line is used in large-scale hybrid seed production by an international seed company. Breeding materials cycled between ICRISAT and KSU show improvements beneficial to both parties. The performance of F_1 hybrids indicates pearl millet yield potential approaches or equals that of sorghum; grain yields in excess of 5000 kg/ha have been obtained.

Forage quality in brown midrib pearl millet (PRF-103A). A bmr mutation which reduces plant lignin concentration 20% and increases forage quality was induced in pearl millet with mutagens. Cherney, et al., 1988.

Breeding pearl millet for developing countries (NU-118). The principal objectives of this project are to supply collaborating scientists at LDC locations with both useful genetic material and information on how best to select the required types of varieties or hybrids for grain production. In order to develop genetic material useful to most collaborating scientists in African situations, crosses must be made between their best varieties and elite

U.S. lines and the early generation progeny used in the collaborative research.

The main emphasis in NU-118 has been the continued development of elite inbred lines which will be used in both custom crosses with host country varieties and to produce parental lines and varieties for the U.S. Over one thousand F_4-F_6 lines from tropical x early parent crosses were evaluated and selfed in 1988, and backcrossing commenced on male sterile testcrosses. Some selection was possible for lodging resistance. Backcrossing, selfing and hybrid production was continued on elite lines sent to the winter nursery. Custom crossing commenced using nine leading Mali varieties in the winter greenhouse and F_2 seed produced.

Recurrent selection continued through modified mass selection on the Nebraska Dwarf Pearl Millet Population and on testing varieties EDS and MLS produced from it. Topcrossing these varieties to a seed parent increased yields 20-30%. Such topcross hybrids are likely to be more stable in LDC conditions and easier to develop.

Post-graduate thesis research studies were commenced on lodging resistance, effects of a recessive chlorophyll mutant on growth and yield, and on the relationship of the performance of a synthetic variety with a given set of parent lines, evaluating these per se and as hybrids. In 1988, a regional pearl millet grain yield trial was conducted for the first time in the U.S. in Mississippi, Indiana, Kansas, and Nebraska as an M.S. thesis for a MSU student from Zimbabwe, and contained KS and NU varieties and hybrids. Andrews, 1986; Andrews and Stegmeier, 1985.

Future

Results obtained to date, and more experience of the constraints, give clear indications to research required in Africa to improve pearl millet production. The value of trained scientists returning to work in their countries cannot be over-estimated and they are a key component in collaborative research.

More emphasis is needed on "production agronomy" research--on technologies which will improve soil moisture and nutrient status. This will involve experiments at farmers production levels on rotation, intercropping, fertilizer application, cultivation and especially residue management. The effects of residue are so dramatic (and have been also demonstrated independently with similar results by IFDC/ICRISAT) that they must be further investigated. As pointed out by PRF-105 new cultivars will be easier to produce and will perform better if the probabilities of moisture and nutrient stress are reduced agronomically. Genetic tolerance to various pathogens and insect pests will be required as before, but it has become apparent that unless the millet head girdler can be controlled, or resistance identified, the strategy of using earlier maturing varieties which are severely attacked, will be denied. Losses of 40% have been reported in Mali and there is an opinion that head girdler incidence has generally increased in the last decade. It is crucial, therefore, that more work be done on control of this pest.

Socio-economic studies have highlighted poor markets and disastrous drops in millet grain prices in good years as serious constraints to the adoption of new production technologies, particularly purchased inputs. Traditional methods of millet production (whose productivity are now being affected by environmental degradation) are low cost/high return situations. Farmers simply will not take the investment risk of relatively costly technology when the outcome is uncertain even in good years, particularly if they have the choice of an alternative safer (partly because of more stable market prices) enterprise, such as a cash crop--sesame, roselle, groundnuts, etc. The main changes needed to strengthen markets are institutional and infrastructural and thus are largely beyond the scope of INTSORMIL (except to highlight the problem). However, diversification of products made from pearl millet can assist in strengthening markets. Research is needed on products which have a long shelf-life and from which it is easy to prepare attractive food (such as arraw). If food product research is not pursued, we will have a deteriorating situation where the utilization of a natural food production resource in pearl millet growing countries is eroded by a shift in peoples food preferences (particularly in urban areas) to imported or higher priced cereals like wheat and rice.

Since the "green revolution" in wheat and rice, plant breeding has been thought to be the prerequisite to improved production. In stressful dryland production, the situation is much more synergistic. Clearly in stressful conditions, agronomic practices which reduce stress effects become very important. Genetic improvement then becomes a component in the total package and it can have more impact as productivity levels rise. Once accepted, new varieties are the most cost effective technology available. Yield potential is important at any level of production and it is in the area of increasing yield potential that U.S. pearl millet breeding programs can make important contributions (as has been the case in other crops). The process by which this will be achieved has commenced, that is making crosses between the best developing country varieties and high yielding U.S. lines, and will be

realized through selection in the resulting populations in collaborative breeding projects in developing countries, where adapted segregates can be identified. Hybrids are potentially useful in parts of some African countries, and some research on these is desirable. New male sterility systems as have been developed by Marchais and Tostain (1985), Hanna (1987), and Hanna et al. (1987) may provide more scope in hybrid breeding. Indeed the use of apomixis, if it ever can be transferred from *Pennisetum squamulatum* (Dujardin and Hanna, 1988) would revolutionize pearl millet breeding, seed multiplication and control of smut and ergot. These examples show the value of basic research and INTSORMIL should be more involved at this level.

In the U.S., breeding for higher yields and adequate lodging resistance will be continued. Good progress has been made recently both in Kansas and Nebraska in developing combine hybrids. A 15 ha dryland field in Kansas produced 65 metric tonnes of grain at 16% protein. A prerequisite to adoption by farmers is market development and more research is underway to characterize the comparative advantages of pearl millet in steer and poultry feeding tests. Commercial interest has also been recently expressed in cooperative feeding tests.

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Striga: A Model for Collaborative Interdisciplinary Research

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Introduction

Striga species are endemic to the semi-arid tropics, occurring on a wide range of wild host plants and producing large quantities of tiny, long-lived seeds, which render their elimination impossible (Doggett, 1984; Edmunds, et al., 1970). Where cereals are monocropped, *Striga* damage and not exhaustion of soil fertility is responsible for deterioration of yield (Basinski, 1955; Wilson-Jones, 1953). As population pressures result in more continuous cereal cultivation the Striga problem is increasing (Ayensu, et al., 1984). Consequently, researchers are seeking ways to improve crop yields and reduce *Striga* damage on *Striga*-infested lands.

One control method advocated since earliest times is hand pulling of aerial stems as they emerge (Wilson-Jones, 1953), but young shoots may break off below the soil surface and regrow rapidly (Ramaiah and Parker, 1982). In addition, removal of emerged plants may reduce competition among *Striga* plants on the host root system and stimulate growth of unemerged plants (Ogborn, 1972). To be effective, removal of *Striga* must begin early (Bebawi and Farah, 1981a; Egley, 1971), should continue throughout the growing season (Tarr, 1962) and uprooted flowering plants must be destroyed to prevent immature ovaries from producing seed (Andrews, 1945). Although there is one report to the contrary (Ramaiah, 1985), hand pulling of *Striga* in dense infestations is generally considered to be impractical due to the intensive labor involved and the absence of immediate return in the form of increased yield (Doggett, 1970; Ogborn, 1972; Wilson Jones, 1953).

Varietal Resistance to *Striga*

Varietal resistance may be the most promising economic control measure since adapted, resistant cultivars can be grown under conditions or erratic rainfall and low soil fertility and require no costly inputs on the part of subsistence farmers (King and Zummo, 1977; Musselman, 1980; Ramaiah and Parker, 1982). Sorghums resistant to *S. hermonthica* in Africa have been identified (Doggett, 1965; Ejeta and Jain, 1982; Kambal, 1979; King, 1975; Ramaiah, 1987) but resistance frequently does not hold up across geographical regions. The variable performance of host resistance in different areas may be due to the existence of intraspecific physiological variants of the parasite (Bebawi, 1981b; King and Zummo, 1977; Parker and Reid, 1979).

We compared six introduced sorghum varieties for yield and *Striga* resistance at several locations in Niger during the 1986 and 1987 cropping seasons. Yield and *Striga* number per hill are summarized in Table 1 for the best resistant variety (SRN39) and the local checks.

Under conditions of heavy *Striga* infestation in 1986 the local cultivars were nearly destroyed (yielding 0-77 kg/ha) whereas SRN39 yielded 1,626 kg/ha. The mean grain yield of the local cultivars under *Striga*-free conditions was only 1,071 kg/ha. In 1987 *Striga* infestation was considerably reduced and the performance of the infested local cultivars greatly improved. Even the, SRN39 outyielded the mean of the local cultivars, producing 2,503 kg of grain/ha compared to 1,606 kg/ha for the local cultivars. In both years *Striga* number was dramatically reduced on cultivar SRN39 compared to the mean of the local cultivars (12.1 vs 37.5 and 0.03 vs 7.6 *Striga*/hill in 1986 and 1987, respectively).

Genetics of *Striga* Resistance

Few reports of investigations into the genetics of resistance to *Striga* in sorghum have been published. Kulkarni and Shinde (1985) reported field tolerance to *S. asiatica* to be governed by non-additive gene action. Obilana (1984), defining resistance as "low total number of *Striga* per sorghum plant", reported high (78%) broad sense heritability of this trait. He found gene action to be non-additive with over-dominance of susceptibility and estimated that two to five genes control reaction to *Striga*.

We investigated the genetics of resistance in sorghum cultivar SRN39 in an outdoor pot trial during the 1987 growing season. SRN39 is a tan plant zerazera derivative and P954063, the susceptible parent, is a colored plant zerazera derivative. We worked with 30 pots of each parent and of their F_1, 100 pots of the F_2 and 50 pots each of the backcrosses to both parents. Pot soil was prepared by hand mixing two parts of clay to one part each of sand and cow manure. The top five cm of soil in each pot was uniformly infested with approximately 70,000 *Striga* seeds

Table 1. Performance of resistant sorghum cultivar SRN39 compared to four local cultivars under *Striga*-free and *Striga*-infested conditions in Niger in 1986-87.

	1986			1987		
	Grain Yield (kg/ha)			Grain Yield (kg/ha)		
Cultivar	U[1]	I[2]	*Striga* no/hill[3]	U[4]	I[2]	*Striga* no/hill[3]
BDF	886	45	20.5	1,874	2,387	5.0
Bagoba	1,324	0	39.1	2,096	1,765	13.3
Tcholori	1,077	24	32.6	1,790	984	5.8
L-30	996	77	57.3	1,754	1,288	6.3
SRN39	926	1,626	12.1	1,807	2,503	0.0
Mean of 4 local cultivars	1,071	37	37.5	1,879	1,606	7.6

1 Mean of three uninfested locations: Kolo, Lossa and Bengou.
2 Infested location: Birni N'Konni.
3 Mean of ten hills at harvest.
4 Mean of four uninfested locations: Kolo, Lossa, Bengou and Birni N'Konni.

which were conditioned by watering pots one week prior to sowing sorghum.

The superior resistance of cultivar SRN39 was evident in pots as it had been in the field. Genotypic differences existed for days to *Striga* emergence and *Striga* number at the various counts. Broad sense heritabilities for *Striga* number at 37 and 44 days after sowing were 43 and 38%, respectively. Increasing *Striga* number was significantly correlated with increasing days to sorghum flowering and decreasing sorghum yield. Mather and Jinks' scaling test showed that observed variation could be explained by its additive and dominance components. Decrease in *Striga* number was inherited recessively and curve fitting showed that this trait may be governed by a single gene.

Cultural Control of *Striga*

Application of nitrogenous fertilizers is a short-term cultural measure which may result in immediate reduction of *Striga* infestation. Nitrogen in the form of sulphate of ammonia was reported to delay emergence of *Striga hermonthica* (Agabawi and Younis, 1965) and reduce its incidence (Last, 1961) and dry weight (Last, 1960b, 1961) on sorghum. Application of urea also reduced *S. hermonthica* incidence (Last, 1960a) and dry weight (Bebawi, 1981a, 1988; Last, 1960a) on sorghum. Nitrogen in the form of ammonium nitrate reduced incidence of *S. asiatica* on maize in South Africa and the United States (Farina, et al., 1965; Shaw et al., 1962).

We conducted field studies addressing the effect of nitrogen fertilizer and tillage treatments on levels of *Striga* infestation on sorghum. Results from 1986 were reported earlier (Hess and Ejeta, 1987). Application of 100 kg/ha of nitrogen (in the form of urea) reduced the number of emerged *Striga* plants, delayed *Striga* flowering and increased sorghum straw and grain yields. Tillage by animal traction did not bury *Striga* seed sufficiently deep to reduce the seed bank in the soil, but nitrogen fertilization used in combination with varietal resistance could reduce the damaging effect of *Striga* in naturally-infested fields in Niger.

***Striga* Biochemistry and Biotechnology**

Although few details are known of the fundamental biology and biochemistry of *Striga*, some unique features are apparent (Riopel, 1983). Because of its complete adaptation to the lifestyle of an obligatory parasite, *Striga* has given up control of its early development to its host plant. Only in response to a chemical signal from the host plant will the *Striga* seed begin the developmental process and germinate. Genes activated by this signal are turned off by another chemical signal, again from the host plant. This second signal also activates another set of genes con-

trolling the second developmental stage, the formation of the haustorium by which the *Striga* radicle attaches to the host root. It is likely that other chemical signals are exchanged at later stages of the host-parasite relationship. There are indications, for example, that *Striga* may produce a toxin which gets transported throughout the host causing the characteristic symptoms of *Striga* infestation (Graves, et al, 1988).

Recently both of these signals controlling initial stages of *Striga* development have been identified from sorghum, the first natural host of *Striga* to yield this information. We reported that sorghum root hairs exude an oily polyphenol/quinone which has various alielochemical activities (Netzly & Butler, 1986). Dr. J. Riopel of the University of Virginia helped us establish that this material contains a germination stimulant for *Striga*. With help from Dr. D. Lynn of the University of Chicago we determined the structure of the major component and found it to be a unique quinone unlike anything previously reported from sorghum or any other cereal (Chang, et al, 1986). It is the unstable hydroquinone precursor of this quinone which is active as a germination stimulant for *Striga*. We have identified three additional minor components of the sorghum root exudate as close analogs of the major quinone/hydroquinone pairs all are active as *Striga* germination stimulants, and also have other activities more likely to benefit the sorghum plant. We have collectively named these materials "sorgoleone" (Netzly, et al, 1988).

The chemical instability of the active hydroquinone of sorgoleone as well as its low water solubility confine its activity as a *Striga* germination stimulant to a narrow zone close to the sorghum root (Chang, et al, 1986). *Striga* seeds are so tiny that only those in close proximity to the host root have any change to reach it, so these characteristics of the stimulant are favorable to *Striga* because the seeds not near the root remain viable for subsequent seasons, making *Striga* control more difficult.

The signal for haustorium initiation, the second developmental signal from the sorghum host, has been identified by Dr. Lynn as a simpler quinone, 2,6-dimethoxy-p-benzoquinone (2,6-DMBQ) (Chang & Lynn, 1986). It has been suggested that this is not directly produced by the sorghum root, but is a breakdown product of sorghum root lignin caused by an enzyme from the nearby *Striga* root (Chang & Lynn, 1986).

Thus we have broken the chemical code of the early, crucial signals upon which *Striga* depends for development. Because of *Striga's* complete dependence upon an external source of these signals, it is uniquely vulnerable to their disruption. Interruption of the signals should prevent development of the parasite; introduction of spurious signals in the absence of the host should cause it to commit to suicidal development (*Striga* can survive only a few days in the absence of the host). There is reason for hope that the new chemical information represented in the structures of these signals can be developed into more effective methods for controlling *Striga*.

Sorgoleone is too unstable and not sufficiently water soluble to utilize in *Striga* control by treatment of infested fields to stimulate germination in the absence of a host, but appropriate analogs should be readily obtained. Some analogs, both synthetic and natural materials, are already commercially available. We anticipate the development of both germination stimulants and germination inhibitors based on sorgoleone. Inhibitors would not clean up an infested field, but would have the virtue of application as a seed treatment rather than the more laborious soil treatment necessary for germination stimulants, and inhibitors should permit normal crop development in an infested field. Inhibitors of haustorium development based on 2,6-DMBQ should also be effective. One sorghum cultivar relatively resistant to *Striga* apparently overproduces 2,6-DMBQ so that haustoria develop further from the root and cannot attach.

