Proj. No. 931057[illegible]
Rnd – PO-AAC-216-[illegible]

PROJECT STATEMENT

Submitted: October 10, 1972
Amended: November 16, 1972

PROJECT SUMMARY

31p

1. Statistical

Project Title:	Development of Improved, High-Yielding Sorghum Cultivars
New or Extension:	New Project
Contractors:	A consortium of three universities --
	The University of Puerto Rico Mayaguez, Puerto Rico 931-577
	The University of Nebraska Lincoln, Nebraska 931-575
	Texas A & M University College Station, Texas 931-578
Principal Investigators:	Dr. O. J. Webster, Mayaguez, Puerto Rico Dr. J. D. Eastin, Lincoln, Nebraska Dr. R. A. Fredericksen, College Station, Texas
Duration:	Five years (see Note below)
Total Estimated Cost:	$1,500,000
Funding by Fiscal Years:	1973 - $225,000 1974 - 275,000 1975 - 300,000 1976 - 375,000 1977 - 325,000
Project Manager:	Charles A. Breitenbach
Project Specialist:	Samuel C. Litzenberger

2. Narrative

During the last three decades a tremendous development has taken place in sorghum production in the United States. The crop is now one of the most rapidly expanding cereal grains in the developing countries as well. It is a crop which came from the tropics in the first place. There

NOTE: Duration proposed by TA/AGR prior to RIGC review. At its meeting on November 13, however, RIGC recommended approval for three years, with a consequent reduction in cost to $800,000. Extension beyond that period will be contingent upon an evaluation of progress in the latter half of the third year. For further detail, see the foregoing Supplement and

is no doubt that it is one of the most [illegible] of the major cereal grains; one which will produce on comparatively poor land and on which can withstand both periods of drought and periods of flooding, and then begin renewed growth when conditions return to normal. More important is the fact that when cultural practices are less advanced than possible with modern farming methods, sorghum is better able to nearly achieve its potential yield than is corn, its closest competitor.

In addition to desiring to satisfy their food needs, the developing countries today are also interested in expanding their animal production industries, particularly poultry and swine. Battery chicken production has been introduced as a modern production method in a majority of the developing countries. The principal drawback in most such countries is the lack of locally grown animal feedstuffs. And, as most of the developing nations are trying to limit their foreign imports, they are interested in expanding sorghum production.

A major constraint to more rapid increase in production and utilization of sorghum in developing countries of the tropics is the supporting production technology. In most cases high-yielding, disease and insect resistant varieties with improved grain quality are not available to the farmers. While a number of commendable projects can be cited of sorghum improvement for the tropics (e.g., the All India Coordinated Sorghum Improvement Project, the A.I.D.-supported East and West African Major Cereals Projects, and the Purdue University Protein Improvement Project), the work has not been commensurate with the need for new technology in developing nations where sorghum is important in human and animal nutrition.

In large measure, due to recognition of this growing need for sorghum production technology for the tropics, a Consultative Group-supported international center (ICRISAT*) is in the process of being established in India. While destined to make an impact in due course, the work of ICRISAT and of the national research systems of the developing countries of the tropics can be substantially accelerated by strengthening relevant sorghum improvement projects in the United States.

Since 1966, A.I.D. has had a contract with Purdue University (csd-1175) to increase the quantity and quality of the protein of grain sorghum in order to help reduce protein hunger among the major sorghum-eating populations of Africa, where about 40 percent of the protein in the human diet comes from sorghum type grains. Now it is A.I.D.'s intent to broaden its assistance to also include work on improving the quantity and quality of the energy

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* International Crops Research Institute for the Semi-Arid Tropics.

(calories) stored in the grain. To achieve this, it is intended to make maximum use of present developments and improvements being achieved in the crop at Puerto Rico, Nebraska, Texas, or Purdue.

Purdue, Nebraska, Texas and Puerto Rico are the U.S. centers where the major grain sorghum research is currently being emphasized. At Puerto Rico, the world collection of sorghum is being evaluated for new sources of germplasm needed to further improve the modern day grain crop. At Nebraska, these factors are being incorporated into the crop to improve the physiological characteristics which determines the plant type and organic structure required to produce more and better grain. At Texas, new factors for resistance to limiting disease and insect pests are being isolated and incorporated into the sorghum plant so as to strengthen its defense mechanisms against these destructive organisms. At Purdue, newly identified factors for improved grain quality are being utilized to develop more nutritious cultivars for those who depend on the crop as their major source of protein.

With this project A.I.D. proposes to supplement, by an investment for research directed towards the needs of the tropics, sorghum research for the temperate zone underway at Puerto Rico, Nebraska and Texas, in cooperation with the USDA. This investment is designed to expedite the development of improved sorghum populations (improved in yield, grain quality, disease and insect resistance) and to make them readily available to ICRISAT and developing countries.

In practice plant breeders never succeed in developing the ideal variety; crop improvement is a continuing research effort. For this reason, it is difficult to precisely determine when U.S. assistance in this area should be terminated. Important factors are: (1) actual success of the contractors in developing populations of sorghum substantially improved with respect to the several mentioned characteristics; (2) utilization of the improved materials in sorghum production and research programs in developing countries; and (3) research capability in the developing countries or elsewhere to take over the work under this project. In view of the already advanced and relevant programs of the proposed contractors, the strength of a number of developing country programs, and the promise of ICRISAT, it is believed that our major contribution can be made in the five-year period proposed. Continuing support for this project, if any, would be expected to be at a much lower level.

