

1 PD-AAT-244

KPA 2-452  
RAC Meeting  
Jan. 28-29, 1971

ONGOING RESEARCH PROJECT SUMMARY  
(PROPOSED EXTENSION - ADDITIONAL TIME AND FUNDING)

ISN 44820

January 10, 1971

A. PROJECT SUMMARY

9310452

1. Statistical

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Project Title: Inheritance and Improvement of Protein Quality and Content in Sorghum Vulgare

Extension: Proposed Extension Period - Three years

000197

Contractor and Address: Purdue Research Foundation  
Lafayette, Indiana

Principal Investigator: Dr. R. C. Pickett, Professor of Agronomy  
Purdue University

Duration: Current Authorized Period: July 1, 1966 - June 30, 1971  
Proposed Extension Period: July 1, 1971 to June 30, 1974  
(Subject to review at the end of FY 1973 to determine whether additional time and funding will be required to accomplish project objectives.)

Total Estimated Cost: July 1, 1966 - June 30, 1974 \$1,443,102  
Estimated Cost: July 1, 1966 - March 31, 1971 693,102

FY 1971	-	\$240,000
FY 1972	-	250,000
FY 1973	-	<u>260,000</u>
		750,000

Project Manager: Samuel C. Litzenberger, TA/AGF

2. Narrative

Sorghum is the third most important cereal crop in the world and the principal source of energy for many millions of people in Africa and Asia who rely on it for food. Though high in carbohydrates and a fair source of total protein, the quality of the protein is poor due to deficiencies in lysine and other essential amino acids. The purpose of this project, approved by the RAC in January 1966, is to develop and release for production in the LDCs superior varieties or strains of sorghum with genetically-controlled higher protein content and improved amino acid balance.

About 4,000 lines of the World Sorghum Collection -- received largely from the Rockefeller Foundation in India -- have thus far been evaluated for level of total protein, lysine content, yield, day-length response and nutritional quality. Of these, superior collections of 200 to 400 lines have been distributed to project cooperators in 53 countries and

are being grown in 103 nurseries overseas. Intercrosses have been made at Purdue to further evaluate selected lines for subsequent release for testing under local conditions. Lines which do not produce seed at Purdue (about 50%) are sent to Puerto Rico for multiplication and screening for improved yield and nutritional characteristics. Seed nurseries at Purdue have been expanded from 15 to almost five times as many acres in 1970 and to five acres in Puerto Rico. Through the combined efforts of Purdue, the USDA in Puerto Rico, and the numerous other cooperators, 2,700 new lines were added to the world collection of sorghums in 1970.

## B. EXPANDED NARRATIVE STATEMENT

### 1. Project Description Background and Accomplishments

A.I.D. has supported this contract research activity at Purdue University since 1966 to develop and release for production in the LDCs superior varieties or strains of sorghum with genetically-controlled higher protein content and improved amino acid balance.

Development during this period of a 53-country network for sorghum research has been a major accomplishment for attainment of the project's overall objective. It has created a two-way channel for the flow of seed samples from the developing nations for testing at Purdue and a return flow of improved materials for field-testing under the environmental conditions needed for productive results; it has stimulated a substantially increased commitment of non-AID resources and personnel for the pursuit of such research; and it has provided an effective mechanism for wide dissemination and use of the research results.

Studies started in 1966 verified the fact that a large range in digestibility of sorghum grain did exist and much possibility existed for improvement. The first rat feeding trials showed coefficients of digestibility ranging from 49 to 77 percent. Subsequent tests have shown a range of protein efficiency ratio of 0.18 to 0.90 percent.

In 1969 several in vitro digestibility tests were conducted with results ranging from 50 percent dry matter digested to 77 percent on a limited range of commercial hybrid germ plasm. (Report No. 6) This compared favorably with the range of 30 to 73 percent digestibility reported by Auburn University on a wider range of germ plasm. Work at Purdue (Report No. 2) showed a range in digestibility from 49 to 77 percent. This extreme great range in digestibility still has not been explained although through the years grain sorghum has always been considered somewhat inferior to other cereals for human and animal nutrition. Superior high-protein high-yielding sorghum varieties with improved digestibility are possible, but more time is required.