The new tools of biotechnology offer potential for *Striga* control. We are adapting our in vitro sorghum tissue culture program to select for somaclonal variants having characteristics such as low sorgoleone production which should contribute to resistance or tolerance to *Striga*. A different approach might be the characterization of the receptor sites for sorgoleone on the *Striga* seeds. It should be possible with appropriate techniques such as fluorescent labelled antibodies to identify and characterize these sites in order to design more effective inhibitors to block them. Eventually we would like to identify and characterize the protein products of the genes activated during the early stages of *Striga* development, and go on to the biology of *Striga*-host interactions at the molecular level of the gene. For this basic research it will be necessary to obtain support from other agencies such as NSF.

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Breeding for Drought Tolerance

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Introduction

Drought is the most important constraint to sorghum and millet production worldwide. Breeding for drought tolerance is a major effort within INTSORMIL involving many scientists, institutions, locations, and all major host countries. In this paper, I will deal essentially only with sorghum.

Investigators and Projects

The major U.S. Principal Investigators involved with drought and breeding for drought tolerance, the major thrust of their program, and their primary host country collaborative sites are:

D.T. Rosenow and L.E. Clark (TAM-122) - Field breeding and screening nurseries in West Texas and germplasm development - Sudan, Mali, Niger, plus some in Honduras, Colombia, and Botswana.

G. Ejeta (PRF-107) - Germplasm development and screening in Indiana and Texas - Niger, Sudan.

D.J. Andrews (NU-115) and NU-118) - Sorghum and Millet - Sorghum (drought cooperative with Kansas-Botswana). Millet (germplasm development - Mali, Senegal).

W.D. Stegmeier (KSU-101) - Millet only - Kansas - Germplasm development - Niger.

F.R. Miller (TAM-121) - Yield, adaptation, food types - rates when drought occurs.

G.C. Peterson (TAM-123) - Insect resistance - rates when drought occurs.

J.D. Axtell (PRF-103A) - McKnight Foundation Grant-Niger.

L.M. Gourley (MSU-104) - Drought aluminum associations - Colombia.

J.D. Eastin (NU-116) - Field screening techniques - Nebraska and Kansas - Niger, Sudan.

C.Y. Sullivan (NU-123) - Physiology of drought - Mali.

Host Countries

The major host country sites involved in drought breeding research include:

Sudan - Major effort
Niger - Large effort
Mali - Large effort
Botswana - Moderate effort
Honduras - Some effort
Colombia - New initiative in Northern Colombia

Concepts

Drought tolerance is a very complex phenomena in sorghum. Until recent years, little effort has been directed specifically to breeding for drought tolerance. Recent developments in the understanding of drought and in field screening techniques have contributed to an increased emphasis on breeding for improved drought tolerance in sorghum in the U.S. and internationally.

When discussing drought tolerance in sorghum, it is essential to consider stage of growth. Three important growth stages are recognized in sorghum as they relate to drought stress:

(1) Seedling establishment - vegetative stage (GS1)

(2) Pre-flowering stage (head differentiation to flowering) (GS2)

(3) Post-flowering stage (flowering to physiological maturity-grain development (GS3).

Most of the INTSORMIL's drought tolerance breeding research on sorghum has been at the pre- and post-flowering stage.

Two distinctly different types of stress response have been identified in the Texas program. One type (pre-flowering) is expressed when plants are stressed prior to flowering during panicle development (GS2), while the other (post-flowering) is expressed when severe moisture stress occurs during the grain filling stage (GS3). Plant symptoms indicating either a desirable or undesirable response to stress at these two stages have been described and can be visually rated in the field. Symptoms of pre-flowering drought stress susceptibility include: leaf rolling; uncharacteristic leaf erectness; leaf bleaching; leaf tip and margin burn; delayed flowering; "saddle effect" - only end plants next to alleyways produce a panicle; poor panicle exertion; panicle blasting and floret abortion; and reduced panicle size. Tolerance to pre- flowering drought stress is indicated by the alternative condition in each instance.

Symptoms of post-flowering drought stress susceptibility include premature plant (leaf and stem) death or plant senescence, stalk collapse and lodging, stalk rot (charcoal rot, *Macrophomina phaseolina*), and sometimes a significant reduction in seed size, particularly at the base of the panicle. Tolerance is indicated when plants remain green and fill grain normally. Such green stalks are resistant to charcoal rot and stalk lodging. The cultivars are referred to as having good "stay-green" or as "non-senescing". The post-flowering response is most obvious and distinct in plants which have been grown under favorable soil moisture and growth conditions until flowering, with a severe water deficit developing during the late grain fill stage. When water stress develops gradually and occurs over the entire season, these distinct stress responses may not be as obvious.

High yielding sorghum genotypes with a large grain sink size relative to the vegetative portion of the plant are more susceptible to post-flowering drought stress than are low grain producing genotypes. Susceptibility to charcoal rot is predisposed by severe water stress during the latter stages of grain fill. Because of this relationship, charcoal rot is treated in the Texas program primarily a post-flowering drought stress problem.

Excellent sources of tolerance to each type of stress have been identified. Many cultivars which possess a high level of tolerance at one stage tend to be susceptible at the other stage; however, some genotypes possess moderate to good tolerance at both stages. Breeding efforts are underway to enhance the pre- or post-flowering drought tolerance in sorghum genotypes as well as combining good levels of both pre- and post-flowering drought tolerance into the same variety or hybrid.

Breeding and Screening Techniques

The association of physiological traits with drought tolerance in sorghum has been studied by several workers. Technology exists for such evaluation, but breeders have made little use of physiological parameters to select for improved drought tolerance in sorghum. It appears that individual physiological traits identified to date are not sufficiently related to drought response to merit selection based on that trait. Distinct plant responses such as those described in the previous section appear to be the best method of evaluating drought response in sorghum.

Many sorghum breeders believe that progress is most rapid when early generation selection is practiced under optimum or near optimum conditions, prior to evaluation under biotic or biotic stresses. This enhances expression of yield and reduces environment x genotype interactions during early generations. Regarding drought tolerance in sorghum, the extreme variability in timing and amount of rainfall, along with soil variability in such traits as soil type, depth, fertility, pH, water content, and nutrient toxicities contribute to a large genotype x year or genotype x location interaction, particularly under low rainfall conditions. The present understanding of the distinctly different reactions to drought stress at different growth stages explains much of the lack of progress in the past when selecting sorghum under low rainfall, dryland conditions.

The approach to breeding for drought tolerance in INTSORMIL is primarily an empirical one utilizing natural stress in large field screening nurseries along with subjective visual scoring of symptoms or actual yield measurements. Regulation of moisture stress at different stages of growth is essential to significant progress in breeding for drought tolerance. Control over the timing and degree of moisture stress can be achieved through varying the amount and timing of irrigation, varying planting dates, and through the use of multiple locations with differing environments. Irrigation differential is best used in dry environments and can be achieved in the same or in adjacent nurseries.

The approach in Texas to breeding for drought tolerance is to practice early generation selection in large field screening nurseries under naturally occurring dryland or limited irrigation conditions. As generations are advanced, nurseries and tests are duplicated under two or more conditions, with one being under favorable moisture conditions where yield potential is expressed. We evaluate a large amount of diverse germplasm in field

screening nurseries at several locations having differing stress environments, different planting dates, and different water regimes. This approach helps to insure stress at different stages of growth. From this, the precise type of drought tolerance in a particular genotype can be defined, and genotypes which combine tolerance over a wide range of stress conditions can be identified.

In the pre-flowering screening nurseries (Lubbock Dryland, Wellman, Chillicothe), the combination of sandy soil (Wellman), high summer temperatures, and low mid-summer rainfall usually creates drought stress during the pre-flowering growth stage, especially in mid or late June plantings. In our post-flowering screening nurseries (Lubbock, Halfway), ample irrigation water is applied during the early growth stages to induce good growth and yield expression. Irrigation is terminated prior to anthesis to allow moisture stress to develop near the flowering stage and intensifying during grain fill.

In nurseries where severe water deficits occur prior to flowering during the panicle development stage, subjective ratings can be recorded whenever distinct differences in drought response appear. Rating is done on a 1-5 scale where 1 = excellent and 5 = very poor response. Prior to heading, ratings can be made on leaf stress symptoms indicating drought susceptibility such as rolling, excessive erectness, bleaching, and firing. Ratings can be made on each trait separately, but are often combined into a single overall drought susceptibility rating. Some cultivars are very susceptible to another kind of leaf necrosis called leaf firing, where large sections of the leaf die rapidly and usually at about flowering time. This type of leaf firing is different from the leaf margin and tip burn described previously and appears to be primarly a heat response. Later appearing symptoms caused by moisture stress prior to flowering include delay in flowering, panicle and floret blasting, poor panicle exsertion, reduced panicle size, and the "saddle" effect. These symptoms can be rated individually or in combination. Delay in flowering is evaluated by comparison with non-stressed plantings. These late-appearing symptoms are the best evaluation of pre-flowering drought tolerance. Such ratings may be made at or after maturity.

In nurseries where post-flowering drought tolerance is evaluated, each entry or plot is subjectively rated for the amount of premature leaf and plant death. Ratings are made on a 1 to 5 scale where 1 = completely green, to 5 = dead. Ratings are normally made at or soon after physiological maturity, but can be made anytime that differences among genotypes appear. Percentage of plant lodged due to stress is also taken. In West Texas, the nursery is often left standing for an extended period following maturity to allow stalk lodging to occur. This facilitates the identification of entries which have stalks weakened by moisture stress. It also allows for selection of genotypes with anatomical stalk strength traits.

Quantitative data such as number of seeds per area or head, grain size, grain yield, grain yield of standing plants, etc., can be taken in drought screening nurseries. It may be useful on advanced materials, however, visual evaluation of these traits is quite easy, accurate, and quick, and is recommended for breeding progeny.

Knowledge of maturity is critical when evaluating sorghum for drought tolerance. Sorghum is particularly susceptible to pancile and floret abortion or blasting when moisture stress is severe just prior to heading. Also, sorghum is very susceptible to post-flowering stress in the period just prior to physiological maturity of the grain. In both cases, plants a few days earlier or later in maturity may show little damage. Therefore, maturity should be considered carefully when evaluating for drought tolerance. Flowering notes should be taken on all plots of advanced materials and comparisons made only among entries of similar maturities.

The use of alternating standard checks every 5 or 10 plots in drought screening nurseries is also important. The checks should vary in drought response and maturity. Short (5-6m), single row plots are adequate in screening nurseries.

Irrigation gradient systems can be very useful for drought tolerance screening in dry environments. They allow evaluation of response to a range of stress under otherwise identical conditions and allow manipulation of the onset, cessation, and degree of stress. Disadvantages are the inability to control rainfall and with sprinkler systems, the amount and timing of irrigation may be less than ideal. They are of only limited value in areas where rainfall is high during the main portion of the growing season. Use of gradients during the dry, off-season is not recommended due to day length differences which can have major effects on yield responses, especially on photoperiod sensitive sorghums.

Rainout shelters are very useful to supplement evaluations made in field nurseries. Untimely rains often prevent evaluation or restrict evaluations to short periods during the growing season. Rainout shelters can be used to greatly accelerate and improve the efficiency of selection by controlling both timing and amount of water applied, while otherwise maintaining a near-normal environment.

In Sudan, drought screening nurseries similar in many respects to those used in West Texas have been successfully used in breeding for drought resistance. Breeding material is screened in large field screening nurseries and subjectively rated. One nursery is under sandy soil, low (350 mm or less) rainfall, and stress prior to flowering is usually severe. The other is under heavy soil and higher rainfall, with stress often becoming very severe late in the season during grain fill.

The drought breeding program at Purdue uses many of the same principles regarding screening, rating for pre- and post-flowering drought tolerance, etc. as are used in Texas. At Nebraska, screening has been primarily for tolerance at the GS2 (pre-flowering) stage. In Texas, emphasis is on both pre- and post-flowering tolerance, combining both into the same cultivar, and yield stability over a broad range of stress environments.

Through germplasm exchange and evaluation, it has been proven that U.S. developed and identified drought tolerant germplasm has direct relevance to use in LDC's. Drought tolerant lines selected in the Sudan and the U.S. (Texas and Purdue) perform very much as expected at the other location. Pre-flowering tolerant lines developed in Texas perform very well on the pre-stress location (El Obeid) in Sudan, while post-flowering tolerant lines identified in Texas also possess very good "stay green" under heavy soil (Gadambalia and Wad Medani) in Sudan. This also appears to be true in West Africa (Niger, Mali) and Botswana. In some parts of West Africa, care must be taken to not confuse drought response with "soil toxicity" problems.

The extreme importance of drought tolerance in the seedling establishment - early vegetative stage in much of the developing world is recognized. However, it is not important in the U.S., and genotypic differences have not been observed in field nurseries in Texas. Off-season screening should be very useful and some has been done in Mali as part of the INTSORMIL/MALI collaborative activities. More information is needed on drought tolerance at this stage, including seed, rooting, etc., effects, and the relationship of seedling drought tolerance to that at more advanced growth stages.

A major portion of INTSORMIL's drought tolerance breeding program activities is in developing elite germplasm for use in LDC host countries. This involves crossing introduced drought tolerant x U.S. elite and x U.S. drought tolerant, and subsequent distribution of F_2, F_3, or F_4 seed to the host country for selection and use. It also involves direct use of U.S. drought tolerant lines in Host Country breeding programs.

It is suspected that drought tolerance in pearl millet may be very similar to that in sorghum, with different and specific responses depending on the stage of growth at which the stress occurs.

Summary and Conclusions

1. The empirical approach, utilizing large field screening and breeding nurseries, subjective scoring, and the principles described in this paper, is a drought breeding and screening technique that has proven successful.

2. For drought tolerance screening, the following is encouraged: multi-locations with differing stress, diverse germplasm, quick visual ratings, screening in early as well as in advanced generations, exchange of drought tolerant germplasm among sorghum workers, and constant exchange of information. Look for stability of yield across environments.

3. Utilization should be made whenever possible of the local environment in the regular growing season. It is important to be familiar with the normal rainfall pattern, soil type, soil problems, and with other major constraints to growth and production, so that the effect of moisture stress will not be confused with or confounded with problems caused by other biotic or abiotic factors.

4. Be familiar with and be able to recognize the various drought responses of sorghum at the three major stages of growth. Know the stage of growth when stress occurs in each nursery, by recording flowering date, rainfall data, etc..., and make selections and interpretations accordingly.

5. The excellent drought tolerance, yield stability, and other adaption traits found in many local cultivars in LDC's should be utilized extensively in drought breeding programs.

6. There is a need for a better understanding of the genetic and physiological mechanisms of drought resistance. Basic studies are encouraged and should contribute to the drought breeding program and the development of more rapid and efficient screening techniques.

7. More research is needed on drought tolerance at the seedling stage.

Utilization Research: An Interscience Approach

Dr. L.W. Rooney
Texas A&M University

Sorghum and millet utilization research activities in INTSORMIL were initially designed to be integrated into the overall sorghum and millet improvement programs. Thus, the utilization PI's have collaborated extensively with sorghum and millet breeders, pathologists, entomologists, economists and sociologists as required to solve major constraints that limit sorghum and millet utilization. At the same time, more fundamental aspects of the chemistry of tannins, structure of sorghum and millet, digestibilities and fundamental chemistry of major processes have been partially elucidated. The CRSP concept has truly accentuated interdisciplinary research activities which have lead to the release of new improved cultivars with acceptable grain quality as well as yield and agronomic qualities.

Major sorghum and millet utilization constraints (Table 1) relate to the fact that sorghum and millets are produced and consumed as food mainly by very poor people. Therefore, until recently very little research was done to improve their quality for food and as incomes increase, consumers buy wheat or rice foods because acceptable processed foods from sorghum and millet do not exist. These constraints can be overcome by judicious research but it requires a long term approach. INTSORMIL has taken a multifacetted long term approach that is answering essential questions and providing potential solutions. INTSORMIL researchers have closely collaborated with ICRISAT and many other agencies on all aspects of utilization with mutually rewarding benefits.