B. EXPANDED NARRATIVE STATEMENT

1. Project description and background

A.I.D. has a contract with Purdue University for the development of high protein quality grain in sorghum, "Inheritance and Improvement of Protein and Quality and Content in Sorghum bicolor (L.) Moench" (AID/csd-1175). Since the inception of that project in 1966, a great deal has been learned about the nutritional quality of sorghum grain. Unlike corn, no single factor, such as the "opaque 2" character for high lysine has been found to date in sorghum. Where improved grain types (protein content and amino acid balance) have been selected, they have been the product of many factors not the least of which were physiologically induced. It is now known that where high quality protein does exist, its assimilation as a food by humans or as feed for animals may be limited by a series of inhibitors including the polyphenols, i.e., tannin pigments present in the testa, a layer beneath the seed coat of many bird-resistant sorghum varieties. These problems were not encountered in breeding for improved quality in corn.

Meanwhile, at the University of Nebraska, with limited funding from the Rockefeller Foundation, a team of plant scientists working on the physiology of grain yield found that sorghum is more responsive to induced changes in its physiology than perhaps any other cereal grain crop. Not only do changes in day-length, temperature, and availability of moisture affect the quality and protein content of the grain, but the Nebraska team also found that the sorghum plant is potentially capable of storing many times more energy units in the grain than is presently achieved by any of the sorghum cultivars thus far screened. A large percentage of these energy units could be protein. The problem is that an abscission layer is formed at the base of each grain, cutting it off from the source of additional energy uptake while the plant is physiologically young and thus still capable of producing and storing additional amounts of energy in the seed. Additional funds are required to extend research with ongoing activities that include certain phases needed to provide answers to questions relating directly to the developing countries, which would not be otherwise investigated.

At Texas A & M, it was found that this crop, long believed to be relatively free of diseases and insects is in fact highly susceptible. Natural resistance has been identified for the control of a whole series of pests which are now known to be dramatically reducing grain sorghum yields in the developing countries, under conditions where chemical control hardly seems practical and could, indeed, leave undesirable accumulations of toxic materials in the environment.

The most promising source of new factors from which to derive improved characters in the sorghum plant, as a whole, and in grain yield, in particular, is the world collection of sorghum cultivars. This, in fact, has been the source of the large majority of all sorghum breeding achievements in recent years. The situation is easily explained. Until comparatively recently, the germplasm which continued to comprise the large percentage of the U.S. commercial sorghum varieties came from a relatively few Kafir and Milo introductions from Africa. These were the varieties capable of flowering and setting seed under the long day-length conditions during the growing season of the continental United States. By the late 1960s, the germplasm of these sorghums had been so thoroughly worked that the potential for deriving new breeding advances from it had become greatly limited. Almost all releases were becoming more alike with each new round of improvement. Yet there remained large numbers of sorghum varieties in Africa, the Near East, and Mainland China that had never been screened as new sources of germplasm because they would not flower in the U.S. under normal growing conditions.

Currently, the world collection is being maintained in Puerto Rico. Promising lines are being converted by the USDA and cooperating state workers to populations which will normally flower in the U.S. and which can thereby be crossed onto the elite American grain sorghums. This conversion program is allowing a vast new array of germplasm to be introduced into some of the best cultivars that have been developed over the past decade. The expanded program promises to produce a host of new sorghum advances of significant benefit to sorghum-producing and sorghum-consuming countries throughout the world.

Each of the major sorghum breeding programs discussed above, at Purdue, at Nebraska, and at Texas, depends on cooperation with the Puerto Rico program and its USDA-University relationships for the conversion of exotic sorghums.

Coordination and integration of the work in Puerto Rico, at Nebraska, and at Texas with the existing A.I.D.-financed project for high protein grain development at Purdue, offers very high odds of producing spectacular advances in improving the quality and yield of sorghum over the next five years. The objective of this project is to capitalize on those advances for the benefit of the developing nations, i.e., those advances which make it possible to attain higher production where the growing conditions are less controlled.

The timing is considered near-optimum to maximize support to the sorghum work of ICRISAT which is just being initiated. It will facilitate establishment of viable links between the contractors and ICRISAT and between the contractors and sorghum improvement projects in the developing countries.

2. Significance to A.I.D. Objectives

Sorghum is the staple food for a large percentage of the indigenous population of Africa and for much of the population of India and Mainland China. Throughout Latin America, in parts of the Middle East and in the Far East, this recently introduced cereal is becoming a permanent new crop in the domestic agriculture scene. Thirty years ago, sorghum was just taking its place in American agriculture and before that it was scarcely known, yet today it has essentially replaced corn in the Southern Great Plains. If what has occurred in the United States in any way indicates what may be possible under tropical conditions from whence the crop came, then work on this cereal may prove to be even more significant in the third world than has been the case in the development of the so-called "miracle" rice and wheat varieties.

It is considered that the improvement of sorghum offers an outstanding opportunity not only for assisting the advanced nations in improving their sorghum crop, but as an even more significant spin-off, and for a relatively small investment, increasing the protein and calorie intake, rural employment, and expansion of the livestock industry, thereby increasing the GNP of the developing countries.

3. Relation to Existing Knowledge

Two crops of almost no significance in the United States, a little over a generation ago, have become among the most important in American agriculture today. These are soybeans and grain sorghum. Soybeans have been fermented and eaten for human food as bean curd in China from time immemorial. Sorghum grain is the indigenous cereal of the majority of Africa's population. Both of these crops have been so modified and so improved by the plant breeders in their new temperate environment that they now have little resemblance to the native strains from which the modern day crop was derived. Still, in the emerging nations, almost no carryover has taken place in general and our advances in soybean and sorghum development have not been made available. Soybeans, though no doubt one of man's best sources of high quality plant protein for food, remain a relatively unknown crop in most of the tropics. Sorghum continues to be pretty much the same in Africa at this time as was the primitive cereal from which today's record-setting grain production sorghums were developed.

