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AGENCY FOR INTERNATIONAL DEVELOPMENT

PROJECT PAPER FACESHEET

1. TRANSACTION CODE: A (A = ADD, C = CHANGE, D = DELETE)

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2. DOCUMENT CODE: 3

3. COUNTRY/ENTITY: TA Bureau

4. DOCUMENT REVISION NUMBER:

5. PROJECT NUMBER (7 digits): 931 1040

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7. PROJECT TITLE (Maximum 40 characters): Pearl Millet Improvement

8. ESTIMATED FY OF PROJECT COMPLETION: FY

9. ESTIMATED DATE OF OBLIGATION: A. INITIAL FY 77; B. QUARTER (Enter 1, 2, 3, or 4); C. FINAL FY 79

10. ESTIMATED COSTS ($000 OR EQUIVALENT $1 =)

A. FUNDING SOURCE	FIRST FY B. FX	FIRST FY C. L/C	FIRST FY D. TOTAL	LIFE OF PROJECT E. FX	LIFE OF PROJECT F. L/C	LIFE OF PROJECT G. TOTAL
AID APPROPRIATED TOTAL	505		505	770		770
(GRANT)	(505)	( )	(505)	(770)	( )	(770)
(LOAN)	( )	( )	( )	( )	( )	( )
OTHER U.S. 1.						
OTHER U.S. 2.						
HOST COUNTRY						
OTHER DONOR(S)						
TOTALS	505		505	770		770

11. PROPOSED BUDGET APPROPRIATED FUNDS ($000)

A. APPROPRIATION	B. PRIMARY PURPOSE CODE	PRIMARY TECH. CODE C. GRANT	PRIMARY TECH. CODE D. LOAN	E. 1ST FY 77 F. GRANT	E. 1ST FY 77 G. LOAN	H. 2ND FY 78 I. GRANT	H. 2ND FY 78 J. LOAN	K. 3RD FY 79 L. GRANT	K. 3RD FY 79 M. LOAN
(1) FN	111 J	963		505				265	
(2)									
(3)									
(4)									
TOTALS				505				265	

A. APPROPRIATION	N. 4TH FY ___ N. GRANT	N. 4TH FY ___ O. LOAN	Q. 5TH FY ___ P. GRANT	Q. 5TH FY ___ R. LOAN	LIFE OF PROJECT S. GRANT	LIFE OF PROJECT T. LOAN
(1)					770	
(2)						
(3)						
(4)						
TOTALS					770	

12. IN-DEPTH EVALUATION SCHEDULED: MM 03 YY 79

13. DATA CHANGE INDICATOR. WERE CHANGES MADE IN THE PID FACESHEET DATA BLOCKS 12, 13, 14, OR 15 OR IN PRP FACESHEET DATA, BLOCK 12? IF YES, ATTACH CHANGED PID FACESHEET.

1 = NO
2 = YES

14. ORIGINATING OFFICE CLEARANCE

SIGNATURE: Leon H. Hess

TITLE: Director, Office of Agriculture

DATE SIGNED: MM 04 DD 13 YY 77

15. DATE DOCUMENT RECEIVED IN AID/W, OR FOR AID/W DOCUMENTS, DATE OF DISTRIBUTION: MM DD YY

AID 1330-4 (3-78)

PROJECT STATEMENT

A. Project Summary.

1. Statistical

Project Title:	Improvement of Grain Yield and Quality in Pearl Millet for Semiarid Areas
New or Extension:	New
Proposed Contractor:	Kansas State University Manhattan, Kansas 66506
Principal Investigator:	Dr. Richard L. Vanderlip
Duration:	Three years beginning with contracting date estimated to be September 15, 1977
Estimated Total Cost:	$770,000 (3 years)
Budget by years:	Year 1 $262,000 Year 2 243,000 Year 3 265,000

(Project may be forward-funded in FY 77 for first 2 or all 3 years)

Project Manager:	Earl R. Leng, TA/AGR/CP

2. Narrative Summary.

Pearl millet (*Pennisetum americanum* (L.) K. Schum.) is the most important food grain in developing countries of the Sahel and is an important staple in many other parts of Africa, the India Subcontinent, and the Far East. In contrast to maize, wheat, rice, and sorghum which are receiving major emphasis from international institutes and/or U. S. institutions, pearl millet has received little attention. One international institute, the International Crops Research Institute for the Semiarid Tropics (ICRISAT) has been assigned responsibility for conducting research to increase production of pearl millet in the semiarid tropics.