Table 1. Sorghum and Millet Utilization Constraints

1. Sorghum and millet are considered coarse grains or poor people's food.
2. Very little research has been accomplished on sorghum and millet.
3. Inexpensive, subsidized imported grains adversely affect prices.
4. Inconsistent supply of grain for processing.
5. Difficult to process sorghum and millet into stable products.
6. No infrastructure to support modern technologies.
7. Need innovative low technology processes that can be applied at village levels.

Utilization Research Objectives of INTSORMIL

The general objectives of the INTSORMIL program on utilization (Table 2) are designed to address the most important researchable major constraints. The program ranges from very applied work of documenting major traditional processes and developing methods of testing for their quality in breeding programs to detailed chemistry of tannins and phenols as related to *Striga* and mold resistance. It includes basic factors affecting the digestibility of sorghum and innovative low technology methods of converting sorghum into SORI, a rice-like product. Each PI has specific objectives that relate to the broad objectives, each PI interacts with the others in INTSORMIL to avoid needless duplication of efforts.

Table 2. INTSORMIL's Objectives for Utilization Research

1. Identify and evaluate traditional sorghum and millet food systems.
2. Develop practical methods to select for quality in the breeding programs.
3. Determine physical, chemical and structural factors affecting food processing methods and nutritional quality.
4. Determine factors affecting grain weathering (mold) resistance and how to select for resistant types.
5. Develop modified or new processes to produce acceptable shelf-stable food products.
6. Determine the chemistry of tannins and phenols and their relation to pest resistance.

Accomplishments

INTSORMIL has made significant progress on all of the major research objectives. A large number of publications in referred journals have documented many accomplishments. Table 3 contains a partial list of accomplishments according to the various research objectives. Workshops, conferences, symposia and field days have been used to get the information to potential users.

Table 3. Some General Accomplishments of INTSORMIL Utilization Research

Objective 1 - Traditional Food Systems

1. Classified traditional sorghum and millet foods into major categories.
2. Defined important process parameters affecting processing quality and nutritional value of traditional food systems.
3. Postulated kernel characteristics required or desired for acceptable sorghum/millet cultivars.

Objective 2 - Methods of Selecting for Quality

1. Lab procedures for producing the major categories of traditional foods were developed, standardized and used to determine essential factors affecting quality.
2. Equipment and methods for decortication of sorghum and millet were standardized and applied in breeding programs to select for quality.
3. New simple methods for determining hardness, density, kernel texture and other properties were applied and developed.

Objective 3 - Factors Affecting Food and Nutritional Quality

1. Protein digestibility of cooked sorghum is lower than other cereals.
2. Traditional village processes, especially those involving fermentation and malting, improve protein digestibility significantly.
3. High sheer extrusion processes improve *In vitro* and *In vivo* protein digestibilities.
4. Lime cooked and raw sorghum fed to swine had 95% of the protein digestibility of lime cooked and raw corn. Lime cooking slightly decreased digestibility.
5. The cross linked kafirin protein fraction surrounds the starch granules affecting the digestibility of cooked sorghum. Addition of reducing agents improved *in vitro* protein digestibility significantly.
6. Protein matrix and protein bodies surrounding starch granules affect starch cooking properties which affects porridge quality.
7. Thick porridge quality is optimum for a sorghum with relatively hard endosperm texture.

Objective 4 - Grain Weathering and Molds

1. Grain weathering and molds significantly affect the milling properties and food quality of sorghum.
2. Brown, high tannin types are most resistant. Some tan, white types have tolerance to molds.
3. Head bugs affect food quality of improved sorghums in W. Africa. An improved sorghum (Malisor-7) has tolerance to head bugs and excellent food quality.
4. Field selection procedures for improving weathering/mold resistance are more effective than lab screening techniques.

Objective 5 - Product/Process Development

1. Prototype sorghum foods have been produced including breakfast cereals, snacks, composite flours for baked products and flours for precooked porridges.
2. Micronized sorghum for dry masa flours, breakfast cereals and snacks.
3. Processes for using sorghum and pearled sorghum for alkaline processing into tortillas and related products.
4. Development of a parboiling process using village level technology to manufacture shelf stable sorghum and millets for cooking like rice.

Objective 6 - Tannins and Phenols of Sorghum

1. Developed improved analytical methods for phenols and tannins.
2. Documented effects of tannins on nutritional value of sorghum.
3. Documented traditional village scale processing methods that inactivate tannins.
4. Determined that condensed tannins are located in the pigmented testa and outer pericarp of sorghum with B_1 B_2 S genotypes.
5. Developed a good understanding of the genetics/inheritance of tannins.
6. Documented the changes in tannins during kernel development.
7. Obtained information on the biosynthesis of tannins and the mechanisms causing their nutritional effects.
8. Isolated and identified Sorgoleon a phenolic that is related to *Striga* germination and may lead to its control.
9. Identified and determined quantities of nontannin phenolic compound in sorghum. Flavan-4-ols in red sorghums appear related to improved mold resistance. Efforts to related specific phenols to mold and insect resistance continue.

Many sorghum and millet programs now have improvement of grain quality as a major, high priority objective. More efforts to integrate post harvest technology

into the National Improvement programs are required; but, progress has been made. For example, the food technology lab in Mali monitors grain quality of cultivars from the breeding program on a continuing basis. Several new cultivars released in Mali have exceptionally high food quality.

Future Utilization Research Activities

The current general research objectives are appropriate, relevant and address the critical constraints. We have identified the major food systems so Objective 1 has been phased out; but, research activities on the other objectives must be continued as rapidly as possible. Restricted budgets have slowed progress in several areas. Table 4 contains a list of objectives that require significant additional future research.

Table 4. Future Needs: Utilization for Food, Feed and Industrial Products.

1. Develop micromalting laboratory and analytical procedures to determine sorghum and millet malt quality for use in beer, porridges, and weaning foods.
2. Introduce new low technology the methods for producing rice substitutes into sorghum and millet consuming areas.
3. Develop innovative low technology processes to increase the utilization of sorghum and millet.
4. Develop sorghums with improved digestibility, higher lysine and good processing properties.
5. Develop white grain with resistance to weathering and molds.
6. Develop specific kinds of sorghum for food processing, i.e., high lysine, sorghum for developing special weaning foods.
7. Improve the forage and stover quality of sorghum and millet.
8. Demonstrate use of sorghum and millet for livestock feeds.
9. Evaluate sorghum residue for fuel pellets, paper, building materials and other industrial products.

Recent developments in Nigeria and other areas have increased the use of sorghum in malting. Sorghum and millet malts generally have low levels of enzymes, varieties with high diastatic power are needed. Effective evaluating malting properties are not available.

Increasing the lysine and tryptophan content of sorghum has been an elusive goal for many years. Currently, quality protein maize (QPM) which has a hard endosperm and very significant increase in lysine and tryptophan is available in open pollinated varieties; hybrids are being developed. This demonstrates that cereals with improved essential amino acid content and good hard texture can be developed. Thus, we need to reexamine the opportunities to increase lysine content of sorghum. Successful QPM development will significantly decrease the nutritional value of sorghum relative to that of corn. Lysine can be increased in a hard endosperm sorghum; but to do so requires a significant commitment of time and funds.

More research on development of low technology processes to convert sorghum/millet into shelf stable processed foods is a very high future priority. Our preliminary work with parboiled sorghum looks promising. The practicality and economics of modified parboiling processes to enhance the value of sorghum and millet is a specific process that should be pursued.

Sorghum and millet stover and forage quality will become even more important. The use of sorghum and millet as feed grains for poultry requires only local adaptation and a consistent low cost supply of grain to enable the local poultry industry to prosper. Forage, stover and biomass properties of sorghum are similar and will require significant improvements in the future.

Utilization research is critically needed if sorghum and millet continue to be of major importance in the world. Research on food, feed and industrial use will improve sorghum and millet for many uses depending upon economics and government policies. For example, sorghum and millet use in Nigeria has expanded into many unexpected areas since the government restricted imports of wheat and barley. The INTSORMIL program is well designed to meet most of the needs; but, funding is short. Nevertheless, much has been accomplished by efficient use of existing resources.

Session VII: Accomplishments and Future Directio
for INTSORMIL Research by Discipli

- Summaries from Discussion groups.

Session Chair: Dr. Jerry Eastin

Speakers:
Dr. Charles Sullivan
Dr. Gebisa Ejeta
Dr. George Teetes
Dr. Larry Butler
Dr. R.A. Frederiksen
Dr. John Sanders

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Agronomy/Physiology

Dr. Charles Sullivan
University of Nebraska

Members of the discipline did not clearly separate goals into short or long-term. Since attaining goals is a continuous process, some progress is expected in the short-term even with goals that appear to be long-term.

The following goals have been identified:

1. To better define the environment in which our experiments are conducted, with emphasis on soils - their physical and chemical properties, type, classification, structure, fertility levels, and related factors, and also to improve on climatic and micro-climatic definition near the specific experimental sites. This is necessary for improved interpretation and comparative, critical evaluation of responses from site-to site and from time-to time.

2. To improve cooperation among CRSPs, for example, with TROPSOILS, in the soil component of agronomy, with the cowpea and peanut CRSPs in intercropping and rotations, and the small ruminant CRSP in relation to forage needs. It is also our goal to enhance cooperative efforts among disciplines within the INTSORMIL CRSP.

3. To increase on-farm research and utilization of farm resources to the extent possible, and with farmer participation promote the advancement of technology transfer.

4. To better utilize improved germplasm in agronomic and physiological experimentation.

5. To introduce and utilize other tools for enhancing objective realization, such as the use of crop models, or "success predicting systems". Modeling efforts would start with a simplified input and progress as needed for this tool to be of maximum use.

6. To establish expanded collaborative research projects on sorghum/millet, e.g., with legume rotations, and evaluate complex intercropping systems that bear on sorghum and millet production.

7. To broaden nitrogen utilization and nitrogen-efficiency studies by more closely examining the interaction of water supply and genotype relative to acute nitrogen stress often encountered in subSahara Africa.

8. To further evaluate residue management as related to grain and forage yields.

9. To more widely utilize stress screening techniques currently defined, and continue development of improved screening methodology for specific aspects of stress resistance.

10. To more clearly define the characteristics of root systems as related to responses in different soils and as related to water and mineral use and use efficiency, interactions with soil micro-flora, and genotype differences - with particular emphasis on differences between sorghum and millet root systems relative to the above factors and growth responses.

11. To continue efforts to attain a better understanding of mechanisms of plant growth, development and responses, particularly as associated with environmental stress at the site of growth. It seems logical that the more basic knowledge that is accumulated about a system, the more likely it can be manipulated to the desired purpose.

12. A final goal is to place increased emphasis on student training and follow with establishment of collaboration with the trained scientist upon return to his country. Agronomy/physiology presently has 20 students in training who will finish their training in the next one to three years.

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Breeding Program

Dr. Gebisa Ejeta
Purdue University

Accomplishments

1. The release for commercial cultivation of numerous sorghum cultivars, by our collaborators in several countries.

2. The development and release of midge resistant sorghum cultivars for use by public and private agencies.

3. The identification of grain mold resistant genotypes in germplasm backgrounds of good food quality grain.

4. The identification of sorghum lines with resistance to *Striga* both under Sudan and Niger conditions.

5. The definition of sorghum genotype reaction to drought as pre- flowering and post-flowering stress resistant has facilitated a practical screening for drought based on the type of the growing conditions in different zones. Germplasm thus developed has been mutually useful for both domestic and international collaborators.

6. One of the major contributions of INTSORMIL plant breeders is the generation of genetic variants for research by other colleagues towards understanding of various mechanisms affecting the productivity, stability, and quality of the sorghum/millet plant.

Cooperative research by sorghum breeders with other colleagues have led to a better understanding of the processes of improving productivity, nutritional quality, and responses to various kinds of stresses.

7. The development and release of Al-tolerant, A, B, and R lines and the promise this offers to wider use of A1-tolerant sorghum hybrids in acid soil zones.

8. Cooperative work with plant pathologists has contributed to the incorporation of high levels of host plant resistance to various diseases in sorghum.

9. Training of graduate students (both national and international) continues to be an important and successful function of INTSORMIL plant breeders.

New Areas of Priority Research

1. The area of whole plant utilization (alternative use, end use, etc.) of sorghum is recognized as a high priority area.

2. Development of appropriate germplasm for collaborative research towards a better understanding of economically important plant traits.

3. Understanding of the physiological and biochemical basis of drought resistance.

4. Basic understanding of the hormonal mechanisms associated with the major maturity genes in sorghum.

5. Pursue work in exploitation of the A_2 cytoplasm, to expand the use of the different taxonomic group in commercial hybrids.

6. Utilization of different cytoplasm backgrounds in pearl millet from related species for commercial exploitation of hybrid millets.

7. Expand the testing and development of A1-tolerant sorghum/millet genotypes to Africa.

8. An excellent potential exists towards use of A1-tolerant sorghum/millet hybrids in the U.S. and Latin America.

9. With proper funding, INTSORMIL research in *Striga* can be expanded for a potentially great pay off.

Entomology

Dr. George L. Teetes
Texas A&M University

The two entomology projects basically are designed and have objectives to provide integrated management systems for several insects pests of sorghum/millet in three LDC prime sites and the U.S.A.

The Mississippi State entomology project of which Dr. Henry Pitre is the P. I. has prime site involvement in Honduras.

Major accomplishments of the MSU entomology project in Honduras are:

1. The identification of sorghum seed and seedling pest species, assessment of their severity and methods for management.

2. Identification of Lepidopterous "Longosta" complex on seedling and whorl stage sorghum, assessment of their severity, and methods for management such as the impact of burning vegetation prior to planting on these pests in intercropped maize and sorghum (burning increases the incidence of the insect pest complex).

3. Population dynamics of the fall armyworm.

4. Identification of the antibiosis resistance characters of maicillos.

New areas of priority research will be to identify and assess the severity of panicle-feeding insect pests of sorghum in Honduras.

The insect pest identification and assessment objectives have been completed. The next step will be to validate the management strategies by incorporation into on-farm demonstrations.

Short term goals include putting into place and practice the knowledge gained on seed and seedling insect pests with extension personnel, and to provide recommendation for control of the Longosta complex to include weed control and limited pesticide use. A long term goal is to provide complete management systems for insect pests encountered by subsistence farmers with minimal input.

The Texas entomology project focuses on the use of plant resistance and biological control to manage insect pests of sorghum and millet in Honduras, Botswana, and West Africa (Mali and Niger). Drs. George Teetes and Frank Gilstrap are the P. I.s.

Major accomplishments have been the identification, evaluation and, with some, value assessment of sorghum resistance to sorghum midge, greenbug, spider mites, and sugarcane aphid. The resistance mechanisms have been determined and the role of these cultivars as a component of integrated pest management and the level of resistance based on economic injury levels have been assessed. This research has been supported by basic biological and ecological studies, and for some insects such as sorghum midge, even to the point of providing temperature driven mathematically models to simulate rates of biological events and population dynamics models that have pest predictive capabilities. Although screening, evaluation, agronomic improvement of resistant cultivars occur in the U.S., all accomplishments are directly applicable to LDC situations based on on-site trials. One insect for which resistance has been identified, the sugarcane aphid, does not occur in the U.S.

Major parasites and predators of aphid and stem borer pests of both sorghum and millet have been identified and the efficacy of several of them has been assessed. Insect pest and natural enemy biology and population dynamics have been studied. The pest/natural enemy relationship has been assessed and the foundation has been set for the colonization and release of natural enemies in selected areas of selected prime sites.

New areas of priority research will be to identify new sources of plant resistance to sorghum insect pests and stack genes for resistance to elevate the resistance level, colonize and release parasites of aphids and stalkborers, and reestablish a sorghum panicle-feeding bug research project from Niger to Mail.

Objectives that have been accomplished include those dealing with the identification of sorghum resistance to sorghum midge and greenbug as germplasm has been released, and the identification of major natural enemies and an assessment of their efficacy.

Short term goals are to improve the acceptance of insect resistant sorghum through demonstration and working with the commercial seed industry, and assessing the impact of colonized and released parasites of aphids and stalkborers. Long term goals are to incorporate the accomplishments in plant resistance and biological control into sorghum and/or millet production systems in the U.S. and the three LDC prime sites. A major goal is to put more trained entomologists into LDC's.