The acreage planted to sorghum is expanding faster in the U.S. than for any other crop. In many states, it is replacing the production of corn for animal feed. This is because under less favorable conditions today's improved sorghum varieties consistently outyield our best U.S. corn.

In the U.S., at first, some resistance was exerted against the use of sorghum in animal rations. Now because in some areas sorghum can be produced cheaper than corn, and because more is known about its nutritive value, this resistance has rapidly disappeared. The fact is that the varieties of grain sorghum most commonly produced for the market are the brown pigmented types. The brown color is caused by tannin in the subcutaneous layer. It is bitter in taste and therefore not liked by the flocks of grain eating, migratory birds that regularly decimate those varieties of sorghum which lack this protection. The tannins have also been related to protective resistance against fungi in humid environments. As a consequence, sorghum breeders continue to select for the tannin character even though it has been known for some time that the white grained varieties have better consumer acceptance and nutritive quality and that theyyellow endosperm types are preferred by the livestock industry.

Until recently it had been widely believed that sorghum grain as a whole was less nutritive than corn as regards available protein for conversion to animal tissue. The livestock industry resolves the problem by adding greater quantities of protein supplements to standard rations when sorghum grain is employed than when corn is used. In the feed industry, this is no different than the fortification with vitamin A when corn is used, although this is not considered necessary when yellow corn serves as the concentrate.

Research under the A.I.D. contract with Purdue has demonstrated that when non-tannin sorghum grain is fed to rats it is equal to most standard varieties of corn in achieving weight gains. During the past year, these results have also been confirmed at the CIMMYT* with the vole and at Washington State University with the chick. In every case, the tannin-free grain proved to provide significantly greater weight gains than when animals are fed the brown, bird-resistant types. Further pursual of this result has demonstrated that when the brown pigmented layer of the bird-resistant grain is polished off, the remainder of the cereal has about the same nutritive value as non-tannin sorghum grain.

Work undertaken in the analytical chemistry laboratory in conjunction with these feeding trials has shown that many sorghums do have as high a percentage of high-quality, assimilable protein as do most varieties of corn. The inhibitory effect of tannin on the utilization of the protein is being studied as are methods of removing the outer layer (polishing) for human consumption.

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* International Corn and Wheat Improvement Center, Mexico.

The increased interest that the developing nations are demonstrating in introducing and expanding sorghum production should be capitalized on. The U.S. has very highly productive sorghum varieties which can be utilized in developing correspondingly superior varieties for the tropics and subtropics through the use of existing knowledge and plant populations derived from the conversion program. Sorghum is much better able to reach its maximum potential yield capacity than corn under the rustic farming conditions of most developing nations. Now with our present knowledge of inhibiting factors in sorghum protein utilization, there is every reason to believe that the production of sorghum can add more and better protein and additional calories to the protein hungry nations of the third world than would have been possible in the past.

4. Relation to Other Research

This project is not intended to be different from other research projects underway in the U.S. Rather, it is intended to ride "piggy back" on the research of the conversion program in Puerto Rico, the pest and disease resistance program of Texas A & M, and the work on physiology of yield at Nebraska. By a moderate additional investment, A.I.D. intends to make the research of these improvement programs applicable for use in the developing nations. This work is to be fully coordinated with the work on protein improvement which A.I.D. has financed at Purdue. At a later date when the ICRISAT has become functional in India and assumes its responsibility as an international center for sorghum and millet research, it is expected to take on parts of the work now included under the proposed consortium for sorghum development. When this happens, activity under this project will be reduced accordingly.

In any case A.I.D.'s contribution in sorghum research will be directly coordinated with the ICRISAT and its outreach programs, and with CIAT,* CIMMYT, IITA* and IRRI* where sorghum is already included in the "crops systems" program. The efforts of this project will complement those of ICRISAT and the worldwide linkage network and will help to make it more effective in its role to serve the world in sorghum and millet improvement. Even when ICRISAT can assume full responsibility for coordinating the worldwide research network, it is believed that a program in Puerto Rico will still be essential or needed to coordinate the work on this crop from the United States with that of the tropics and subtropics. Financing of the Puerto Rican element could possibly be provided through ICRISAT as a substation for the Western Hemisphere.

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* CIAT - International Center for Tropical Agriculture, Colombia;
IITA - International Institute for Tropical Agriculture, Nigeria;
IRRI - International Rice Research Institute, Los Banos, The Philippines.

5. Proposed Work Plan

a. Scope of Work

It is A.I.D.'s intent that this consortium project will supplement the work at Purdue. Since the Nebraska and Texas research programs as well as the project at Purdue depend on the sorghum conversion program at Puerto Rico for new germplasm, it is considered that the consortium contract can integrate the overall research into a single network with Puerto Rico the focal point.

A.I.D. funds provided to the University of Puerto Rico during the initial 12-month period will be used to evaluate new improved germplasm from exotic sorghums available to sorghum breeders around the world. The UPR will also assist in the maintenance and processing of the world collection of sorghum varieties.

Funds provided to the University of Nebraska during the same period will be devoted to research on the physiological characteristics which control increased grain production in the tropics and subtropics. A.I.D. contributions will serve to support investigation on the soil and climate conditions which have prevented higher yields being achieved in the warmer and more moist latitudes.

A.I.D.'s initial contribution to Texas A & M University will be limited to research on resistance to sorghum plant and seed pests and diseases prevalent in the tropics and subtropics.

b. Program of Work

Detailed work plans for each of the three cooperating institutions are presented in Attachment A. Puerto Rico will serve as the focal point for the tropical sorghum improvement program; Texas A & M will specialize on limiting diseases and insect pests of sorghum; and Nebraska will concentrate on the physiology of grain yield improvement. These three institutions, together with Purdue which provides needed research on the improvement of protein content and quality, constitute an integrated team. Their combined efforts will make it possible to capitalize on the tremendous advances being achieved in sorghum development in the U.S. and their transfer to developing nations where sorghum is especially important both for human nutrition and animal feed.