Studies of the chemical nature of proteins of sorghum endosperm and embryo are regularly being conducted. Embryo size and composition has been shown to be very important. Studies beginning in 1968 and 1969 are continuing currently show that the embryo percent in the seed varies greatly. The initial range found was 9.7 to 14.1 percent of the seed as embryo. The protein in the embryo was 18.1 to 24.7 percent and the lysine 5.5 to 6.5 percent of the protein; thus on the average the embryo has almost twice the percent protein as the endosperm and almost three times as much lysine.

## 2. Relativity to AID Objectives

The Purdue project is one of three AID centrally-funded research efforts addressed to combatting malnutrition in the developing countries by improving the quantity and quality of protein in the cereal grains, which are the mainstay of their peoples' diets. The other two are wheat and maize. All qualify for the key problem area "Higher-Protein Crop Production" and meet the criteria for highest priority.

## 3. Anticipated Objectives

The long-range objective of this project will remain unchanged during the proposed three-year extension period. However, top priority will be given to (a) completing the task of screening the World Sorghum Collection and (b) the new task of developing, with Purdue's sorghum cooperators, a pool of high-protein, high-quality germ plasm utilizing all superior materials as they become known. This could be the major tool to increase protein production in the worldwide sorghum crop.

## 4. Other Related Research (within/without AID)

Continuous, extensive monitoring through personal visitation and correspondence has been the mechanism used by the contractor to insure that cooperative efforts in support of the Purdue project's objective are being satisfied at all levels. This includes the USAID Missions wherever sorghum is an important crop, the Rockefeller Foundation (Thailand), the Ford Foundation (Brazil), the FAO, the USDA (Nigeria, Uganda, Ethiopia, and Puerto Rico -- the latter in support of the conversion program, i.e., converting tropical adapted types into genotypes capable of being grown in temperate latitudes), as well as commercial experimental programs in the U.S. and Latin America such as De Kalb, Asgrow, Northrup - King, etc.

## 5. Project Program

### Scope and Methodology

The scope of work, as defined when the project was started in 1966 encompassed the following: (a) screen the world collections and various breeding programs in the U.S., Africa and India for materials

with high lysine and protein levels, and examine crosses and inbred derivatives to determine the nature of inheritance; (b) briefly examine for other amino acid components (particularly threonine, tryptophan and methionine) and determine the complete amino acid distribution for select high-lysine lines and recombined lines and hybrids among them; (c) recombine the lines with highest levels of essential, limiting amino acids with the highest-level protein content possible in high-yielding inbred lines and hybrids; (d) determine the nutritional value of high-protein, high-quality amino acid selections; and (e) study the chemical nature of protein on sorghum endosperm and embryo.

As the work progressed it was realized by responsible contracting and contract personnel that the scope of the project should be expanded to include the following complementary functions: (1) systematically disseminate the research results to all significant sorghum research program sponsors in the U.S. and abroad; (2) distribute and arrange for effective utilization by sorghum researchers in the LDCs of the superior experimental materials selected for outstanding yield and nutritional quality potential; (3) encourage investment in sorghum improvement programs in the LDCs and assist in planning new or expanded research programs; and (4) develop effective cooperative work, particularly complementary and supplementary studies, with key sorghum research programs around the world.

#### Work Plans

The proposed three-year extension will facilitate completion of certain elements of work scheduled for earlier years which have not yet reached fruition. Improved lines have been released, but it is not yet known whether the best genotypes for increased quantity and quality of protein have been isolated and used in breeding. Hybrids must be made and subsequent selection effected with known genetic strains, and their progeny studied to determine the nature of inheritance. In this way it can be determined what part inheritance plays and what part is played by the environment (nitrogen, fertilizer, date of harvest, etc.). Some work has begun, but additional time and effort are required.