Food Quality/Utilization

Dr. Larry Butler, Purdue University and
Dr. Ralph Waniska, Texas A&M University

Accomplishments

1. Identification, publication and understanding of the gross grain characteristic (genetics of kernel characteristics).

2. Documentation of sorghum foods and what types of sorghum are used in these foods.

3. Tannin analysis and composition and documentation of affects during processing and digestion.

4. Incorporation of sorghum flour into common foods - bread, cookies, cake, etc.

5. Multidisciplinary perspective/interactions with entomology, pathology and breeding (eg., headbug and grain mold effect on grain quality).

6. Publication of Cereal Quality Laboratory Manual for West Africa (supported by INRAN).

7. Training students, particularly by Dr. Rooney's project and Dr. Kirleis's projects.

Socioeconomic study of increased sorghum and millet production, processing (small decortication mills) and utilization in traditional and new food/livestock feed.

New Areas

1. Determine genetics of kernel characteristics of millet and how this affects food products.

2. Socioeconomic studies involving (sorghum and millet).

   a. processing (dehulling, milling and parboiling)

   b. utilization (traditional and new foods and livestock feeds and industrial uses).

3. Integration of basic science studies (proteins, tissue culture, tannins, starch) with current problems in foods.

4. Development of nutritionally enhanced foods using available legumes (cowpea, peanut, banbara groundnut, etc.).

Areas Completed

Genetics of gross kernel characteristics of sorghum.

Goals

Five year

Commercialization of sorghum and millet food products at competitive prices (Sori, couscous).

Ten year

Improve the nutritional value of sorghum and millet to be equal to maize.

Development of sorghums with good nutritional quality, high digestibility, yet resistant to weathering.

Continuous

Assure that released sorghum/millet cultivars have acceptable processing and food product qualities.

Plant Pathology

Dr. R.A. Frederiksen
Texas A&M University

Major Accomplishments:

A. Development of an international network of sorghum/millet plant pathologists through training, germplasm deployment, and nursery evaluation of diseases such as sorghum downy mildew, head smut, anthracnose, and long smut.

B. Establishment of a program and policy of interdisciplinary research for the control and management of sorghum and millet diseases.

C. Creation of an awareness that changes in plant disease importance are often associated with cultural and other changes in sorghum and millet production. Examples include dwarfing of sorghum or millet increases (grain mold, foliar diseases) fertility effects on some diseases and the enhancement of diseases by some cropping systems (maize and sorghum, for example). Most of these can be reduced or controlled.

D. Graduate student training has produced scientists who are located at research institutions around the world and make significant contributions to sorghum and millet pathology research. This was documented at the 2nd Global Conference on Sorghum and Millet Diseases in Harare, Zimbabwe where about 25 participants were graduates of, or recipients of, specific research training in disease management at INTSORMIL Institutions.

E. Development of global, regional, or specific subject matter conferences with ICRISAT and national programs. Examples are the 2nd Global Conference (1988), the Sorghum Root and Stalk Rot Workshop (1983), Sorghum and Millet Grain Quality, and the Regional Disease Workshop for Central America (1981).

New Areas of Priority Research:

A. We are attempting to balance the disciplinary responsibilities with the problem solving needs for each commodity and each prime site and country. This balance is extremely critical for workers in both developing and developed countries. Because of extremely limited resources and because our quality of the science is greatly dependent upon the independent approach brought by each discipline to the solving of a production problem.

B. More attention should be focused on soilborne pathogens, including nematodes, organisms associated with stand establishment, and root rotting fungi.

C. The recognition of cereal viruses and their vectors was recently determined as a major deterrent to production in the tropics.

D. Networking to establish more cooperation and collaboration among pathology and associated researchers in the developing countries.

Project Termination:

Many projects, which in our opinion were vital to INTSORMIL, were terminated prematurely. Some goals in pathology projects involve identification of disease management strategies consistent with existing and potential germplasm and production systems. This type of interaction by pathology projects with associated country and other programs is most consistent with effective management and monitoring of constraints rather than specific alleviation of constraints.

What are the short term (5 years) and long term (10 years) goals for this discipline?

The short and long term goals for pathology have been explicitly detailed by disease and ecogeographic zone in the Proceeding from the 2nd Global Conference on Sorghum Disease.

Socio-Economics

John H. Sanders
Purdue University

Major Accomplishments

The University of Kentucky's work in Sudan and Honduras provided excellent baseline studies of the farming systems and nutritional situations. The Jabara-Thompson Ag. Sector study in Senegal and the Roth-Abbott Ag Sector study in Burkina were excellent applied macro modeling.

Presently the program emphasizes farm-level evaluation of the potential effects of new sorghum and millet technologies and the constraints to their introduction. Field research is ongoing in four INTSORMIL priority countries -- Sudan, Niger, Honduras, and Burkina Faso (secondary country to INTSORMIL). Mathematical programming includes risk. Other sources of funding are found to supplement the programming activities with field surveys of farmers in the priority regions. Ph.D. theses are being written on Niger, Sudan, and Honduras. Research activity is continuing in Burkina Faso through involvement in a World Bank financed project.

New Areas of Priority Research

In the Sudan, modeling is trying to estimate the long-run economic impact of various technologies, including soil-mining effects from not replacing chemical nutrients. In Burkina the project is involved in the evaluation of new technologies in the river valleys recently cleared of river blindness. An important issue in Niger is whether, with high-risk levels, the rational producer would be interested in making investments in new agricultural technologies.

In the '90s the economic evaluation of the potential effects of new technologies and related agricultural policies will be expanded to also include long-run concerns with sustainability.

Project Termination

Two Ph.D. theses will be finished shortly on technology evaluation in different regions of Niger. We plant to synthesize and publish this work. Another thesis is being finished on Honduras. We plan to put less emphasis on research in these two countries and more emphasis on the Sudan as cooperation with the ARC is presently progressing very well. We plan to continue our long-term involvement with Burkina.

Goals

Short-term (next five years):

1. Continue involvement in economic evaluation of agricultural research in the four INTSORMIL priority countries.

2. Continue publishing and training graduate students in this research program.

3. Improve ties to national agricultural research institutions and other institutions in these countries.

4. Extend our field involvement to Mali.

5. Improve our modeling and conceptual understanding of the technology introduction process.

Long-term (10 years)

1. Evaluate the diffusion of INTSORMIL technologies and identify the barriers to more rapid introduction.

2. Estimate the costs and benefits to specific INTSORMIL technologies internationally and domestically.

Session VIII: Shaping INTSORMIL's Future

- External Evaluation Panel Findings
- Global Plan Summary

Session Chair: Dr. Richard Frederiksen

Speakers: Dr. Bruce Maunder
Dr. John Axtell

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INTSORMIL EXTERNAL EVALUATION REPORT - 1988

July-September, 1988, reviews of all U.S. INTSORMIL programs were conducted and discussed by External Evaluation Panel (EEP) members with some 23 individual project evaluations to be found in the appendix of this report. This review essentially covered progress through year 9 of the CRSP which ended June 30, 1988. Previous reviews available for reference include 1980, 1982, 1984, 1986, and on-site reviews as recently as 1987. Since country reviews comprise most of the 1986-87 reports i.e. Mali, Niger, Honduras, and Botswana, most of the attached report deals with projects at the five primary U.S. institutions, namely Kansas State University, Mississippi State University, the University of Nebraska, Purdue University and Texas A&M University. Reviews and those participating were as follows:

Texas A&M University **July 11-15, 1988**

College Station/S. Texas

Dr. Glenn L. Johnson, Team leader
Dr. N.G.P. Rao
Dr. Ricardo Bressani
(Yohe and Schilling of ME)

University of Nebraska **Sept. 12-14, 1988**

Lincoln

Dr. Clarence Gray, Team leader
Dr. Orrin Webster
(Yohe of ME)

Kansas State University **Sept. 15-16, 1988**

Hays/Manhattan

Dr. Bruce Maunder, Team leader
Dr. Clarence Gray
(Yohe of ME)

Mississippi State University **Sept. 15-16, 1988**

Starkville

Dr. Glenn L. Johnson, Team leader
Dr. N.G.P. Rao
(Schilling of ME)

Purdue University **Sept. 19-21, 1988**

West Lafayette

Dr. Bruce Maunder, Team leader
Dr. Ricardo Bressani
Dr. Glenn L. Johnson
(Yohe of ME)

Texas A&M University **Sept. 19-21, 1988**

Dr. Clarence Gray, Team leader
Dr. N.G.P. Rao
(Yohe of ME)

Unfortunately, an original and current team member, Dr. Brhane Gebrekidan, was unable to participate in the 1988 review due to an accident. We, however, greatly appreciate the assistance given by his replacements, Dr. N.G.P. Rao and Dr. O.J. Webster, both outstanding sorghum scientists.

The beginning of the year 10 appears to be a new phase and certainly a period of opportunity for this CRSP to (1) put its many INTSORMIL accomplishments to use and (2) restructure itself for maximum future accomplishments. By encouraging more involvement in host country planning and priority setting, the PI's have promoted collaborator enthusiasm and progress. More qualified collaborators are also the result of extensive training efforts the first nine years. Activity with *Striga* continues to increase and we applaud the Board for dedicating more funding to solving this costly weed problem of Africa and Asia. Two positive developments include: biochemical results on *Striga* germination by means of a sorghum root exudate, sorgolene, and the able work on resistant strains conducted by graduate student (Dale Hess). Finally, we see a significant shift out of areas of the world in which sorghum is limited into regions of greater economic opportunity. Market development research is now needed. Also, possibilities exist for using INTSORMIL in the Lake States and in the Southeastern part of the U.S. to develop new phases of the sorghum industry in the U.S.

In recent years, INTSORMIL has brought the objectives of its social science efforts into line with its limited funding of such work. The result is a smaller, but more relevant and leaner, social science component that is generating useful information on the relevance of different kinds of sorghum and millet technologies in specific on-farm environments.

This evaluation looks first at accomplishments and then at constraints and opportunities. Finally, given the constraints and opportunities, the EEP's recommendations are presented.

Accomplishments

Key changes and progress following the last review have been noted in the preceding paragraph. However, some broader generalizations about accomplishments are pertinent. The prime site/global plan concept that is continuing to build is a wise route to follow especially under reduced funding. The effective SADCC (Southern Africa Development Coordination Conference) training program brings overseas monies into the CRSP while the conventional INTSORMIL student programs continue to increase the available pool of collaborators. The germplasm/technology transfer must certainly be considered an important success. So too, are the productive workshops and such publications as the food quality manual for West Africa. Inter-institutional as well as multi-disciplinary cooperation and team efforts continue to illustrate how PI objectives successfully channel personal ambitions and needs for recognition into highly productive and well coordinated group outputs. Generally and most importantly, U.S. inputs overseas have been kept at levels that can probably be sustained should US/AID be forced to pull out. Another accomplishment is improved understanding, often from basic, relevant research in such disciplines as biochemistry, of the biological limitations to sorghum and millet around the world.

The collaborative Research Support Projects (CRSPs) are an important U.S. institutional innovation now being emulated by Australia and West Germany. Unfortunately, this valuable way of organizing agricultural research is now being "whittled away" in AID budget processes to the extent that it is in danger of becoming AID's latest forgotten "fad." As one of the very successful CRSPs, INTSORMIL has an important story to tell. Combined with stories from other CRSPs, the INTSORMIL story can be used outside of AID's project planning and budgetary processes to help build broad support for the CRSPs in scientific, political, academic and industry circles.

An important factor contributing to the ongoing support of the International Agricultural Research Centers (IARCs) is the analytical evaluation work done outside that system to assess its productivity. Some of the CRSPs now have histories long enough to permit similar quantitative- qualitative assessments of their performances and potential contributions. Such assessments would help open new, highly legitimate, public relations channels and financing opportunities for INTSORMIL and the CRSPs. These opportunities should not be missed.

The following subsections deal with more specific accomplishments in subject matter areas involving sorghum and millet:

Agronomy/Physiology:--Through INTSORMIL research, nine water stress-resistant sorghums have been released and are being tested in Niger. Water and nitrogen availabilities are major bottlenecks to increasing sorghum and millet production in developing nations, especially in food-deficit nations of Africa. This is significant progress, given the period of operation of INTSORMIL. Further, INTSORMIL research has shown clear improvements in nitrogen availabilities and increased water use efficiency when sorghum is intercropped with cowpeas and/or grown in rotation with cowpeas. These research results show that there are excellent opportunities to significantly increase sorghum and millet production in the difficult environments of Asia, Africa, and Central and South America through the use of water and fertilizer nutrients and stress-tolerant genotypes used alone or in combination with certain agronomic practices. A case in point is identification of genotypes that can be productive on high aluminum soils where few crops can now be successfully grown. The basic research on sorgolene, an exudate from sorghum that triggers *Striga* seed germination, promises to produce agronomic recommendations to help control that parasitic weed in Africa. On-farm economic research in Niger continues earlier Burkino-Faso research on agronomic practices to produce important results for conserving water and making effective use of fertilizer in West Africa.

Plant Breeding:--Cooperative efforts in the area of sorghum breeding have furnished data and breeding materials valuable to producers in the U.S. as well as in the less developed participating countries, some of the more prominent being:

a. The release of Hageen-Dura 1 sorghum hybrid in Sudan and Sureno for some Latin American situations;

b. The development and release of lines highly resistant to midge that can be used by public and private agencies all over the world; further contributions to the understanding and incorporation of resistance to various biotypes of greenbug; and the development of integrated insect management strategies for sorghum pests;

c. Significant contributions towards the incorporation of high levels of host plant resistance to the prevalent diseases and the development of disease management strategies (see pathology below);

d. The development and release of Al-tolerant A, B, and R lines and promising advance generation progenies for the acid soil situations of Latin America;

e. A better understanding of the processes governing productivity, nutritional quality, and responses to the various kinds of stresses encountered;

f. Training of graduate students with exposure to applied problem situations in their respective countries as well as to basic science aspects. Such students will eventually provide the personal and scientific linkages as collaborators at the prime sites.

The above accomplishments are ongoing and hence indicative of opportunities to be exploited.

Entomology:--The midge screening nurseries in Texas have made important contributions to the development of the midge resistant varieties reported as "item b" under **Plant Breeding** above. Materials are also screened for head bug resistance in Niger. Entomological studies at Texas, Mississippi and in Africa of stem borers, the sugar cane aphid, the fall armyworm, and millet head girdlers have increased knowledge of pest life cycles, the population dynamics of pest parasites and the damage done by pests as conditioned by plant characteristics. Such studies contribute to breeding programs and the development of integrated pest management programs of which the release and establishment of *Cotesia flavipes* (a stem borer parasite) in Honduras is an example.

Food Quality and Nutrition:--The review of the different projects under the area of food quality and nutrition revealed that significant advances have been made in our understanding of the potentials and limitations of grain sorghums as food and feed. Although this understanding and knowledge is still short relative to that for maize and more so for wheat, such information suggests opportunities to expand the uses of grain sorghum and is removing it from the category of the "poor man's food." Accomplishments may be divided for purposes of presentation into basic and applied.

a. Among the important basic results, which can be applied are those on tannins and phenols; the detailed study of proteins during grain development and in the mature grain; the roles of carbohydrates and proteins in the nutritional functions of food products; the important impacts of food processing on protein digestibility; the possible association of the low digestibility with protein fraction III; and the protein differences between the hard and soft endosperm to mention a few.

b. Accomplishments on the applied side include: the use of sorghum flour to extend wheat flour; the sorghum quality laboratory manual on methods for physical, chemical, and food quality analysis; the development of sorghum food products for Latin America and Africa; the development of parboiled sorghum to be consumed similar to parboiled rice; factors affecting food quality and acceptability of sorghums; and high quality foods (including fermented products) made from sorghum and food legumes. Increased knowledge of the break-down of tannins after treatment with ash is also important.

Biochemistry:--Important basic biochemical accomplishments by INTSORMIL include new knowledge and understanding of the synthesis of cytokinins as a way to increase resistance to charcoal rot; sorgolene as a potential *Striga* germination stimulant/inhibitor; flavan-4-ols and/or precursors in weathering; polyphenols and bird resistance; osmolytes for drought resistance; tannins or other biochemical compounds for storage resistance as they have recently been studied for beans; and chemical substances which aid against midge.

Pathology:--Regional disease nurseries have been developed to screen exotic varieties in southern Africa. Disease surveys and studies have been conducted for charcoal rot, sooty stripe, leaf blight, anthracnose and sorghum viruses in southern Africa. These and other results contributed to the successes reported above under **Plant Breeding**, "section c."