6. Research Methodology

The research methodology to be employed in this project will be that regularly used as standard practice by plant breeders in the improvement of cereal crops. In the proposed project, Texas A & M and Nebraska will screen new materials from the worldwide germplasm collection of sorghums in Puerto Rico for new genetic factors they seek both to obtain pest and disease resistance in the first instance, and to obtain favorable physiological factors (superior plant type and root systems), to increase grain production in the second instance. The processing of new materials not previously screened provides high promise for the isolation of desired germplasm for the tropics. This would not be the case if the screening were to be undertaken only on American germplasm.

The conversion program in Puerto Rico consists in crossing exotic sorghum varieties having desired characteristics with standard American varieties. Generally, the exotic types tend to be extremely tall and they will not flower in the long days of the continental U.S. growing season. By the time they have been backcrossed for four generations with the U.S. parent, they are reduced to normal stature and readily flower under long-day conditions; in all other characters, however, they should maintain the desired features of the genotype of the exotic variety.

The conversion process consists of the following steps. An improved North American variety is crossed with a selected exotic variety in Puerto Rico in October. The hybrid seed is harvested in February and the subsequent generation is immediately planted again in Puerto Rico. The second generation is harvested in May and sent to a cooperating institution (Purdue University, Nebraska, or Texas A & M) for immediate planting. There the plant populations are screened for two factors, reduced stature and the ability to flower under the long-day growing season of the continental U.S. Seed from these plantings which possess the above characteristics are harvested in September and the selected lines are again returned to Puerto Rico and planted. The lines are backcrossed for the second time to the exotic variety. This process is repeated for four years. Each year for the four years, the backcross to the exotic variety is planted in Puerto Rico, and the following generation is planted in the U.S. where selections are made for early flowering and short stature. At the end of this conversion process, the resulting seed may be considered genetically uniform for a majority of the exotic variety's characteristics, although converted in stature and in flowering capacity to a U.S. sorghum type.

During early generation of the conversion program, or if more convenient after the exotic variety has been converted, the material is screened for the desired new gene characters. In the case of improved protein quality, this is investigated under the A.I.D. contract with Purdue. Factors which may improve the crop's physiological process to produce more efficient and larger quantities of grain are screened by Nebraska, and resistance to disease and insect pests are especially sought by Texas A & M.

The new factors once identified and isolated can be incorporated into an improved sorghum variety used by any country in the world, either temperate or tropical. The objective of this project is to develop and make available to developing countries superior germplasm for improved nutritional quality, increased grain yield, and disease and insect resistance.

7. Researcher Competence

The three organizations selected as cooperating institutions in this project are already highly competent in their respective fields. No other institutions are undertaking similar research for the tropics and subtropics. The USDA serves as a cooperator in each instance to support both state and federal programs. As such, the USDA would indirectly provide support to the consortium's effort.

The USDA is the agency which has the control of the world germplasm collection of sorghums and, as such, was responsible for initiating the conversion program at its tropical experimental station in Mayaguez, Puerto Rico. This work by its very nature must be continued under short-day conditions and the University of Puerto Rico, with USDA cooperation, is well prepared to assume responsibility for it and for making the materials in the conversion program available for use by developing countries.

The University of Nebraska is the only institution working on the physiology of yield in sorghum and its research has already proven that the sorghum plant is capable of producing considerably more grain than has been achieved until this time.

Because Texas is a major sorghum producer, the state is vitally interested in sorghum improvement. Texas A & M has a superb program in the selection of sorghum cultivars for resistance to diseases and insect pests and its work is already being employed by the private sorghum breeders to improve their commercial varieties.

8. Contribution to Institution Building

One of the functions of the consortium program in sorghum research will be to train students from the developing nations where sorghum production is assuming importance and to send them home prepared to utilize the information they have learned to improve the production of the crop in their own countries. It is expected that after training in the program these men and women will return to their national agricultural development institutions and become the cooperators with whom a strengthened international network of sorghum activities will operate.

Both the University of Nebraska and Texas A & M are already training some foreign students in their sorghum research programs. Under the stimulus of the proposed contract, it is expected that more students from the developing nations will be encouraged to study there.

Special training for foreign students in various aspects of sorghum research and sorghum production will be emphasized at the University of Puerto Rico. The University shares a common language and cultural heritage with the Latin American republics and is able to relay to those countries the highly developed agricultural technology of North America without encountering barriers imposed by a different language and tradition.

The Island of Puerto Rico, though comparatively small in area, has a varied range of soil types and climatic conditions representing many of those found throughout the tropics and therefore provides an agricultural laboratory in which students from other tropical countries will find conditions similar to their own. Participants working in the sorghum program will, as a consequence, find that as they learn specific measures and principles developed in Puerto Rico these will have broad applicability at home.

More important than the similarity of culture and that of the ecology to a large number of developing nations throughout much of the world, however, is the fact that here the student will find a most modern university at which to study and experience the impulse of a country which has undergone the transition from primitive agriculture to modern farming methods in a relatively few years.

At least once each year a workshop will be conducted, in cooperation with ICRISAT, for technical and administrative personnel of the developing nations in a different specialty. The locations of the workshops will be rotated to include major sorghum growing areas of the world.

9. Utilization Plans

It is intended that improved varietal developments resulting from this project will be multiplied and made available to developing countries. The method of utilization will be the same as that provided under A.I.D.'s contract with Purdue University for the development of sorghums with increased availability of high quality protein. The new materials and techniques will be provided to interested cooperators for trial and testing purposes in the sorghum program throughout the world. With the direct inclusion of Puerto Rico in the A.I.D.-assisted sorghum development effort, special emphasis will be placed on conducting the initial trials there. Only the more promising materials will be included in the tests with developing countries.