It is now recognized that all protein and carbohydrate components of sorghum in the different varieties of sorghum are not equally digestible; accordingly a quick method of evaluation will be determined, perhaps one similar to the method being explored at Nebraska for wheat improvement which uses the chicken egg as the standard for comparison. When determined, the major strains will be evaluated for digestibility of the two components. Once genetic control is determined, the governing factors will also be incorporated by breeding into otherwise adapted varieties for commercial production.

There are two priority tasks in the work plan for the project, when extended: (a) earliest possible completion of the screening of the World Sorghum Collection and (b) development, with Purdue's sorghum cooperators, of a pool of high-protein, high-quality germ plasm utilizing all superior materials as they become available. This could be the major tool to increase protein production in the worldwide sorghum crop.

The plan is to examine threonine, tryptophan, methionine, and isoleucine (high ratio with leucine) contents and determine the complete amino acid distribution on select high lysine lines and recombined lines and hybrids among them. The inheritance of the levels of each will be analyzed.

This objective has been partially satisfied although additional work will be necessary and is being planned. Wide ranges of amino acid composition have been identified and isolated among the sorghum genotypes. The work plan is to include the following activities:

To recombine the lines with highest levels of essential limiting amino acids with highest levels of essential limiting amino acids with highest level protein contents possible in high yielding inbred lines and hybrids.

Recombination studies designed to satisfy this objective involve extensive crosses to male sterile Redlan, which is the highest yielder available, and male sterile Martin which is the highest quality protein male sterile available. In addition large numbers of crosses among lines of various compositions selected from the world collection are being made by hand emasculation and hot water emasculation. Over 2800 single crosses are being evaluated this year. Several thousand lines are being considered for possible use as sources of improved protein amount and quality.

To systematically disseminate research results in timely manner to all significant sorghum research programs at home and abroad.

Results of the work completed under this project during the last four years have been reported in six research reports. These reports have been distributed to some 550 workers in the United States and 53 foreign countries. Other popular versions of the results have been published in magazines with world-wide distribution.

To encourage investment in sorghum improvement programs in the developing nations and to assist in planning new or expanded research programs.

The encouragement and planning for additional work in support of this objective has been accomplished to date by extensive correspondence with workers at each location and personal contacts by the principal

investigator. Some locations already have committed well-supported programs e.g. East and West Africa, Uganda, India, Thailand, Senegal, Nigeria, Upper Volta, Ethiopia, Sudan, Cameroons, Mexico, Brazil, Peru and Costa Rica, but many other locations have become newly interested and have since made great progress.

To distribute and to arrange for effective utilization by sorghum researchers in the developing nations the experimental materials selected for outstanding yield and nutritional quality potential.

Inbred or non-hybrid open-pollinated lines were selected to include the best combiners, the most genetically diverse material possible, and at the same time have potential superiority for grain yield, high protein and improved amino acid profile. In providing seed of such materials it gives the opportunity of the recipient to select for best adaptive material for open pollinated as well as parents for hybrids where they might be used.

To disseminate to interested workers abroad significant results obtained by other scientists pursuing the improvement of protein quality and quantity in other crops.

Work toward this objective has involved visiting corn, wheat and rice improvement centers and checking their research methodology. Their results and methods used have been studied to see what information might be of interest and use to sorghum workers. Regular distribution of much of this pertinent information remains to be accomplished and is planned in the next expansion period. Expected research on Triticales at CIMMYT is also expected to be of special significance as biological evaluation is to be considered as a major means evaluating superior lines for improved protein and amino acid balance for food.

To develop effective cooperative work, particularly complementary and supplementary studies, with key sorghum research programs around the world.

A key point in the development of this program is to have continuous monitoring through personal visitation and correspondence to make sure these studies are supplemental and complementary to the improvement programs supported by the USAID in the many sorghum-growing countries, The Rockefeller Foundation in India, Thailand, and Nigeria, the Ford Foundation in Brazil, the USDA in Uganda, Nigeria, and Puerto Rico, as well as U.S. State and commercial experimental programs.