Socioeconomics:--In 1983, INTSORMIL social science work was extensive, underfinanced and, in some instances, of questionable relevance. What is left is relevant and well focused with financing at levels appropriate to the remaining project. Substantial accomplishments have been attained by rural social scientists in farm-level technology assessments in Niger and Burkina Faso. While these assessments are superior to those commonly used in administering and planning INTSORMIL agricultural research, difficulties still exist with respect to data quality and the logical structures of assessment models. Present work indicates that water conserving and fertilization practices are important in the adaptation of INTSORMIL technologies. This work complements the plant breeding work on the development of stress resistant varieties of sorghum reported above in **Plant Breeding** "section c" while also increasing millet yields.

Constraints

Farmers, INTSORMIL administrators, and researchers encounter more than biological and physical constraints to sorghum and millet production. One such constraint is budgetary; other constraints involve poor institutions, inappropriate policies, undeveloped markets, lack of trained personnel (collaborators), inadequately developed and maintained natural and man-made resource bases. Also important are social unrest and political and military instability that constrain ongoing production systems and particularly with the introduction of new technologies such as Hageen-Dura 1. Probably, the most severe constraint faced by INTSORMIL is the budgetary one. This constraint is the concern of INTSORMIL's administrators: Its ME, Board of Directors, PIs, and EEP as well as of the administrators of

INTSORMIL's U.S. and international collaborating institutions.

Biological and physical constraints have been the main focus of INTSORMIL's **crop and soil science research.** Sorghum and millet production is biologically and physically constrained by:

> Inadequate varieties for coping with drought, high and low temperature, insects, diseases, and weeds; tastes and preferences; human and animal nutritional (particularly protein components) needs; polyphenol limitations on digestibility and acceptability; and bird damage. These constraints are the concerns of **plant breeders.**
>
> Diseases such as anthracnose, ergot, charcoal rot, long smut, sooty stripe, *fusarium*, and downy mildew are the concerns of the **pathologists.** Common domestic and international diseases make it important that pathological research on these constraints be conducted at both domestic and overseas locations.
>
> Constraints of concern to **entomologists** include: sorghum head bugs, shoot fly, stem borer, greenbugs, armyworms, midge, head girdlers, and sugarcane aphids.
>
> Poor food quality and acceptability traits are of particular concern to **nutritionists (both human and animal) and food technologists.** Included here are digestibility, protein composition, cooking characteristics and a vast number of other constraints on the usability of sorghum and (to a less extent) millet that influence the welfare of the world's poor and both international and domestic food and feed grain markets. U.S. sorghum producers have a vital stake in the elimination of these constraints.
>
> Market, demand, social and political instability, international trade, human and entrepreneurial, capital (natural and produced) and institutional and related constraints are all important for U.S. and LDC sorghum and millet productivity and utilization. These important constraints are the concerns of **rural social scientists.**

Opportunities

Progress reveals additional opportunities and INTSORMIL's progress to date is no exception:

Agronomy/Physiology:--INTSORMIL has generated materials and methods ready or near-ready to be used that have a potential for achieving progressive increases in millet and sorghum production in collaborating countries over the next decade. At this time, there is an opportunity to concentrate INTSORMIL's activities in several priority prime sites for field testing and demonstrating the use of yield-increasing agronomic practices with improved cultivars. INTSORMIL must take advantage of this opportunity which will be noted also under socioeconomics.

Entomological opportunities for INTSORMIL include the establishment of a head bug screening nursery in West Africa. Establishment of this much needed facility has been inordinately delayed by administrative and other difficulties in Niger and Mali. There is now danger that AID's budget limits may permanently postpone it. The opportunity to establish this nursery is in addition to continuing the excellent entomological work being done abroad and at such U.S. sites as those in Texas.

Opportunities for **pathologists** consist largely of a continuation of the present good work with an important exception--a long smut nursery is needed in West Africa for screening new materials for resistance.

Biochemistry:--The important biochemistry accomplishments summarized in the earlier section illustrate continued opportunities to exploit the important synergism between basic, more disciplinary research and INTSORMIL's prime concern with the practical objectives of its breeding and related practical supporting programs. Undoubtedly, besides training, the greatest U.S. input will very likely be problem solving of a basic/biochemical nature.

INTSORMIL's basic and applied research results are increasing opportunities for greater use of sorghum as a food and as a feed. The identification of the reason for the low protein digestibility will make it possible to develop better quality human food and animal feeds with greater bio-utilization. This will make it possible to utilize more effectively the high lysine sorghums. Greater understanding of the effects of different methods of food processing will make it possible to incorporate greater amounts of sorghum flour into composite flours for breadmaking. It will be possible, also, to develop better quality weaning foods and foods for pregnant and lactating women and to use higher yielding varieties for producing such traditional foods as basha and tortilla as well as new products to be made in developed countries. With respect to **food quality and nutrition**, there are extensive opportunities to continue and expand the excellent breeding and food technology work now underway. Work on tastes, preferences, and nutritional values constitutes building blocks for demand analysis and market development work by social scientists.

INTSORMIL's present **socio-economic** component is sparse and lean to the extent of being almost non-existent.

However, INTSORMIL's successes have generated multiple opportunities for socio-economic work. INTSORMIL's contributions to world and domestic agricultural need to be analyzed on a cost and returns basis. Domestic contributions need analysis to answer potential "Bumpers Amendment questions" that could threaten INTSORMIL's AID funding. Opportunities exist to do feasibility studies for "CRSP-like" activities to help develop sorghum/millet production in the SE states of the U.S. and in more northern, short season regions.

At year 10, INTSORMIL is well positioned to initiate forced-paced increases in sorghum and millet production through applied research at one or more selected prime sites. INTSORMIL now has improved materials and methods which need to be tested/adapted rapidly and made available for use as soon as possible in priority Ecogeographic zones. Such materials and methods can impact production significantly if put to use. The arrangements and resources are available. Adjustments in priorities, operations, and budgets will be required. What is lacking is a specially designed research strategy and the will and sense of urgency to put it into effect. Over the next several years, INTSORMIL has an opportunity to demonstrate the role of its research in accelerating food and agricultural development.

In addition to the biological and physical opportunities for sorghum and millet production are the opportunities to help overcome marketing, institutional, policy, and human constraints on production, distribution, and utilization of sorghum and millet. World developed countries and LDC's and the U.S. domestic food and feed grain markets for sorghum are underdeveloped in view of the great improvements being made in sorghum grain quality. Research, extension, price, input, and production programs are so inadequate as to severely constrain researchers, producers and consumers. Poor national policies and inadequate human development programs are also constraining. Sorghum production and storage are constrained by managerial limitation of LDC producers.

INTSORMIL biological and physical researchers are increasingly constrained by lack of budget just as the CRSP is attaining major capacity to contribute both internationally and domestically. Socio-economic analytical and evaluation research is needed on the CRSP to help overcome these budgetary constraints.

In the AID context there is the constraining danger that the so called Bumpers Amendment (Congressional Record Senate, June 6, 1986) might be invoked to limit expenditures on INTSORMIL's sorghum research even if it is beneficial to domestic producers. As indicated above INTSORMIL has many opportunities to initiate market development, strategic planning, and technology assessment of its own; fortunately much such work can be done cooperatively with rural social science departments of its member universities and collaborating institutions. Many U.S. rural social science departments are already funded to do the kinds of work required.

Recommendations

The following are general, rather procedural recommendations. They, like the subsequent, more specific recommendations, are based on INTSORMILs demonstrated or available skills, accomplishments, and the opportunities and constraints considered above:

a. INTSORMIL must continue to upgrade its overseas linkages to assure maximum productivity, application, and utilization of its results. Effective communication and two-way feed back concerning research activities and problem recognition should be stressed.

b. A more aggressive approach to funding from within or outside AID resources is recommended. We commend this activity where it already exists.

c. The EEP must again recommend as much collaborator involvement in planning as possible to insure effective conduct of on-site research. Also, more research activities should be conducted under host country conditions.

d. Activities of the Technical Committee, the Ecogeographic Zone Council, and the ME need to be coordinated in depth rather than in a peripheral manner. Two or more projects for the same science require effective workplans to attain productivity while avoiding unproductive duplication. These committees should be the best source of recommendations for the PI's and cooperating institution's of INTSORMIL. For example, the EEP sees substantial reasons to include Dr. Wayne Hanna of Tifton, Georgia in INTSORMIL activity; he has an outstanding reputation and record in millet research. Also the EEP has previously suggested Dr. Ronny Duncan of the same state as a logical source of acid soil expertise in sorghum improvement.

e. While grain storage research within INTSORMIL has been inadequate certainly much has been done by the IARC's which may suggest a greater input now as an economic issue. The same could be said for "value added" input by the CRSP to enhance greater support through appropriate public relations.

f. Formula reduction or expansion of budgets should be avoided. Budget changes should be on the basis of contribution or opportunity for success. Discipline or state bias should be avoided. The need for prioritization is there, the opportunities are great, and no better group of sorghum scientists have ever been assembled into one program.

g. We encourage basic inputs including **biotechnology** to help solve some of the challenges confronting PI's and collaborators. Programs in place at INTSORMIL institutions or elsewhere, if necessary, may be required for effective progress on topics e.g. acid soil adaptation, disease and insect resistance, and nutritional improvement. h. An effort to present the objectives and accomplishments of INTSORMIL for better seed industry relations is essential. Current opinion by the seed industry suggests INTSORMIL may have diluted U.S. sorghum improvement.

Agronomy/Physiology:--The EEP suggests that:

a. INTSORMIL should select priority prime sites for testing and demonstrating the use of improved agronomic practices with the improved cultivars being produced by INTSORMIL.

b. Increased physiological research will benefit both millet and sorghum improvement.

Breeding:--The EEP recommends the following:

a. INTSORMIL should critically assess the current status of its germplasm utilization and the breeding methods it employs to devise ways and means of attaining further breakthroughs in qualitative and quantitative improvements of sorghum. Our understanding of the genetics of height and maturity genes, the discovery of cytoplasmic-genetic male sterility, and its exploitation in developing commercial hybrids, and the use of tropical germplasm through the conversion program are considered the major milestones that have contributed to progressive qualitative and quantitative improvements in sorghum production and productivity. In recent years, the zerazeras and the yellow endosperm caudatums, in particular, have contributed a large share of the advances in quality as well as yield.

b. A testing network should be established to enable identification of materials with broad adaptation and high yield, important elements in cooperative programs. Such a network should be designed to promote cooperation between participating scientists and to select materials for further enrichment through incorporation of multiple resistances. Weather and climate related parameters should be incorporated into the network studies. INTSORMIL scientists could look into the establishment of an adaptation network for sorghum. Except for those imposed by maturity genes, genotype alterations diminish the barriers to adaptation per se. This was true for the use of hybrids based on combinations of Kafir 60 and similar females, the performance of lines and hybrids based on derived zerazeras, and the use of yellow endosperm caudatums on a global basis.

c. Whole plant, food grain, and feed grain utilization should receive greater attention in the INTSORMIL programs. Developed countries look at grain sorghums as feed grains and developing countries as food grains. INTSORMIL programs designate breeding nurseries accordingly. The good quality, white grain types, devoid of tannins should be good for both food and feed; they now command a premium in several markets. The use of sorghum grain for direct food use is on the decline in several countries. It is, therefore, necessary that sorghum improvement programs also be oriented towards whole plant utilization of silage, stalks for forage, hay, energy source, etc., and grain for food, feed, malting and other industrial uses. The protein profile of the grain, the digestibility of starch and protein, the brown mid rib, the tan plant, etc., are all compatible and amenable for breeding to fill specific needs.

d. Pearl millet breeding programs in the U.S. universities should have a strong orientation towards disease resistance, particularly downy mildew and ergot. Since these diseases are not serious in the U.S., experiment station research may concentrate on basic aspects including biotechnological approaches with emphasis on field screening at overseas prime sites.

e. As India has vast acreages of sorghum and millet, it is recommended that INTSORMIL develop cooperative research projects with the Indian National Program. Some suggested areas for cooperation are food and feed quality, alternative uses, cytoplasms, apomixis, head bugs, ergot, and drought, etc. Both basic and applied aspects could be included.

f. An organized effort at germplasm collection, evaluation, maintenance and distribution should be established within INTSORMIL. This obvious ingredient in a total effort for sorghum/millet improvement will result in a closer, more appreciated support from the seed industry and will make INTSORMIL more effective.

Entomology:--For this discipline the following recommendations are made:

a. INTSORMIL should supplement its effective U.S. insect screening nurseries with a head bug nursery in West AFRICA.

b. continue the excellent work being done at Texas.

c. reorient the entomological work at Mississippi to major insects of the Southeastern U.S. and to millet as well as sorghum.

Food Quality and Nutrition:--A number of specific recommendations follow:

a. INTSORMIL should research and study storage facilities to decrease grain damage; the factors responsible for resistance to insect attack (see next section) in storage; the effects of storage on function and nutritive value of sorghums in the diet using more in vivo nutritional evaluations of both highly productive varieties and processed sorghum foods. It is important to include storage studies in the research program as they are an important component for LDC food chains.

b. High grain production should not be achieved at the expense of lost nutritive value. Also, processing may easily affect biological value. There is need to implement some of the technologies which have been developed, for example, "parboiled sorghum" to be used as with rice.

c. Other food products from sorghum should be developed besides those already known, with attention to the bioavailability of such nutrients as oil, mineral and vitamins.

d. Non-food uses for sorghum should be researched--for example, the use of sorghum as a source of starch would leave the germ available as a by-product for oil extraction.

Biochemistry:--INTSORMIL should continue and expand its emphasis on basic biochemical and biotechnological research of known and suspected relevance for INTSORMIL's applied objectives for sorghum and millet. Such work has contributed substantially to INTSORMIL's important successes to date (see accomplishments) and is expected to make increasing contributions in the future. It is reasonable to expect such research to be supported from central university sources, the NSF, as well as the US/AID and the experiment stations. There is synergism between basic disciplinary and plant breeding work that INTSORMIL is beginning to exploit.

Pathology:--The following is recommended:

a. INTSORMILs good pathological work for sorghum should be continued in close collaboration with its plant breeders. This work should be expanded to include a long smut screening nursery in West Africa.

b. INTSORMIL should emphasize millet diseases with collaborators in millet producing countries.

c. The EEP encourages a continued and strong awareness of economic priorities with response often only possible in the collaborating country.

Socioeconomics:--It is now time to expand INTSORMIL's social science work. Much of the needed relevant research outlined here can likely be financed outside of regular INTSORMIL funds. INTSORMIL should take steps to initiate rural social science and related research in the opportunity areas mentioned at various points in this report and summarized here:

a. possible foreign market expansions for the higher quality feed and food sorghums being more rapidly developed as a result of INTSORMIL's domestic and international collaboration,

b. possible domestic market developments for both food and feed grain based on INTSORMIL's contributions to sorghum grain quality,

c. the feasibility of further development of sorghum and millet production in the southeastern states of the U.S. with publicly supported research and extension. Both Mississippi and Georgia are interested in developing grain sorghum and millet production in the southeastern states of the U.S.

The above socio-economic recommendations can probably be carried out at low cost to INTSORMIL through collaboration with domestic agencies and personnel having responsibilities and funding for doing such work. Texas A&M, for instance, has an effective Agricultural Economics Department with personnel capable of collaborating with other INTSORMIL agricultural economics departments and industry, including the National Grain Sorghum Producers Association, in doing **foreign and domestic market development research.** So

do Kansas, Oklahoma and Nebraska, all large sorghum producing states. Such research would help leaders in the domestic sorghum industry such as The National Grain Sorghum Producers Association realize the benefits they are deriving from INTSORMIL, thus legitimately forestalling Bumpers Amendment questions about INTSORMIL's research.

d. INTSORMIL should also support and help mobilize support for relevant basic, conceptual and theoretical work by economists and other social scientists researching farming systems, doing technology assessment studies and the adoption of new technologies. Basic discriptionary research is needed on, (1) improved measurements of the non-monetary values associated with food quality, food security, family size, environmental degradation, institutional reform and education and the like, (2)managerial processes, (3) ensuring (control of events) as contrasted to insuring and chance taking (adjusting to existing probability distributions).