Of course, in many instances, it will not be possible to use the new materials or techniques directly in the cooperating countries exactly as they have been received; however, the adaptive research required to render them useful in a given country should be relatively simple. Generally, if only a special character needed incorporation, it would require such well-known breeding methods as the backcross technique to transfer the new factors, isolated by use of the conversion program, into the preferred varieties of a specific country. This requires the type of breeding program which participants who have studied and been trained in Puerto Rico and returned home will be prepared to undertake.

There should be no difficulty in disseminating improved populations or varieties of grain sorghum or supporting cultural practices. In many developing countries, international and national agencies already exist which are willing and able to incorporate these advances in their respective crop improvement programs. Because of the success the crop has attained in the U.S., there is a tremendous interest in extending its production in the developing countries. Experience has shown that when farmers are provided, by their research and extension services, with new crops whose production is dramatically better than the varieties they have been accustomed to, the transition to their use is rapid and sells itself.

10. Budget Analysis

The budgets presented for Puerto Rico, Nebraska and Texas A & M in Attachment B are each for a one-year (12 month) period. During the second year, aggregate funding will be increased from $225,000 to $275,000. The University of Nebraska's budget will remain about the same as in the first year, or about $75,000. The Texas A & M budget will be

increased from $50,000 to $75,000 to allow for the assignment of an entomologist to the project staff and thereby expand the work in screening and developing populations for insect resistance. The University of Puerto Rico's budget will also be increased in the second year, from $101,000 to $125,000, to allow for the employment of three additional research assistants to be recruited from developing countries.

11. Internal and External Reviews

The proposal was reviewed by the Inter-Bureau Technical Committee and subsequently reviewed and approved by RIGC. RIGC specifically requested assurance of appropriate links with ICRISAT. To this end TA/AGR has already contacted the Director of that Institute and a reply is anticipated in advance of the RAC meeting in January, 1973.

The basis for this proposal was included in the justification for extension of the protein improvement contract with Purdue, approved by both the RIGC and the RAC in 1971.

12. Proposing Office General Evaluation

This proposal is given a very high priority by TA/AGR because of the following reasons:

a. Sorghum's tremendous expansion, during the last decade, in the area of cultivation and use as feed in the U.S. vividly projects what it is capable of achieving in agricultural development of developing countries.

b. There is enormous interest in increasing the production of sorghum in a majority of these countries.

c. The increased production of improved sorghum varieties can increase the protein carbohydrate intake in the human diet where it constitutes a major staple of the food intake. It will increase rural employment, is economical to produce, and as an animal feed will assist in the development of animal industries.

d. The proposed three-university consortium will coordinate their respective efforts very closely with the work being done under A.I.D.'s existing contract with Purdue and, together with it, will make a package of improvements available as a unit to be incorporated in the crop in developing countries.

e. The work to be accomplished will serve as a valuable contribution to the program in sorghum development contemplated by the ICRISAT -- the new International Crops Research Institute for the Semi-Arid Tropics.

It will advance the development of the sorghum crop until such time as the consortium of world donors can assume responsibility for all or parts of the ICRISAT program in India and its outreach or linkage programs.

Attachments: a/s

Omer J. Kelley, Director
Office of Agriculture

Samuel C. Litzenberger
Project Specialist

COST REIMBURSEMENT CONTRACT WITH AN EDUCATIONAL INSTITUTION

AGENCY FOR INTERNATIONAL DEVELOPMENT NEGOTIATED CONTRACT NO. AID/ta-C-1068

NEGOTIATED PURSUANT TO THE FOREIGN ASSISTANCE ACT OF 1961, AS AMENDED, AND EXECUTIVE ORDER 11223	TOTAL ESTIMATED CONTRACT COST $160,000 File
CONTRACT FOR: Development of Improved High-Yielding Sorghum Cultivars PROJECT NO: 931-17-130-575	CONTRACTOR (Name and Address) University of Nebraska
ISSUING OFFICE (Name and Address) Agency for International Development Office of Contract Management Central Operations Division Washington, D. C. 20523	NAME STREET ADDRESS Lincoln, Nebraska 68508 CITY, STATE, AND ZIP CODE
ADMINISTRATION BY CM/COD/TAB	COGNIZANT SCIENTIFIC/TECHNICAL OFFICE TA/AGR
MAIL VOUCHERS (Original and 3 copies) TO: Agency for International Development Office of Financial Management Washington, D. C. 20523	ACCOUNTING AND APPROPRIATION DATA PIO/T NO. 931-17-130-575-73-3147558 APPROPRIATION NO. 72-11X1001 ALLOTMENT NO. 456-31-099-00-22-41
EFFECTIVE DATE FEB 12 1974	ESTIMATED COMPLETION DATE June 30, 1975

The United States of America, hereinafter called the Government, represented by the Contracting Officer executing this Contract, and the Contractor, an educational institution chartered by the State of Nebraska with its principal office in Lincoln, Nebraska, agree that the Contractor shall perform all the services set forth in the attached Schedule, for the consideration stated therein. The rights and obligations of the parties to this contract shall be subject to and governed by the Schedule and the General Provisions. To the extent of any inconsistency between the Schedule and the General Provisions and any specifications or other provisions which are made a part of this contract, by reference or otherwise, the Schedule or the General Provisions shall control. To the extent of any inconsistency between the Schedule and the General Provisions, the Schedule shall control.

This Contract consists of this Cover Page, the Table of Contents, and the Schedule consisting of 1 through 11 pages, the General Provisions (Form AID 1420-25), dated 9-72.