The research proposed in this project is intended to augment and assist the efforts of ICRISAT, as well as developing countries (DC) regional and country programs. Emphasis will be on the development of high yielding,

widely adapted populations, investigating the feasibility of hybrids in developing countries, solving principal problems in plant breeding and production, and increasing nutritional qualities of pearl millet food products in the developing countries. The project has been developed through working-level coordination with ICRISAT, emphasizing areas such as special plant breeding efforts, stress physiology, and food/nutrition research where the proposed contractor has strengths which will complement ICRISAT's efforts. Improved germplasm, breeding, selection and production techniques, nutritional and processing knowledge, and other information will be distributed to developing countries through international agencies and local national programs.

B. Research Purpose and Objectives.

1. Purpose

This project will utilize linkages and cooperation between U. S. institutions and ICRISAT, as well as research and extension agencies in developing countries, to improve production and utilization of pearl millet. It is expected that products of this project will be of immediate usefulness in developing countries where pearl millet is a major crop, and thus that farmers and consumers in those areas will be benefited in a reasonably direct fashion.

2. Objectives of Proposed Program

a. Accelerate improvement in pearl millet grain yield by creating widely adapted high yielding populations and synthetic varieties and investigate possibilities of creating inbred lines and hybrids for use in developing countries.

b. Determine factors related to and genetic variability in seed and seedling vigor, water use, and drought resistance, and herbicide susceptibility of pearl millet.

c. Determine the nutritional quality and digestibility of pearl millet grain by analyzing protein in germplasm introductions and breeding materials and determining magnitudes of variation in lysine content among and within populations and varieties. Determine the characteristics and digestibility of pearl millet protein and carbohydrates.

d. Determine the storage stability of pearl millet grain and millet meal by determining the factors contributing to grain losses during storage and determing the factors contributing to the development of rancidity in millet meal.

C. Significance and Rationale for the Research.

1. The Development Problem

Pearl millet is one of the five most important cereal grains used directly for human food (the others are rice, wheat, maize, and sorghum). In Africa and the Indian subcontinent, pearl millet is the most important food cereal in the drier cropping areas. Much less attention has been paid to the breeding, agronomy, and utilization of this crop than to the other major cereals. Yields under actual production conditions are very low and have not shown much recent improvement as has been the case in other cereals. Little is known about the possibilities for nutritional improvement or the utilization of the grain for food products other than those traditional in India and Africa.

Pearl millet is typically produced on the poorest soils and consumed by the poorest people in countries where it is grown. In these areas, pearl millet is produced where no other crops will grow; sorghum and then maize are produced as the soils increase in fertility and moisture status. It is the most important food grain in the Sahel of Africa, where drought has had devastating human effects. Improved, widely adapted, drought resistant pearl millets are urgently needed for such areas.

Pearl millet improvement has been neglected worldwide as compared with work on other major food crops. The only significant pearl millet grain programs outside the U. S. have been some U. S.-supported work in Africa, the India national and state programs, the IRAT program in Senegal, the former EEAFRO program in Uganda and, more recently, the program of ICRISAT in India. In the U. S., only the Kansas State/ARS Program is of significant size.

Pearl millet is a staple food of poor people. However, little is known about the major nutritional components of this food resource or the digestibility and availability of these nutrients once the milled grain has been consumed. The studies that have been done (Brit. J. Nutri. 15, 339, 1961; J. Nutr, Dietet. 4, 102, 1967) indicate that lysine and threonine are the limiting amino acids. Recent research indicates that there is a wide range of lysine in pearl millet. Therefore, it is important that rapid methods be developed to detect lines which have high levels of these 2 amino acids. Knowledge concerning the mineral and vitamin contents of pearl millet would be helpful in determining the losses of these nutrients during processing. Furthermore, the determination of factors which may interfere with the digestibility of millet protein and carbohydrates would also aid in the genetic manipulation and selection of lines which provide the greatest nutrition.

Although large quantities of pearl millet may be lost during storage, the stability of pearl millet grain and millet meal to various storage conditions has not been extensively studied. The data that has been reported (J. Nutr. and Dietet. 6, 316, 1969) indicates that the development of rancidity is a major problem. A knowledge of the lipid components of pearl millet and the changes occurring in these components during storage would be useful in specifying the conditions that must be met in order to prevent rancidity. In addition, since losses may also occur through insect infestation, the susceptibility of various lines of pearl millet to various stored grain insects should be determined so that guidelines for storing the grain can be developed.