Conclusion

INTSORMIL needs to elaborate and publicize their very significant accomplishments. Combined with stories from other CRSPs the INTSORMIL story should also be used outside of AID's project planning and budgetary processes to build broad legitimate support for the CRSPs in scientific, political, academic and industry circles to help overcome funding constraints. Two broad approaches are needed--one by the CRSPs collectively and one by the individual CRSP including, specifically, INTSORMIL. More than the recounting of success stories is needed. There is homework to be done. Current and prospective costs and benefits--nonmonetary as well as monetary and social as well as private--need analysis. While the accomplishments to date have been remarkable their appreciation and recognition has for too long gone mostly unnoticed. Now is the time to put these practices and products in front of LDC producers. Also, now more effort must also be made to secure the understanding and support of the seed industry throughout the world.

INTSORMIL should proceed within its own institutions to first analyze the significance of what has been done, i.e. "situations and outlook" analysis should be done for the different phases of INTSORMIL's biological and physical science efforts--grain quality, insect and disease resistance, cold tolerance, drought resistance, aluminum toxicity tolerance and the like. Second the momentum of what is underway must be described and communicated. We must describe and effectively communicate prospective benefits and payoffs both for domestic producers and the disadvantaged hungry of the LDCs who depend on sorghum and millet for subsistence. With respect to domestic sorghum producers, the seed industry and U.S. consumers, it is particularly important to document past and prospective accomplishments.

Finally, we of the EEP recognize and value the strong support for INTSORMIL by the Management Entity (Nebraska) and certainly from the Board representing Texas A&M, Mississippi, Kansas, Purdue, and Nebraska. Only with their universal effort and backing could this program have come so far the first nine years yet have so much opportunity to make even greater progress in the immediate future.

Respectfully submitted,

1988 EEP members:

Dr. Bruce Maunder, Chair
Dr. Clarence Gray, Vice Chair
Dr. Glenn Johnson
Dr. Ricardo Bressani
Dr. N.G.P. Rao
Dr. O. J. Webster

Global Plan Subcommittee Report

D.T. Rosenow, L. Gourley, D.J. Andrews, J. Axtell

The INTSORMIL Board of Directors instructed the ME to work with a Subcommittee in preparing a draft process and policy paper for discussion by P.I.'s at the P.I. Conference, January 3-5, 1989. Accordingly, the EZC Chair, Dr. L.W. Rooney appointed D.T. Rosenow, L. Gourley, D. Andrews and J. Axtell to serve on a Subcommittee "to evaluate the Global Plan and recommend any changes which might be needed in the INTSORMIL Global Plan for the next five years." The mandate of the Subcommittee was to identify the issues and present them to the P.I.s in Arizona for their input and discussion.

The Subcommittee identified the following principal issues for discussion:

1.The CRSP mode of collaborative research is now firmly established within USAID, however, funding levels continue to be inadequate to support development of the full potential of those CRSP's which are operating well.

2. The Subcommittee recommends that the Board consider the addition of Mali as a prime site, since the collaborative research program has developed very well and now merits equal consideration with other prime sites.

3. The relationship between INTSORMIL and several AID "graduate" countries continues to be an unresolved issue. This is a mutual benefit for the development of research relationships with India, Brazil and Mexico for example, but no mechanism exists to expedite this relationship.

4. David Andrews reported on the opportunities for INTSORMIL in Senegal. There are excellent opportunities in the areas of millet breeding, sorghum breeding and food quality research in Senegal. A new AID contract with Michigan State University may provide opportunities for funding this collaborative research.

A new subcommittee headed by D.T. Rosenow will incorporate the P.I. suggestions into the revised Global Plan.

Session IX: Technical Presentations - Abstracts

Agronomy

Improving Sorghum Yields in Botswana through Collaborative Research on Tillage, Crop Rotation, Rainfall Harvesting, and Residue Management - D.C. Carter, L. Gakale and N. Persaud

Grain Sorghum Yields as Influenced by Soil Fertility under Low Rainfall (< 300 mm) Conditions in Botswana - M.D. Clegg, J.B. Youngquist, D.C. Carter

Sorghum Stress Screening - J.D. Eastin, P.K. Verma, P. Bramel-Cox and D.J. Andrews

Increasing N Use Efficiency by Dryland Sorghum under Conventional Spring Disk and No-Tillage Systems - M.V. Marake, D.T. Walters and D.H. Sander

A Population Study on Pearl Millet - M.Y. Mortlock and R.L. Vanderlip

Effect of Pearl Millet and Sorghum Seed Quality on Stand Establishment in Botswana - M.Y. Mortlock and R.L. Vanderlip

Effect of High Temperature on Germination and Establishment of Pearl Millet of Different Seed Sizes and Densities - M.Y. Mortlock and R.L. Vanderlip

Effect of Rotation and Fertilizer Treatment on Density and Dry Weight of Sorghum and Soybean Roots - W. Roder, S.C. Mason and M.D. Clegg

Responses of Sorghum to Applied Abscisic Acid - M. Traore, C. Sullivan, S. Dione and B. Coulibaly

Millet/Cowpea Intercropping and Crop Residue Research in Niger - P.K. Verma, J.D. Eastin, M. Nouri, C. Reddy and I. Mohamadou

Breeding

Stand Establishment in Relation to Seedling Mesocotyl and Coleoptile Length in Pearl Millet - B. Khaleeq and W.D. Stegmeier

Pearl Millet: A Potential Early Maturing Dryland Feed Grain Crop - William D. Stegmeier, B. Khaleeq, R.L. Vanderlip and D.J. Andrews

Entomology

Biological Control of Millet Stalk Borer in Niger - F.E. Gilstrap and O. Youm

Sorghum Resistance to Sorghum Midge - George L. Teetes and Gary C. Peterson

Sugarcane Aphid Resistance Screening in Botswana - George L. Teetes, Chris Manthe and Gary C. Peterson

Sorghum Head Bug Research in Niger - Gary J. Steck and George L. Teetes

Fall Armyworm/Stemborer Research in Honduras - F.E. Gilstrap, K.L. Andrews, D. Meckenstock, L. Lastres, and R.W. Jones

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Food Quality and Utilization

Water Solubility and Protein Digestibility of Tô, a Sorghum Porridge - A.B. Bello, A. Kante, L.W. Rooney and R.D. Waniska

Somaclonal Variation in High Tannin Sorghum - T. Cai and L.G. Butler

Characterization of Native Sorghum Starch and Starch from Extruded Decorticated Sorghum by HPLC-Size Exclusion Chromatography - D.S. Jackson, M.H. Gomez, R.D. Waniska and L.W. Rooney

Traditional Food Processing Technologies in East Africa Improve Nutritive Value of High Tannin Sorghums - S. Mukuru, E. Monyo, G. Ejeta, M. Hassen, E. Mertz and J. Axtell

Mechanism of Antinutritional Effects of High Tannin Sorghum - John C. Rogler, Simon Mole and Larry G. Butler

Effects of Prolamin Protein Fractions on Sorghum and Maize Digestibilities - R.M. Sikabbubba and C.F. Klopfenstein

Effect of Weathering and Fungi on Phenolic Acids in Sorghum - R.D. Waniska, J.H. Poe, G.A. Forbes, R. Bandyopadhyah and R.A. Frederikson

Processing Characteristics of Parboiled Sorghum - R. Young, L.W. Rooney and R.D. Waniska

Plant Pathology

Effects of Maize Dwarf Mosaic Virus Strain B on Growth and Yield of Sorghum - J.D. Alexander and R.W. Toler

Unusual Fusarium Isolates from Sorghum - C.J.R. Klittich and J.F. Leslie

Vegetative Compatibility Groups as a Measure of Population Diversity in Fusarium - J.F. Leslie and C.J.R. Klittich

AGRONOMY

Improving Sorghum Yields in Botswana through Collaborative Research on Tillage, Crop Rotation, Rainfall Harvesting, and Residue Management. D.C. Carter, L. Gakale and N. Persaud, DAR, Gaborone, Botswana.

Sorghum yields in Botswana are constrained primarily by the rainfall, climate, and soil characteristics. The low, irregular, low use-efficiency rainfall pattern results in intra-seasonal drought and crop stress. The luvisols and arenosols used for sorghum production have low organic matter, P, and N content and an unstable surface structure. They are often shallow with low profile moisture storage capacity and become massive and hard when dry. These factors contribute to the low and variable yields of sorghum obtained by traditional Botswana farmers. INTSORMIL collaborative research in Botswana was founded on the philosophy that sorghum grain yields must be stabilized at a higher level than currently exists. This will encourage farmers to invest higher levels of labor and other resources in their otherwise marginal cereal production farms. Research efforts concentrated on tillage practices, cereal/legume crop rotation, macro- and micro- rainfall harvesting systems, and management of crop residues and manure. Results have shown that response to tillage practices appeared to be strongly influenced by seasonal rainfall pattern and any soil management factor such as weed control operations that directly affect the soil moisture content. The rotation experiments showed that soil productivity for sorghum was improved following groundnut or cowpea. Results from the macro-rainfall runoff harvesting investigations have demonstrated grain yields of over 2 T/ha. compared with the traditional check of less than 1 T/ha. Sorghum grain yields responded positively to manure and to the incorporation or surface mulching of crop residues. The response was, however, not uniform over all sites.

Grain Sorghum Yields as Influenced by Soil Fertility under Low Rainfall (<300 mm) Conditions in Botswana. M.D. Clegg, J.B. Youngquist and D.C. Carter, NU, Lincoln, NE.

In many developing countries available water is considered the major constraint for crop production. However, when soil fertility is not adequate to support desired plant growth low crop yields occur even when ample water is present. Therefore, low fertility (particularly nitrogen) is often a major constraint for production of cereal crops. The objective of this research was to determine the effect of improved soil fertility on grain sorghum [*Sorghum bicolor* (L.) Moench] productivity grown in low rainfall environments. Grain sorghum was grown in Botswana in 1984/85 and 1985/86 under a total of 12 environments of varying rainfall (259-350 mm). Fertility was improved with the application of 9 Mg/ha of manure. Sorghum productivity as influenced by fertility was compared using an environmental model to minimize or normalize the effects of environment. Grain and total biomass (grain + stover) yields ranged from 0.16 to 3.1 Mg/ha and 1.2 to 6.7 Mg/ha respectively. Grain yield was increased in only seven of the environments by increased fertility whereas total biomass was increased in eleven of the environments. The model indicated that improved fertility was more effective in increasing both grain and total biomass yields when the environments were capable of supporting yields greater than 1.0 Mg/ha. At yield levels below this, improved fertility was ineffective or even detrimental. This last observation may indicate why fertility isn't considered limiting because many farmers' cereal grain yields are not above 1.0 Mg/ha.

Sorghum Stress Screening. J.D. Eastin, P.K. Verma, P. Bramel-Cox and D.J. Andrews, NU, Lincoln, NE.

Developmental stage research has exposed microsporogenesis and megasporogenesis to be the two most sensitive preflowering stress periods. Stress during these periods has an adverse effect on yield through a reduction in the seed number component of yield. Also, the seed number component of yield correlates more positively with grain yield than does seed size. Based on this knowledge, a field overplanting technique has been used to exhaust soil water prematurely and exert extra water stress pressure at the late panicle development stage. Definite genotype differences in stress resistance have been exposed as shown by yield data. Three A/B pairs, N94, N95 and N96, plus 2 R lines, N91 and N92, have been released.

There are, no doubt, a variety of contributing stress resistance mechanisms for which individual stress screening techniques are either unavailable or impractical on a plant breeding scale. However, one parameter, the canopy temperature - air temperature differential, during mid to late panicle development may reflect the cumulative effect of several pertinent stress resistance mechanisms and merits further research. The pros and cons of such research will be discussed. Anatomical investigations probing specific stress resistance mechanisms point to damage relating to the tapetum during the tetrad stage of meiosis plus some ovule damage at a slightly later time since these injuries can be inflicted by either 17 C or 29 C night temperatures (considering 22 C near optimal respiration related events are of interest). Consequently field carbon balance experiments as opposed to photosynthesis experiments alone may be useful in further understanding and modeling yield limitations under stress.

Increasing N Use Efficiency by Dryland Sorghum under Conventional Spring Disk and No-Tillage Systems. M.V. Marake, D.T. Walters and D.H. Sander, NU, Lincoln, NE.

No-tillage systems have the potential for increasing grain production of dry-land sorghum in Nebraska. Nitrogen management is complicated by changes in the soil environment that effect plant development and soil N transformations. A experiment was conducted to evaluate the interaction of two tillage systems: a conventional spring disk and no-tillage with N source/placement (anhydrous ammonia and urea ammonium nitrate 28% N either surface dribbled or knifed), N application time (preplant or sidedress) and N rate (0, 40, 80 and 120 kg/ha) on grain production, fertilizer N use efficiency and water use. Maximum grain yield required an additional 40 kg/ha of N under no-till regardless of time and an additional 40 kg N /ha when N was applied at sidedress regardless of tillage. A 17 day dry period following sidedress resulted in a significant yield loss surface applied N under disk tillage with no apparent yield reduction under no-till. Fertilizer use efficiency was increased by sidedress for knifed N placement but reduced at sidedress for surface applied N. Significant N mineralization under no-till resulted in very low fertilizer use efficiency for surface applied N. Measurement of soil water content indicated greater use of water below 45cm under conventional spring disk.

A Population Study on Pearl Millet. M.Y. Mortlock and R.L. Vanderlip, KSU, Manhattan, KS.

Pearl millet [*Pennisetum glaucum* (L.)] is one of the most important subsistence crops in the drier semi-arid regions in the world. It often is grown in the same area as sorghum but is more tolerant of nutrient poor soil and low rainfall than sorghum. It is capable of rapid growth and tillering under favorable conditions and has a well developed compensatory ability. Similar yields and dry matter productivities have been reported over a wide range of plant populations. Millet, however, is absent in commerce as a grain crop in the U.S. It was on this basis that studies were conducted in 1985 and 1986 at the Agronomy Farm, Manhattan, and the Sandyland Experiment Field, St. John, Kansas, to determine millet yield response to plant population. Randomized complete block experiments with populations of 25, 49, 99, 198, and 395 thousand plants/ha of Senegal bulk millet were used in all studies. There was no effect of population on yield at either location either year. Most of the yield compensation was through heads/plant, some by seeds/head, and least by seed weight.

Effect of Pearl Millet and Sorghum Seed Quality on Stand Establishment in Botswana. M.Y. Mortlock and R.L. Vanderlip, KSU, Manhattan, KS.

Poor stands of pearl millet often occur due to low seed vigor and high soil temperatures. On-farm experiments examined the contribution of seed characteristics to stand establishment in Botswana. Five farmers hill planted millet on three dates. Bold, >2.58 mm diameter and >1.26 g/cc, and control 'Serere 6A' millet was planted by hand and with a jab planter. Establishment was measured on 20% of the plot area at 4, 6, and 8 days after planting (DAP). Plants established earlier from the hand planted bold seed with 12,500 hill/ha at 6 DAP compared to 6,500 hill/ha for control seed. Thirty-seven percent of viable seeds emerged with hand planting. There were no seed effects with jab planting

and only 16% of viable seed emerged. Six farmers broadcast planted bold (as above) and control 'Serere 6A' and dense, >1.29 g/cc, and control 'Segaolane' sorghum on two dates. Establishment was measured on 5, 8, and 12 DAP. Bold millet seed emerged faster (32,000 plants/ha at 8 DAP) than control (13,500 plants/ha). By 12 DAP, 10.6% of viable millet seed had emerged. Sorghum had 18.4% of the viable seed emerged by 12 DAP, with no seed effects.

Effect of High Temperature on Germination and Establishment of Pearl Millet of Different Seed Sizes and Densities. M.Y. Mortlock and R.L. Vanderlip, KSU, Manhattan, KS.

Three selected seed diameters (1.79-2.18, 2.18-2.38 and >2.78 mm and two densities (> or <1.12 g/cc) of pearl millet (*Pennisetum americanum* L.) were planted in trays of 98 pots per treatment in growth chambers at temperatures of 35, 42.5, and 50°C. Emergence was counted on 7 days and seeds dug up on the 7th day and germination assessed. Average germination was 81%. Larger seeds had higher germination (85%) compared to the smaller two seedlots. The higher density had higher germination, 84% compared to 79% for low density. Emergence was 82% for the 35°C and down to 15.5% for 50°C temperature. Large seed had higher emergence than small; medium was not significantly different from large or small. When adjusted for percent germinated, density and size effects were no longer significant. The establishment index (speed of establishment) showed seeds emerged faster from the lower temperature and from dense seed. Plant development was faster for large and medium compared to small seed. Plants from high density seed also developed faster. At 42.5°C, 18% were chlorotic by six days after planting compared to 50% at 50°C. Shoot dry weights at 7 days reflected seed size and density with no size by density interaction. Root weights also reflected the seed size. There were no differences in the shoot:root ratio.