NAME OF CONTRACTOR University of Nebraska	UNITED STATES OF AMERICA AGENCY FOR INTERNATIONAL DEVELOPMENT
BY (Signature of authorized individual) Kermit Hansen	BY (Signature of Contracting Officer) V. C. Porelli
TYPED OR PRINTED NAME Kermit Hansen	TYPED OR PRINTED NAME V. C. Porelli
TITLE Chairman	CONTRACTING OFFICER
DATE Febr. 2, 1974	DATE FEB 12 1974

AID 1420-23A (4-73)

SCHEDULE

COST REIMBURSEMENT TYPE CONTRACT

Contract No. AID/ta-C-1068

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SCHEDULE

SCHEDULE

Article I - Statement of Work

A. Objectives

The principle objective of this project is to develop and make available to LDCs high-yielding varieties of sorghum with improved nutritional value and multiple resistance to prevalent diseases and insects and improved cultural practices for the tropics and subtropics.

With this project A.I.D. proposes to supplement, by an investment for research directed towards the needs of the tropics, sorghum research for the temperate zone.

This investment is designed to expedite the development of improved sorghum populations (improved in yield, grain quality, disease and insect resistance) and to make them readily available for use in developing countries.

The world collection of sorghum will be evaluated for new sources of germ plasm needed to further improve this crop for the tropics and sub-tropics.

The improvement of sorghum offers an outstanding opportunity not only for assisting the advanced nations in improving their sorghum crop, but as an even more significant spin-off, and for a relatively small investment, increasing the protein and calorie intake, rural employment, and expansion of the livestock industry, thereby increasing the GNP of the developing countries.

B. Work Plan

For a period as hereinafter set forth in the Schedule, the Contractor shall make available and employ its research and development facilities and

personnel at the level of effort hereinafter set forth, and shall perform a research and development program directed toward the development of an improved high-yielding sorghum cultivars project. The Contractor's scope of work shall include the following:

1. Incorporate yellow endosperm lines into a Nebraska-developed random-mated population. Yellow endosperm lines are being incorporated into good yielding germplasm in current random mating populations because of 1) potentially higher food value, 2) extensive vigorous root systems which may function in a water stress avoidance capacity and 3) offer potential for gain in seed size.

2. Develop suitable selection techniques and breeding methods for use with random-mating populations destined for the tropical environments. Grain yield, when grain number and size are not limiting, is a function of plant metabolic efficiency and length of the grain filling period. Particular emphasis will be placed on determining what the correlation is between length of the grain filling period and the yield of grain. A random mating population shall be selected and evaluated for variability in length of grain filling period.

3. Evaluate the utility of soil bedding as a limited tillage practice for sorghum on dryland soils initially and on wet soils later. Use of such practices on wet soils may produce better stands and growing conditions as well as reduce the number of tillage operations required and subsequently reduce expense. Hopefully, water loss will be lessened as the tillage is decreased. When soil is wet sorghum planted on beds may have better root aeration.

4. Develop screening techniques applicable to random-mating populations for stress tolerance and stress avoidance mechanisms. A simple heat test will be used to evaluate germplasm from many sources including populations for heat and drought tolerance.

5. Investigate survival mechanisms operative in environmentally stressed plants in the more marginal crop production areas of the tropics. An attempt shall be made to develop additional screening methods.

6. Develop screening methods for early season cool tolerance growth capability. Germplasm development shall be coordinated with CIMMYT.

7. Conduct analysis of energy requirements of sorghums for the developmental stages including the periods from planting to panicle initiation, panicle initiation to bloom, and to physiological maturity.

8. Publish results in appropriate journals and/or circulars.

9. At least once each year the contractor will meet with other AID financed institutions involved in sorghum improvement to review results, exchange information, etc.

C. Reports

During the first year of operation, the contractor shall provide, six months after the initiation of the project, 100 copies of a semi-annual Substantive Progress Report describing work performed and an outline of the work to be performed during the next six-months period. Thereafter, the contractor shall provide an Annual Progress Report (100 copies) due at the end of each calendar year.

Beginning February 12, 1974 the contractor shall submit at the end of each 6-month period 6 copies of a fiscal report showing actual expenditures

during the reporting period and firm estimated expenditures during the remainder of the fiscal reporting period for the project.

The contractor shall submit upon request by AID/W, copies of progress reports and related technical information to cooperating institutions and plant breeders.

Article II - Technical Directions

Performance of the work hereunder shall be subject to the technical directions of the cognizant A.I.D. Scientific/Technical Office indicated on the Cover Page. As used herein, "Technical Directions" are directions to the Contractor which fill in details, suggest possible lines of inquiry, or, otherwise complete the general scope of the work. "Technical Directions" must be within the terms of this contract and shall not change or modify them in any way.

Article III - Level of Effort

A. The level of effort for the performance of this contract shall be 65 total man-months of direct labor.

B. The estimated composition of the total man-months of direct labor is as follows:

	No. Man-Months
Professional (Plant Physiologist)	24
Non-Professionals (Technician, Graduate Research Assistant, Undergraduate Assistant)	41

Article IV - Period of Contract

A. The effective date of this contract is the execution date by the Contracting Officer and the estimated completion date is December 31, 1975.

B. In the event that the Contractor fails to furnish the level of effort set forth herein for the specified term, then the Contracting Officer may require the Contractor to continue performance of the work beyond the estimated completion date until the Contractor has furnished the specified level of effort or until the estimated cost of the work for such period shall have been expended.

Article V - Estimated Cost

The total estimated cost of this contract to the Government is $160,000.

Article VI - Budget

The Contractor may not exceed the grand total set forth in the budget hereunder. However, within the grand total the Contractor may adjust individual line item amounts as reasonably necessary for the performance of this contract.