## 6. Evaluation of Contractor Competence

Purdue University is the leader in this type of research, having been the discoverer of the opaque-2 and floury-2 genes for increased lysine in maize which started the general movement for nutritional improvement of the cereal grains through genetic control. During the period of this contract, Purdue's competence has continued to be very good for research and training in sorghum improvement, particularly as related to increased nutrition through breeding and quality control evaluation. Eight graduate students have been or are being trained for acceptance of greater responsibility in developing a worldwide network for sorghum improvement. Additional expertise is available to the sorghum project, as required, in such fields as phytopathology, biochemistry, agricultural engineering, economics, entomology, nutrition and statistics. The protein - amino acid laboratory is functioning efficiently and the staff is well-trained and dependable. And adequate plot land, suited for research, is available.

## 7. Utilization/Dissemination of Project Results (within/without AID)

The dissemination of project results, both within and outside AID, has been rapid and current under existing procedures. However, it is now felt that greater cooperation would be forthcoming from U.S. breeders if annual field days and laboratory workshops were held at Purdue.

## 8. Technical Evaluations (within/without AID)

Continued requests for increased assistance from Purdue from cooperating AID Missions in Africa, Asia and Latin America would indicate favorable response in the field and need for this type of research. Their interest has probably been enhanced by the advent of severe losses sustained this year by U.S. farmers growing commercial hybrid corn varieties which have been seriously damaged by a new race of Southern Leaf Blight to which sorghum is highly resistant.

## 9. Linkages

Project personnel have been in contact with numerous USAID Missions, local LDC scientists in universities and ministries, research institutes and foundations. This has been through correspondence and visits. Selected experimental material has been distributed to over 100 cooperators in 53 countries.

Cooperating research organizations include the USDA, Agricultural Experiment Stations in Puerto Rico, Nebraska, Texas, Kansas and Indiana; CIMMYT, Ford Foundation (Brazil); Rockefeller Foundation (India, Thailand); USDA/AID cereal PASAs in Africa; and U.S. seed companies. These linkages will be strengthened in the coming year.

BUDGET REQUIREMENTS

Salaries and Wages

Project Director (50%)	\$11,000
Biochemist (5%)	1,300
Sorghum Improvement Agronomist (100%)	12,500
Post Doctorate, Agronomy (100%)	10,000
Post Doctorate, Biochemist (100%)	15,000
Resident Graduate Assistants 2 + (100%)	10,000
Resident Graduate Assistants	5,000
Lab. Technicians 2 - (100%)	12,000
Administrative Assistant (50%)	3,000
Senior Clerk (50%)	3,000
Field Technician (40%)	3,000
Laborer (hourly)	17,000

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99,800

Indirect Costs of Above  
Fringe Benefits

49,000  
5,900

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Sub Total

164,700

Other Costs

Equipment	10,000
Expendable Supplies, Equipment & Material	11,000
Winter Nursery (Puerto Rico)	7,000
Travel	5,000
Workshops - Seminars	5,000
Computer Services	2,000
Sub-Contract Services	35,300

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75,300

Sub Total

164,700

GRAND TOTAL

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\$240,000

### Project Review

On December 1 and 2, 1970, an on-site review was held. The review team included TA/AGF personnel, and a TA/AGF consultant, a representative from TA/RUR, and two USDA scientists. The following is a summary of the committee findings:

The review committee, after conferences, visits to the research plots, supporting facilities and the amino acid laboratory, recommended approval of the project and extension for an additional three years, with a thorough review scheduled at the end of the second year.

All of the original ten objectives of the project were not being satisfied equally, however, some had advanced beyond expectations. The greatest shortcomings related to (a) completing screening of the world sorghum collections for high protein and amino acid balance, (b) reporting results to potential users in the U.S. and the LDCs, (c) increased emphasis on biological evaluation of sorghum lines, and (d) lack of results from observational nurseries being returned to Purdue with consequence that there is no report to date on these materials.

The review committee recommended, and contractor personnel concurred, that (a) priority be given to completing analysis on all available entries in the World Collection and that the results should be published early in 1971, (b) budget include funds for additional rat feeding trials but not for swine and poultry feeding trials, (c) additional full-time scientific manpower be assigned to the project, (d) increased efforts be directed at increasing research capabilities of the LDCs, (e) research results be published as soon as obtained and evaluated for publication, beginning immediately, (f) that while superior, high-protein, high-yielding varieties with improved digestibility are possible, more time is required and (g) consideration be given to establishing a worldwide research network through a consortium coordinating all interested agencies through responsibility assignments based on capabilities and interest -- to be initiated in 1972.