Effect of Rotation and Fertilizer Treatment on Density and Dry Weight of Sorghum and Soybean Roots. W. Roder, S.C. Mason and M.D. Clegg, NU, Lincoln, NE.

Root distribution of soybean [*Glycine max* (L.) Merr.] and sorghum [*Sorghum bicolor* (L.) Moench] were measured in a cropping experiment with a 6-year history of continued soybean, continuous sorghum, sorghum-soybean, and soybean-sorghum rotation. Fertilizer treatments consisted of control, nitrogen (44.8 kg ha^{-1} on sorghum plots), and 89.7 kg ha^{-1} on sorghum plots), and manure (15.8 Mg dry matter ha^{-1}). Measurements were made from core samples. Root densities for the depths 0-7.5, 7.5-15, 15-30, 30-60, 60-90 and 90-120 cm were 4.4, 3.5, 2.0, 1.2 and 1.1 and 1.2 cm cm^{-3} for soybean and 6.9, 4.8, 3.4, 1.8, 1.5 and 1.5 cm cm^{-3} for sorghum, respectively. Root dry weights were 1.09, 1.42, 1.81 and 1.10 Mg ha^{-1} for continuous soybean, soybean after sorghum, continuous sorghum and sorghum after soybean, respectively. Average root density and root dry weight was 62 and 30% higher for soybean and 39 and 63% higher for sorghum, respectively, if the previous crop was sorghum instead of soybean. Manure and nitrogen treatment was associated with an 8.6 and 13.3% decrease in sorghum root density, while soybean root density was reduced by 10.3% under manure treatment.

Responses of Sorghum to Applied Abscisic Acid. M. Traore, IER, Bamako, Mali; C. Sullivan, S. Dione and B. Coulibaly, NU, Lincoln, NE.

The plant metabolite abscisic acid (ABA) reportedly has many influences on plant growth. In our studies a series of experiments were conducted on the responses of sorghum to small quantities of ABA applied as a seed pretreatment, sprayed on the foliage, or watered into the soil. Differences were found in genotype response to the ABA, but in general seed germination was enhanced and root growth stimulated by the ABA treatment. Germinated seed and seedlings grown from ABA treated seed had greater stress resistance and survival than water treated controls in both controlled conditions and a field environment with soil filled charcoal pits. When dilute ABA solutions were sprayed on plants in the vegetative stage, generally nonstressed plants had increased shoot-to-root ratios, shoot height and shoot dry matter. Total grain weight and seed numbers were reduced. Grain and root weights were essentially unaffected. However, when plants were drought stressed and compared to controls, the ABA treatment did not affect shoot height or shoot

and root dry weights, but grain yields were significantly increased. This was due primarily to increased seed numbers and to some extent seed weight. Applied gibberellic acid and kinetin both had an antagonistic effect on the ABA. Solutions of ABA applied to the soil immediately after seeding also resulted in increased stress tolerance and greater dry matter yields of greenhouse pot experiments. These results have the implication of practical seed treatment for improved stress tolerance, or genotype selection for increased inherent levels of ABA in the seed or seedling stage.

Millet/Cowpea Intercropping and Crop Residue Research in Niger. P.K. Verma, J.D. Eastin, NU, Lincoln, NE; M. Nouri, C. Reddy and I. Mohamadou, INRAN, Niger.

Millet/cowpea intercropping is the most common practice in Niger. The best way to increase the agricultural production seems to be the use of improved cropping systems and cultural practices.

Reduced light due to the shading from the millet canopy perhaps limits the growth of cowpea is the recommended millet/cowpea intercropping system. Water-use efficiency (WUE) responses of millet and cowpea were characterized. Using artificial shades it was determined that the WUE and production of cowpea was maximum at full sunlight. An alternative system consisting of alternate millet and cowpea rows, an arrangement that increased light availability to the cowpea canopy, was proposed. The cowpea is this system seemed to have a higher WUE compared to the cowpea in the recommended intercropping system.

Several millet/cowpea intercrop arrangements were tested for grain and total dry matter yields to identify the intercropping systems that might be more productive than the ones currently being used or recommended under both high and low input situations. The alternative to the recommended intercropping system referred to above increased cowpea grain and total dry weights by 15% and 24%, respectively. While millet arrangement and millet and cowpea populations were the same in this system as in the recommended one, it had alternate millet/cowpea rows as opposed to 2 rows of cowpea between millet rows in the recommended system. For the low input situations another system consisting of paired millet rows alternating with a cowpea row seemed promising. Millet grain and total dry matter yields were 24% and 42% higher, respectively, and cowpea total dry weight was 53% higher compared to the farmers' traditional system. These systems should be further researched to confirm their advantage over the ones that are currently being used.

An experiment to quantify the beneficial effects of crop residue on crop production was initiated. Application of 1, 2 and 3 t ha^{-1} of crop residue increased millet grain yield by 306%, 458% and 545%, respectively, compared to the no residue treatment. Corresponding increases for total dry weight were 253%, 347% and 382%, respectively, for the three treatments. During the first 5 weeks after planting, the daily mean, maximum and minimum soil temperatures at 30 cm depth were higher by 1-2 C in the no residue treatment compared to the 2 t ha^{-1} treatment. Soil temperatures at 2 and 15 cm depths were not different in these two treatments.

BREEDING

Stand Establishment in Relation to Seedling Mesocotyl and Coleoptile Length in Pearl Millet. B. Khaleeq, W.D. Stegmeier, KSU, Hays, KS. and R.L. Vanderlip, KSU, Manhattan, KS.

Stand establishment problems of pearl millet (*Pennisetum glaucum* (L.) R. and Br.) are severe constraints to successful production under subsistence farming conditions in the dry tropics and with mechanized farming practices in the Great Plains of the U.S. Failure to obtain adequate plant populations is often associated with adverse weather conditions occurring at critical times during the germination process; i. e., rapid soil drying prevents germination, soil crusting prevents emergence, and rainstorms during emergence flatten and bury seedlings in the wet soil. Studies were initiated 1) to examine germination temperature effects on seedling elongation in the germinator, and 2) to determine if deep planting (75 or 100 mm) under field conditions of materials previously selected for increased seedling length and rapid elongation in the germinator and greenhouse would identify lines possessing improved stand establishment capabilities. Seeds were germinated in rolled paper dolls in a dark germinator at desired temperatures for 8-day periods,

allowing maximum elongation of mesocotyl (MC) and coleoptile (CL) organs and rupture of the CL releasing the first leaf. Seeds were planted in greenhouse and field beds at 75 or 100 mm depths and compared to controls planted 37 or 50 mm deep. Germination of 100 lines at temperatures of 30, 35, and 40°C showed maximum MC elongation occurred at 35°C, but CL elongation at 35°C was not significantly different from elongation at 30°C. A significant reduction in both MC and CL elongation occurred when these lines were germinated at 40°C. Highly significant differences in elongation of MC and CL organs were found among 1100 entries germinated at 30°C with MC and CL lengths ranging from 14 to 130 mm and 6 to 40 mm, respectively. Seedling emergence was significantly higher under field conditions for those entries with long seedling length (MC + CL) in 75 mm depths-of-planting in comparison to short seedling length entries.

Pearl Millet: A Potential Early Maturing Dryland Feed Grain Crop. W.D. Stegmeier, B. Khaleeq, KSU, Hays, KS., R.L. Vanderlip, KSU, Manhattan, KS. and D.J. Andrews, NU, Lincoln, NE.

Pearl millet (*Pennisetum glaucum* (L.) R. & Br.) an early maturing cereal of African origin, is widely grown (25 m. ha) as a staple food crop in drought prone areas of Africa and India. Pearl millet is potentially a feed grain in areas of the U.S. where drought, soil type (low pH, or very sandy soils), short season or excessive heat reduce the yield potential for sorghum, for example, in parts of western Nebraska and Kansas. The huskless grain is nutritious, contains 5-7% oil, no tannin, has higher protein and energy levels than corn or sorghum and has been tested with advantage in feed rations of chickens and steers. Breeding programs at the University of Nebraska and Kansas State University, supported by INTSORMIL (USAID, Title XII funds) have produced experimental dwarf combine hybrids yielding 80-90% of sorghums of a comparable maturity. Research continues on yield, lodging resistance, and herbicides. Sorghum planting, cultivating, and harvest machinery can readily be used to manage pearl millet.

ENTOMOLOGY

Biological Control of Millet Stalk Borer in Niger. F.E. Gilstrap and O. Youm, TAM, College Station, TX.

The millet stalk borer (MSB), *Haimbachia ignefusalis* (Hampson), was collected in Niger from 14 plant species and seven gramineous and non-gramineous families, with *Andropogon gayanus* being the most commonly infected plant over locations studied. MSB apparently utilizes these non-crop plants primarily as a diapause refuge. *Euvipio* sp. attacked MSB on more host plant species than other parasites. Though several parasites attacked MSB in millet, densities of MSB are not suppressed by these parasites supporting a decision to import additional parasites from other parts of the world into Niger. *Bracon hebetor*, a common parasite of MSB in millet has a short life cycle and a high rate of population increase, is easy to culture in the laboratory, and if released in large numbers has potential for reducing prediapausing populations of MSB. Our studies indicate that MSB causes serious damage to both early and late planted millet, though greater numbers of MSB occurred in early millet. Studies on MSB preference for ovipositional sites indicated that green millet stalks with intact leaf sheaths were more preferred than flat green or dry leaves. This behavior would probably complicate attempts to control MSB with insecticides because larvae bore into the stalks immediately after hatching. Studies on MSB damage versus millet grain production showed a negative correlation between grain weight and numbers of exit holes in mature plants, diapausing MSB larvae occurred in all stalk internodes but were most numerous in internodes distal to the plant base, and damage was greatest when MSB occurred on internodes distal to the plant base.

Sorghum Resistance to Sorghum Midge. George L. Teetes and Gary C. Peterson, TAM, College Station, TX.

Sorghum midge is the most widely distributed of all sorghum insect pests, occurring in almost all sorghum producing regions. Early, uniform planting and flowering is the most effective management tactic, and successive planting favors the pest. Resistant sorghum cultivars would provide an additional, significant and much needed management component. The cooperative entomology/breeding program in Texas has defined sorghum midge biology, elucidated its population dynamics, and is developing resistant cultivars along with ancillary, support information that will define

their role and function in integrated pest management strategies in either developed or developing agricultural production systems. Resistant cultivars are provided to any LDC scientist upon request, and direct collaboration exists in Honduras. New resistance sources are continually screened for newly converted lines and genes from different sources are combined. Resistance mechanisms have been identified as nonpreference for adult visitation and oviposition, and antibiosis to larvae. Inheritance is complicated and quantitative. Agronomically improved cultivars are damaged at least five times less than susceptible cultivars under the same midge density, and are compatible with insecticide use, reducing the number of needed applications and improving their effectiveness.

Sugarcane Aphid Resistance Screening in Botswana. George L. Teetes, Gary C. Peterson, TAM, College Station, TX., and Chris Manthe, DAR, Gaborone, Botswana.

Of the three aphid species, namely, corn leaf aphid, greenbug, and sugarcane aphid, that infest sorghum in Botswana, the sugarcane aphid is the most abundant and persistently present species. A collaborative research project with the Department of Agricultural Research exists to screen sorghums for resistance to the aphid, determine resistance mechanisms and inheritance, and assess natural aphid enemies. The research project constitutes a Ph.D. dissertation research problem. At least 38 sorghum lines show moderate to high levels of resistance. Many of the resistant lines show moderate to high levels of resistance. Many of the resistant lines are of the zera zera group. An improved zera zera line from the Texas sorghum breeding program, TAM428 is highly resistant and is used as a standard resistant check for screening purposes. Sorghum lines show nonpreference, tolerance and antibiosis types of resistance and aphids reared on TAM428 sorghum have a higher mortality rate than aphids on susceptible sorghums. Most lines resistant to sugarcane aphid are susceptible to greenbug. The most important aphid natural enemies are *Xenthogramma aegyptium* (Weid) (Diptera: Syrphidae) and *Leucous* sp. (Diptera: Chamaemyiidae). Natural enemies most affect the abundance of greenbug and appear to suppress its ability to reach damaging levels. Density regulation of the sugarcane aphid appears to be brought about by joint action of plant condition, aphid dispersal and action of natural enemies. The introduction of a resistant cultivar into the local production system would likely relegate the sugarcane aphid to an occasional pest.

Sorghum Head Bug Research in Niger. Gary J. Steck and George L. Teetes, TAM, College Station, TX.

A collaborative research project on sorghum panicle-feeding bugs was conducted in Niger with INRAN entomologists. *Eurystylus marginatus* Odhiambo (Hemiptera: Miridae) is the most important and abundant insect pest of sorghum panicles in West Africa. First generation adults initially infest sorghum panicles in late August, and two succeeding generations develop on sorghum. Economic losses are manifested in yield and grain quality reduction. Yield losses from natural infestations to certain local sorghum cultivars range from 14 to 19%. Losses in vitrosity are the best indication of the effect on grain quality. Using cages with 20 introduced female/male pairs causes losses ranging from 19 to 62% of grain weight, 1000-kernel weight, percent low density grain, and vitrosity. Damage results from both oviposition and feeding. The percentage coverage of the grain surface by glumes, and the time from anthesis to opening of the glumes were significantly correlated with reduced head bug numbers and kernel damage. Measurable damage occurred with as few as five female/male head bug pairs per panicle. Most eggs are oviposited into exposed, apical portions of sorghum grains during the milky stage of kernel development.

Fall Armyworm/Stemborer Research in Honduras. F.E. Gilstrap, K.L. Andrews, D. Meckenstock, L. Lastres, and R.W. Jones, TAM, College Station, TX.

Research in Honduras has focused on *Spodoptera frugiperda* (J. E. Smith) (the fall armyworm or FAW) and *Diatraea lineolata* (Walker) (the neotropical cornstalk borer or NCB). Research objectives were to evaluate and colonize parasites of NCB, characterize and evaluate sources of mortality to FAW, and determine effects of cropping systems on pests/biological control agents. Regarding parasites of NCB, *Cotesia flavipes* was colonized in 1986-87 in Honduras

and El Salvador. Evaluations of the parasite's spread and impact are continuing in Honduras to learn how important this new parasite is compared to previously existing parasites and whether additional parasite species should be colonized in the future. Regarding characterizing and evaluating predatory mortality to FAW, *Solenopsis geminata* (F.) (the tropical fireant) and *Doru taeniatum* (the yellow-stripped earwig) were identified were previously identified as important for early and late season mortality to FAW. Field studies revealed lower infestation by FAW in plots where *Solenopsis* sp. was present. *Solenopsis* also seemed to reduce infestation by *Listronotus*, a weevil pest of corn and sorghum seedlings. In the field, *D. taeniatum* caused no reduction in infestation by FAW. This was probably due to the low numbers present at the time of the experiments. Five Hymenoptera and two tachinid parasitoids, a parasitic nematode, and two fungi were identified as mortality agents of FAW. *Chelonus insularis* (Hymenoptera:Braconidae) was the most abundant parasitoid recovered from field-collected larvae. Percentage parasitism was highest during the first planting season, reaching 80%. FAW infestations were lower during the second planting season than during the first. This was probably due to mortality of FAW caused by heavy rain and to the abundance of predators. Under cage-study conditions, *D. taeniatum* did not feed on second instar FAW larvae infested to sorghum or corn plants when plants were younger than three weeks old. *D. taeniatum* did stay in the whorls of plants three weeks old and older, and preyed on small FAW larvae thereafter. On the ground, mortality of second instar FAW larvae in a reduced tillage corn field averaged 93%. The most abundant and ground predator of second instar FAW larvae was *Solenopsis geminata*, accounting for a mean 79% mortality at a density of 67 ants per m^2. Other ant species accounted for 13% mortality at a density of 45 ants per m^2, and spiders accounted for 1% mortality. Additional studies on Doru are in progress. Cropping systems seems to have very little impact on pests or their potential biological control agents. Numbers of FAW and NCB in monocultures versus mixed plantings were usually more abundant in maize than in sorghum, usually greatest in mixed sorghum/maize plantings than in sorghum monoculture, and essentially the same in mixed maize/sorghum as in maize monoculture. These results suggest that differences among the cropping systems are not sufficiently important to recommend either monoculture or mixed plantings of maize and sorghum as a way of minimizing damage from pests.