Budget

Category	Firm Budget 2/12/74 to 12/31/74	Firm Budget 1/1/75 to 12/31/75	Total
Salaries & Wages	$26,400	$31,357	$ 57,757
Fringe Benefits	2,427	2,885	5,312
Travel and Per Diem	1,000	2,500	3,500
Equipment	26,013	15,876	41,889
Other Direct Costs	2,000	2,000	4,000
Subcontract	4,000	6,000	10,000
Overhead	17,160	20,382	37,542
	$79,000	$81,000	$160,000

Article VII - Costs Reimbursable to Contractor

The United States dollar costs allowable under the contract shall be limited to reasonable, allocable, and necessary costs determined in accordance with the Clause of the General Provisions of this Contract entitled "Allowable Cost, and Payment."

Article VIII - Establishment of Overhead Rate

Pursuant to the provisions of the Clause of the General Provisions of this contract entitled "Negotiated Overhead Rates," a rate or rates shall be established for the period beginning July 1, 1973 and ending June 30, 1974. Pending establishment of final overhead rates for the initial period, provisional payments on account of allowable indirect costs shall be made on the basis of the following negotiated provisional rates applied to the base(s) which are set forth below:

On Site (Home Office)	65% (Rate)	Salaries & Wages (Base)	7/1/73 - 6/30/74 (Period)

Article IX - Personnel Compensation

A. Limitations

Compensation of personnel which is charged as a direct cost under this contract, like other costs, will be reimbursable in accordance with the Schedule Article entitled "Costs Reimbursable to Contractor," and the General Provision entitled "Allowable Cost, and Payment," and other applicable provisions of this contract but subject to the following additional specified understandings which set limits on items which otherwise would be reasonable, allocable, and allowable.

1. Approvals

Salaries and wages may not exceed the Contractor's established policy and practice, including the Contractor's established pay scale for equivalent classifications of employees, which will be certified to by the Contractor, nor may any individual salary or wage, without approval of the Contracting Officer, exceed the employee's current salary or wage or the highest rate of annual salary or wage received during any full year of the immediately preceding three years, provided that if the work is to be performed by employees serving overseas for a period in excess of one year, the normal base salary may be increased in accordance with Contractor's established policy and practice, but not to exceed 10 percent of base U. S. salary excluding benefits. There is a ceiling on reimbursable salaries and wages paid to a person employed directly under the contract of the maximum salary rate of FSR-1 (or the equivalent daily rate of the maximum FSR-1 salary, if compensation is not on an annual basis), unless advance written approval is given by the Contracting Officer.

2. Salaries During Travel

Salaries and wages paid while in travel status will not be reimbursed for a travel period greater than the time required for travel by the most direct and expeditious air route.

3. Return of Overseas Employees

Salaries and wages paid to an employee serving overseas who is discharged by the Contractor for misconduct or security reasons will in no event be reimbursed for a period which extends beyond the time required to return him promptly to his point of origin by the most expeditious air route plus accrued vacation leave.

4. Merit or Promotion Increase

Merit or promotion increases may not exceed those provided by the Contractor's established policy and practice. With respect to employees performing work overseas under this contract, one merit or promotion increase of not more than 5% of the employee's base salary may, subject to the Contractor's established policy and practice, be granted after employee's completion of each twelve month period of satisfactory services under the contract. Merit or promotion increases exceeding these limitations or exceeding the maximum salary of FSR-1 may be granted only with the advance written approval of the Contracting Officer.

5. Consultants

No compensation for consultants will be reimbursed unless their use under the contract has the advance written approval of the Contracting Officer; and if such provision has been made or approval given, compensation shall not exceed, without specific approval of the rate by the Contracting Officer, (1) the current compensation or the highest rate of annual compensation received by the consultant during any full year of the immediately preceeding three years or (2) maximum daily salary rate of a Foreign Service Officer Class 1 whichever is less.

Note: The daily rate of a Foreign Service Office Class 1 is determined by dividing the annual salary by 260 days.

6. Third Country and Cooperating Country Nationals

No compensation for third country or Cooperating Country nationals will be reimbursed unless their use under the contract is authorized in the Schedule or has the prior written approval of the Contracting Officer. Salaries and wages paid to such persons may not, without specific written approval of the

Contracting Officer, exceed either the Contractor's established policy and practice or the level of salaries paid to equivalent personnel by the A.I.D. Mission in the Cooperating Country; or the prevailing rates in the Cooperating Country, as determined by A.I.D., paid to personnel of equivalent technical competence.

7. Work Week

a. Nonoverseas Employee. The work week for the Contractor's nonoverseas employees shall not be less than the established practice of the Contractor.

b. Overseas Employee. The work week for the Contractor's overseas employees shall not be less than 40 hours and shall be scheduled to coincide with the work week for those employees of the A.I.D. Mission and the Cooperating Country associated with the work of this contract.

B. Definitions

As used herein, the terms "Salaries," "Wages," and "Compensation" mean the periodic remuneration received for professional or technical services rendered exclusive of overseas differential or other allowances associated with overseas service, unless otherwise stated. The term "compensation" includes payments for personal services (including fees and honoraria). It excludes earnings from sources other than the individual's professional or technical work, overhead or other charges.

Article X - Modifications to the General Provisions

The following alterations have been made in the General Provisions of this contract:

1. Delete Clause No. 9 entitled "Limitation of Funds" and in lieu thereof insert the following:

"9. Limitation of Cost

(a) It is estimated that the total cost to the Government, exclusive of fixed fee, for the performance of this contract will not exceed the estimated cost set forth in the Schedule, and the Contractor agrees to use his best efforts to perform the work specified in the Schedule, and all obligations under this contract within such estimated cost. If at any time the Contractor has reason to believe that the cost which he expects to incur in the performance of this contract in the next succeeding sixty (60) days, when added to all costs previously incurred, will exceed seventy-five percent (75%) of the estimated cost then set forth in the Schedule or if at any time, the Contractor has reason to believe that the total cost to the Government, exclusive of any fixed fee, for the performance of this contract will be substantially greater or less than the then estimated cost thereof, the Contractor shall notify the Contracting Officer in writing to that effect, giving the revised estimate of such total cost for the performance of this contract.