Summary Conclusions

It is recommended that this project be extended for a minimum of three years with a further review at the end of the second year to determine more firmly the duration and funding required to reach its objective.

The additional time now proposed is necessary to complete work already under way for indexing, selecting, breeding and testing until improved varieties are produced which incorporate the desirable genetic characteristics of high yield, high protein and amino acid balance. Selected lines from the continuing effort will be sent to cooperating countries for further evaluation under local conditions. Purdue technical personnel will assist and train local breeders to facilitate the incorporation of these superior lines into local breeding programs and ultimate release for production by farmers.

To date only one variety has been released for production under this program. Further evaluation will be necessary to determine its true merits for protein content and quality in the environment of its commercial production.

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PROJECT SUMMARY

9315112

Major Type of Activity: Key Problem Area - Higher-Protein Crop Production

Project Title: Inheritance and Improvement of Protein Quality and Content  
in Sorghum Vulgare

Contractor: Purdue University, Lafayette, Indiana 47907

Contract Number: AID/csd-1175

Contract Coordinator: Dr. Robert Pickett  
Title: Professor of Agronomy

931-  
Project Number: 130-452

Project Duration: Started 6/30/66 Termination Date 6/29/72

Comments: On Jan. 28, 1971 RAC approved an extension for one year with the provision that the program be re-designed in accordance with recommendations made by them and that before the end of the one-year extension RAC would review the program to determine whether the project's restructuring has been sufficiently modified to satisfy the original project objectives.

Budget: a) Funds obligated through FY 70 : \$693,302  
b) Funded for FY 71 : 240,000  
c) Funds requested for FY 72 : 240,000  
d) Estimated fund requirement FY 73: 255,000

TA/AGF Project Manager:  
Mr. C. A. Breitenbach

TA/AGF Project Specialist:  
Dr. S. C. Litzenberger

Purpose: Sorghum is widely used in Asia and Africa as an energy foodstuff and in the Americas as a livestock feed. There are great differences between varieties of sorghum in total protein and in certain amino acids need to make it a nutritious food. The major purpose of this project is to identify strains with superior protein content and quality and to incorporate these characteristics into otherwise high-yielding varieties which will contribute significantly to dietary improvement in developing countries.

Description of Activity: The world collection of sorghums is being screened for genetically controlled improved protein content and quality, and these factors are bred into promising varieties for the tropics. The higher yielding and most promising selections are grown in nurseries at Purdue and in Puerto Rico, and are further evaluated at selected locations worldwide by cooperating plant breeders. Biological evaluations of improved cultivars are being effected as in vitro and chemical evaluations do not necessarily measure true biological values of improved lines.

Accomplishments and Utilization: About 4,000 lines of the world collection have been screened for protein, lysine and other amino acids, day-length response and preliminary yield performance, and seed characteristics. Inter-

crosses have been made at Purdue and other locations and inbred and hybrid derivatives from these have been selected and assessed for yield, protein and amino acid composition. Seed of the best of these selections and hybrids (sets of 100, 200, or 400) have been made available to sorghum breeders in over 53 countries for evaluation under local conditions. Nursery plantings at Purdue have been expanded from 15 to 50 acres and to about 5 acres at Puerto Rico. One improved variety from the material distributed through this project has been selected by workers in Colombia and named 'ICA- Marupaanste.'

Future Plans: Indexing, selection, breeding and testing will continue until superior varieties have been produced which incorporate the desirable genetic (inheritable) characteristics of high yield, high protein and desirable amino acid balance. Biological evaluation by small animal feeding trials will be conducted on the more advanced materials to determine nutritional merits as food or feed. Selected lines will be sent to collaborating countries for further evaluation under local conditions. Purdue University technical personnel will help local breeders incorporate these superior lines into local breeding programs.

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