FOOD QUALITY AND UTILIZATION

Water Solubility and Protein Digestibility of Tô, a Sorghum Porridge. A.B. Bello, A. Kante, L.W. Rooney, and R.D. Waniska, TAM, College Station, TX.

A good quality thick porridge (Tô) is firm and non-sticky, can be molded between the fingers, and does not deteriorate in texture upon overnight storage. Tô samples were prepared under acid and alkali conditions using flour from two varieties of sorghum that were decorticated i.e. SC205 (good quality Tô) and SC605 (poor quality Tô). Water soluble materials (WSM) were prepared by dispersing fresh Tô in water (1:4 w/v), blending, and centrifuging. The water insoluble materials (WIM) were dispersed in 50% ethanol and sieved on standard U.S. sieve No. 20, 40, 60, 80, 100 and 325 under vacuum. In vitro protein digestibility was determined using a pepsin digestion method.

SC265 (thick pericarp) had an intermediate endosperm texture while SC605 (thin pericarp) had a very corneous texture. Grit yields after decortication were similar; however, the amount of pericarp removed was 90% for SC265 and 50% for SC605. The gel structure of poor quality Tô may have been disrupted pericarp in the flour.

Acidic (pH4.6) Tô was firmer in texture than alkaline (pH8.4) Tô. The WSM of the alkaline Tô (80-70%) were higher than that of the acidic Tô (40-50%). The good quality Tô had more WSM (50-70%) than the poor quality Tô (40-60%). The WSM were rich in starch (> 50%). The fraction of WIM greater than 150 microns in diameter was more in the alkaline Tô (40-50%) than in the acidic Tô (15-25%). Also, the WIM of good quality Tô had larger particles (> 150 u) than the poor quality Tô.

In vitro protein digestibility of uncooked sorghum flour was 8-13% higher than that of the Tô. Similarly, the digestibility of the good quality Tô was 2-5% higher than that of the poor quality Tô. The digestibility of acidic and alkaline Tô were not significantly different.

Somaclonal Variation in High Tannin Sorghum. T. Cai and L.G. Butler, Purdue University, West Lafayette, IN.

Over 6,000 plants (R_1) were regenerated from embryogenic calli derived from mature or immature embryos or from developing inflorescences of eight sorghum cultivars selected for their high levels of tannin. Field assessment of somaclonal variation has progressed to the R_2 population, with over 48,000 R_2 seedlings (27,000 plants) in 1,126 rows from 1055 R_1 plants and to the R_3 generation of 72 R_2 plants. Grain from over 2,000 selected heads of R_1 and R_2 plants have been analyzed for total phenols, condensed tannins and flavan-4-ols. Most of these tested somaclones originally derived from calli which had been maintained for 7-10 months. Variants with significantly increased and decreased levels of these polyphenols were selected, as well as qualitative variants with respect to the flavan-4-ols and tannins produced. A wide range of morphological and developmental variants such as ragged leaf, multi-branched heads and "crazy" sorghum previously unreported, were also observed. Variant production greatly depends on parent genotype and appears to increase with increasing time in culture. The average somaclonal variation rate (based on R_1 plants) and somaclonal variant frequency (based on R_2 plants) estimated in the tested population were 24.0 per 100 R_1 plants and 7.7 per 100 R_2 plants for polyphenolic variation, as well as 11.0 and 1.6 for morphological and developmental variants, respectively. Estimated size of the mutated sector ranged from the whole plant to 3.3% of a single head. In chimeric R_1 plants very small sector mutations do not appear until the R_3 generation. Some of these variants may be useful for further study or for use in breeding programs.

Characterization of Native Sorghum Starch and Starch from Extruded Decorticated Sorghum by HPLC-Size Exclusion Chromatography. D.S. Jackson, M.H. Gomez, R.D. Waniska, and L.W. Rooney, TAM, College Station, TX.

The characterization of starch by HPLC-Size Exclusion Chromatography (HPLC-SEC) has proven useful for the study of amylose structure, separation and quantification of amylose and amylopectin, and the characterization of starch extracted from food products. Laboratory isolated waxy, heterowaxy (2 types), and non-waxy sorghum starches, from crosses made with very closely related Kafir sorghums (non-waxy TX3197 and waxy TX615), were characterized by HPLC-SEC. These starches contained < 1, 17, 23, and 24% amylose (AMY). Also, starch suspensions from extruded decorticated sorghums (a food system model) with 27, 22, and 12% AMY were analyzed. The decorticated sorghum were each extruded at 45, 32, and 18% moisture, dried and ground prior to HPLC-SEC sample preparation.

One percent (1%) starch (or exudate) suspensions were prepared by bringing 1.0g of starch and 0.5ml methanol to a volume of 100ml with water. Ten (10)ml of this suspension was gelatinized by placing a test tube of the sample in boiling water for 10min and then autoclaving for 10min. After the suspension cooled to 65°C, the starch was further dispersed by an ultrasonic processor (Vibra-cell VC40, Sonics and Materials, Danbury, CT). The solution was then centrifuged and filtered through a 5μm nylon filter. Twenty-five (25) μl of starch solution was injected into four S-series Shodex Ionpack columns connected in series. Water was used as the mobile phase, and the separated compounds were detected using a Waters 410 refractive index detector. Apparent molecular weight (MW) calibration was performed using pullulan MW standards.

Soluble AMY from native sorghum starches higher in total AMY has a lower apparent MW than does AMY from sorghum with less total AMY. Also, AMY from sorghum with more amylopectin (AMP) is, on a percentage basis, more soluble than AMY from sorghum with less AMP. As the "waxy character" of the sorghum starch increased, the solubility of AMP decreased.

The starch from decorticated sorghum extruded at 45% moisture was less damaged than that extruded at 18% moisture. HPLC-SEC fractionation showed two populations of AMP. The apparent MW of AMP fractions decreased as the total percentage of AMP in the starches increased. Harsh extrusion (15% moisture) greatly increased the solubility of the larger apparent MW AMP, while the solubility of the lower MW AMP was not appreciably increased. At low extraction temperatures, and/or high extrusion moisture, the majority of soluble AMP was the low MW fraction. At higher extraction temperatures, and/or low extrusion moisture, more of the total AMP was solubilized as high apparent MW AMP. As the extraction temperature increased, AMY solubility also increased. Harsher extrusion conditions increased AMY solubility above that found in raw or mildly cooked material. Aqueous HPLC-SEC can be used to study sorghum starches, and the effects of food processing on starch properties.

Traditional Food Processing Technologies in East Africa Improve Nutritive Value of High Tannin Sorghums. S. Mukuru, E. Monyo, G. Ejeta, M. Hassen, E. Mertz and J. Axtell, ICRISAT, Hyderabad, India and Purdue Univ.

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 where it is used in cooking beans. Cooking high tannin sorghum grain, (cv. IS1291) in magadi extract raised in vitro pepsin digestibility values to that of low tannin sorghum.

Mechanism of Antinutritional Effects of High Tannin Sorghum. John C. Rogler, Simon Mole and Larry G. Butler, Purdue University, West Lafayette, IN.

Because tannins inhibit virtually all enzymes tested in in vitro assays, and because feeding tannins results in an increase in protein in the feces, it has long been assumed that the decreased weight gains and feed utilization efficiency associated with dietary tannin is due to inhibition of digestion of dietary protein. But in vivo inhibition of digestive enzymes is difficult to demonstrate, presumably because of the presence of many other proteins competing for binding the tannin. Moreover, the increase in fecal protein is largely endogenous, rather than dietary protein. Using on rats a technique previously applied only to insects, we can distinguish the effects of dietary tannin on digestion from the effects on the conversion of digested and absorbed protein or dry matter to new biomass (dry matter or protein). In a typical experiment we found that the digestibility of the dry matter in a low tannin sorghum was 88%, and this was diminished to 78% in a high tannin sorghum. In contrast, the efficiency of conversion of digested and absorbed dry matter to new biomass averaged 75% vs. 45% for high tannin sorghum, so the effect of tannin on digestibility of protein is greater than on digestibility of dry matter. But the efficiency of conversion of digested and absorbed protein to new body protein was affected even more strongly: 30% for the low tannin sorghum vs. -5% for high tannin sorghum. These results, which have been repeated several times, show that the major antinutritional effect of dietary tannin is on post-digestion metabolism rather than on digestion.

Effects of Prolamin Protein Fractions on Sorghum and Maize Digestibilities. R.M. Sikabbubba and C.F. Klopfenstein, KSU, Manhattan, KS.

Sorghum and corn have almost the same nutrient composition, but sorghum is usually less digestible than corn. One difference between the two grains appears to be the structure and composition of their alcohol-soluble storage proteins. The primary objective of this experiment was to extract and quantify those proteins from sorghum grain and corn with different endosperm types and textures and compare their in vitro protein digestibilities. We then compared differences in in vitro starch digestibilities of grains with varying concentrations of alcohol soluble proteins, and on the extracted starch. The amino acid composition and available lysine were determined in the whole and fractionated samples.

Effect of Weathering and Fungi on Phenolic Acids in Sorghum. R.D. Waniska, J.H. Poe, G.A. Forbes, R. Bandyopadhyan and R.A. Frederikson, TAM, College Station, TX.

Phenolic compounds (PC) and phenolic acids (PA) were quantitated in the mature caryopses of sorghum grown in wet or dry environments. Twelve cultivars varying in pericarp color exhibited different levels of resistance to molding in the wet environment. Sorghum caryopses with a white pericarp contained in lower levels of free PC (14 μg/caryopsis) than those with a red pericarp (41 μg/caryopsis) when grown in the dry environment. Higher levels of free PC and free PA, especially free p-coumaric, ferulic and caffeic acids, were observed in molding-susceptible cultivars, i.e. p-coumaric (0.76 vs. 0.14 μg/caryopsis), ferulic (1.74 vs.).10 μg/caryopsis) and caffeic (1.52 vs. 0.55 μg/caryopsis) in wet and dry environments, respectively. Bound PA were present at higher levels than free PA in all three cultivars; and higher levels of bound p-coumaric, vanillic and caffeic acids were observed in mold-susceptible cultivars.

Phenolic compounds (PC) and phenolic acids (PA) were also quantitated in 6 sorghum cultivars inoculated with *fusarium moniliforme* at different stages of development. Inoculation with fungi caused an increase of PC in glumes at 10, 14 and 20 days after anthesis, especially in resistant and moderately resistant cultivars. Levels of free PC in sorghum caryopses were similar for inoculated and control treatments during development. Free para-coumaric acid contributed to the higher levels of PC in glumes and caryopses; the resistant cultivars and one of the moderately resistant cultivars had earlier or higher levels than their control treatments. Hence, p-coumaric and caffeic acids appear to be involved in the bio-chemical response to fungal invasion. Glumes appear to be the plant's first defense against fungal invasion and colonization, and later, it is the chemical and physical properties of the caryopsis that appear to be more important in the resistance of grain to molding.

Processing Characteristics of Parboiled Sorghum. R. Young, L.W. Rooney and R.D. Waniska, TAM, College Station, TX.

The effect of different parboiling techniques on milling yield and cooking quality was investigated. The whole kernels of four sorghum cultivars (Dorado, 77CS-2, BTx3197 and Hegari) differing widely in kernel characteristics were 1) soaked overnight and boiled for 10 min, 2) brought to boiling point, soaked overnight and then brought to boiling again, or 3) left untreated (raw). The cooked samples were dried at ambient temperature prior to abrasive decortication with a TADD mill. After decortication, the yield of whole kernels, color and cooking characteristics were determined.

Parboiling significantly increased the yield of decorticated grain, presumably due to the annealing effect of starch gelatinization which mainly "salvaged" cracked kernels and reduced destruction of kernel integrity during the milling operation. The yield of whole, decorticated grain increased from about 70 to 90% for soft endosperm types, and from 80 to 90% for hard endosperm types. All treatments caused darkening of the kernels while enhancing their translucency.

After boiling the decorticated kernels, no significant color differences were observed between treatments within a cultivar. The optimum cooking time of untreated boiled sorghum (34-47 min) was decreased by 8 to 15% while texture of the boiled kernels was not significantly affected by the parboiling procedures. Parboiling may be a practical method of improving the milling properties of soft sorghums for rice-like foods.

PLANT PATHOLOGY

Effects of Maize Dwarf Mosaic Virus Strain B on Growth and Yield of Sorghum. J.D. Alexander, R.W. Toler, TAM, College Station, TX.

Twenty-seven sorghum accessions were tested in field and greenhouse trails for susceptibility to infection by maize dwarf mosaic virus strain B (MDMV-B). Disease incidence and severity were compared to reactions caused by MDMV-A. The effects of MDMV-B infection on plant height, panicle length, stem diameter, kernel size, weight and density,

and yield were also measured. Fourteen accessions were apparently immune to MDMV-B while thirteen were susceptible. No accessions were found which were susceptible to infection by MDMV-B and immune to MDMV-A. Ten of the accessions immune to MDMV-B are susceptible to infection by MDMV-A and may serve as host differentials based on infectivity. Five of the susceptible accessions developed various levels of necrosis, or "redleaf", in response to infection by MDMV-B. Four of these develop little or no necrosis when infected with MDMV-A and may be used to differentiate MDMV-B from MDMV-A based on symptomology. In general, accessions with necrotic reactions were reduced in plant height, panicle length, and stem diameter by 40%, 40% and 25%, respectively. Yield was reduced an average of 70% in plants showing necrotic reactions. Differences in kernel weight, size, and density were not significant. Accessions with non-necrotic symptoms developed mosaic symptoms of various intensities when infected with MDMV-B. Plant height and panicle length were not significantly affected by infection within this group, although there was a trend towards slight increases in both parameters. Stem diameter was decreased an average of 6% and yield was reduced an average of 10%. Kernel weight and volume were increased 4% and 6%, respectively, with a corresponding 2% decrease in kernel density.

Unusual Fusarium Isolates from Sorghum. C.J.R. Klittich and J.F. Leslie, KSU, Manhattan, KS.

Fusarium strains with an unusual appearance have been isolated from sorghum plants in Kansas. On semi-synthetic complete medium or PDA, the colonies produce a yellow-brown, diffusible pigment giving them a speckled, metallic appearance. Based on spore morphology these strains would be classified as *Fusarium moniliforme*, although the microconidial chains are short. Yellow strains are heterothallic and interfertile with each other when sexual crosses are made on 20% carrot agar. None of the yellow strains could cross successfully with standard *F. moniliforme* testers, however, indicating that the yellow strains are genetically isolated from *F. moniliforme* and that they form a separate species. Yellow strains were isolated almost exclusively from sorghum. Over 20% of the 300 Fusaria isolated from sorghum stalks and seeds in Kansas were yellow strains, but only one of 250 isolates from maize was a yellow strain. Similar strains have been identified by W. F. O. Marasas from sorghum grown in South Africa. The Kansas yellow isolates belong to several vegetative compatibility groups, and therefore are multiple strains rather than clones of a single strain.

Vegetative Compatibility Groups as a Measure of Population Diversity in Fusarium. J.F. Leslie and C.J.R. Klittich, KSU, Manhattan, KS.

Measurements of genetic diversity in *Fusarium* populations are often lacking because differences between strains (such as virulence or host range) are difficult to discern. These difficulties are compounded with nonpathogens and pathogens causing disease on mature plants. Vegetative compatibility groups (VCGs) are a useful tool to measure population diversity because a single test samples many loci (at least 10 in *F. moniliforme*) and can be done rapidly in a petri dish. Strains are vegetatively compatible (belong to the same VCG) only if alleles at each locus are identical. VCG is determined by placing complementary auxotrophic mutants of different strains on minimal medium. If the strains are vegetatively compatible, hyphae can fuse and form a heterokaryon which will grow vigorously. Incompatible combinations remain as thinly growing colonies. The efficacy of VCG classification depends on the rapid generation of complementary, auxotrophic mutants. Nitrate-nonutilizing (nit) mutants are produced spontaneously at a high frequency on medium containing chlorate, a toxic analog of nitrate. VCG classification using *nit* mutants is a rapid, convenient technique for examining population diversity in *Fusarium*. VCGs provide information on the importance of sexual reproduction in the population, and will aid in elucidating how Fusaria infect and colonize plants.

ANNEX

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