(b) The Government shall not be obligated to reimburse the Contractor for costs incurred in excess of the estimated cost set forth in the Schedule, and the Contractor shall not be obligated to continue performance under the contract or to incur costs in excess of the estimated cost set forth in the Schedule, unless and until the Contracting Officer shall have notified the Contractor in writing that such estimated cost has been increased and shall have specified in such notice a revised estimated cost which shall thereupon constitute the estimated cost of performance of this contract. When and to the extent that the estimated cost set forth in the Schedule has been increased, any costs incurred by the Contractor in excess of such estimated cost prior to the increase in estimated cost shall be allowable to the same extent as if such costs had been incurred after such increase in estimated cost.

2. Notwithstanding, Paragraph (c) of Clause No. 17 entitled "Government Property," title to each item acquired by the Contractor pursuant to this Contract shall pass to and vest in the Contractor upon completion of this Contract.

3. Add the "Price Stabilization Certification" which is attached hereto and made a part hereof.

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SUPPLEMENT TO PROJECT STATEMENT*

November 6, 1972

Development of Improved, High-Yielding Sorghum Cultivars

incorp in 11/16/72 draft

With this project A.I.D. proposes to supplement, by a relatively small investment, research underway on temperate zone sorghums at the Universities of Puerto Rico, Nebraska and Texas A & M, with USDA cooperation, so as to direct their research findings toward the needs of the tropics. This investment of $225,000 in 1973 which would progressively increase to a peak of $375,000 in 1976 is intended to expedite the development of improved plant populations and related cultural practices in developing countries where sorghum is especially important both for human nutrition and animal feed. It would also make critical research findings available to ICRISAT and its outreach programs, and to CIMMYT, IITA and IRRI where sorghum is already included in the "crops systems" programs. Uniform testing, training of research and production personnel, and the planning and expediting of specialized workshops would also be integral parts of the coordinated programs with interested cooperators.

This project is not intended to duplicate or greatly alter ongoing sorghum research projects in the United States and Puerto Rico. Rather, it is intended that it ride "piggy back" on research results from the sorghum conversion program in Puerto Rico, the pest and disease resistance program of Texas A & M, and the physiology of yield improvement project at Nebraska -- all started and still being financed from private, state and federal sources other than A.I.D. These three institutions, together with Purdue which provides needed research on the improvement of protein content and quality under another A.I.D. contract, depend on the sorghum conversion program at Puerto Rico for new germplasm. The proposed consortium arrangement will serve to integrate the overall research into a single network, with Puerto Rico the focal point. Thus, by its moderate investment, A.I.D. would be able to make the research of these integrated improvement programs applicable for use in developing nations of the tropics and subtropics.

At a later date when ICRISAT has become functional in India and is able to assume its leadership role as an international center for sorghum and millet research, it is expected to take on parts of the work now

*The detailed Project Statement, dated October 10, 1972 was presented for RIGC discussion at the October 26 meeting, prior to formal review on November 13. The purpose of this supplement was to clarify points raised during the October 26 meeting.

included under the proposed consortium for sorghum development. When this materializes, the activity under this project will be reduced accordingly.

Even when ICRISAT can assume full responsibility for coordinating the worldwide research network, it is believed that a sorghum program with Puerto Rico will still be essential to integrate U.S. research into a single network and to coordinate the work on this crop with that of the tropics and subtropics. At that time, financing of the Puerto Rico element could possibly be provided through ICRISAT as a substation for the Western Hemisphere.

It is A.I.D.'s intent that this consortium project will supplement and be coordinated with the work done at Purdue (under AID/csd 1175). The funds provided to the University of Puerto Rico during the initial 12-month period will be used to evaluate new improved germplasm from exotic sorghums available to sorghum breeders around the world. The University also will assist in the maintenance and processing of the world collection of sorghum varieties.

Funds provided to Nebraska will be devoted to research on the physiological characteristics which control increased yield in the tropics and subtropics. A.I.D. contributions will serve to support investigations of soil and climatic factors which will favor attainment of higher yields in the warmer and more moist latitudes.

Contributions to Texas A & M will be limited to research on resistance to sorghum plant and seed pests and diseases prevalent in the tropics and subtropics.

The research methodology to be employed in this project will be that regularly used as standard practice by plant breeders in the improvement of cereal crops. Texas A & M and Nebraska will screen new materials from the worldwide germplasm collection of sorghums in Puerto Rico for new genetic factors needed for increased disease and insect resistance in the first instance, and to obtain superior plant type and supporting root systems to increase production in the second instance. The processing of new materials not previously screened for the tropics provides high promise for isolation of desired germplasm for the developing countries.

The conversion program in Puerto Rico consists of crossing selected exotic tropical sorghums with standard American varieties. Generally, the exotic types tend to be extremely tall and will not flower in the

long days of the continental U.S. growing season. By the time they have been backcrossed for four generations with the U.S. parent, they are reduced to normal stature and ready to flower under long-day conditions; in all other characteristics, however, they would retain the desired features of the genotype of the exotic variety. And, by moving the segregating populations between long-and short-day environments during the backcrossing process, plant populations relatively insensitive to day-length can be developed for developing countries, such as has been done with "Mexican" wheat and the IRRI "miracle" rice varieties.

TA/AGR: SCLitzenberger:sad