2. State-of-the-Art

In the United States, only four universities have any significant research in progress on this crop. Breeding and agronomic studies have been under way for some time at several Indian agricultural research centers and at a few locations in Africa. Recently, ICRISAT has taken international responsibility for pearl millet improvement and its research is starting to show promise.

Pearl millet is a cross-pollinating species and therefore highly variable as grown under usual field conditions. High yielding hybrids were produced in India some ten years ago, utilizing a combination of types developed in the U. S. and those native to India. These hybrids have not been successful, for the most part, because of major disease problems (especially ergot, which can produce fatal poisoning in humans) and poor seed set, the causes of which are not well understood. Some of the research stations in Africa have produced varieties which yield well under experimental conditions, but there is little evidence that these have been distributed to farmers on any significant scale.

In India, pearl millet has the "folk-wisdom" reputation of being a "strengthening" food, particularly in winter. Until recently, little was known about its chemical composition or actual nutritive value. Recent studies have indicated that it usually is higher in protein than most other cereals (averaging 13-15%) and also that some selections, at least, are quite high in lysine (up to 3.5% or more of total protein). It also has been determined recently that alpha-amylase activity is high in millet flour. This greatly improves the quality of risen breads made without added sugar or malt, and therefore could be important in carbohydrate utilization.

Within the past few years, Kansas State University has combined selections from Uganda with strains developed in Georgia to produce promising breeding populations. The selections now available, while

while not yet ready for release to cultivators, have excellent seed set, good seed quality, short plant height, good yield under stress conditions, and very high levels of protein and lysine content. The total lysine per 100 grams of grain exceeds that in opaque-2 maize. With further selection and international testing, these types could rapidly be utilized in developing countries, either directly or as components of further breeding and improvement programs.

The Kansas State University-ARS, USDA program has the only active U. S. team of personnel and facilities engaged in pearl millet research that can assist and reinforce developing countries' efforts in millet improvement. The team can make improved germplasm available to developing countries' national programs, devise methods for improving pearl millet releases of national programs, improve nutritional quality of pearl millet food products, and foster cooperation among pearl millet workers.

D. Plans to Develop Linkages and to Facilitate Utilization of Research Results.

Appropriate linkage relationships and coordination with international and national and regional agencies will be developed. Kansas State University has developed plans for undertaking this coordination from the planning stage of the project. These plans include:

1. ICRISAT

Cooperation with the International Crops Research Institute for the Semiarid Tropics (ICRISAT) will be developed and continued. This cooperation will take the form of exchanges of germplasm, results, ideas, joint research, and conduct of International Pearl Millet Trials. KSU had a long association with Andhra Pradesh Agricultural University at Hyderabad. It is recognized that close coordination with ICRISAT will be required to achieve the maximum benefit, and this coordination has been undertaken by a visit of a KSU team to ICRISAT. The project in its present form was developed as a result of agreement between the KSU representatives and ICRISAT personnel as to the work which needed to be done and an appropriate "division of labor" between the two institutions.

2. SAFGRAD

Coordination with the Africa Bureau regional project on Semiarid Food Grains Research and Development (SAFGRAD) will be effected, initially through the KSU-ICRISAT relationship. SAFGRAD is not yet in operation, and more precise coordination mechanisms will be developed as it evolves. Since the SAFGRAD plan contemplates some involvement by U. S. universities, there is scope for direct participation by KSU in some SAFGRAD activities.

3. Country Programs.

In coordination with ICRISAT and SAFGRAD, KSU will be prepared to provide materials and information to strengthen country programs in pearl millet. Also, KSU has a unique capacity for providing certain types of training which country institutions and even international centers cannot furnish (in particular, advanced training in specialized areas such as nutrition, processing, and stress physiology).

4. Other U. S. Institutions.

Mutual benefit will be gained from complementary pearl millet and sorghum studies at the University of Nebraska, Purdue University, Texas A&M University, the University of Arizona, and the Georgia Coastal Plain Experiment Station. Cooperation will be developed with these institutions. This cooperation may take the form of additional sites for wide adaptation of breeding material, germplasm exchanges, specialized investigations other institutions cannot undertake, conferences, and workshops.

Plans are in progress for the formation of a "Sorghum and Millet Improvement Consortium" involving most if not all the above institutions and possibly others. This consortium would provide a permanent vehicle for collaborative work with these two major crops for semiarid areas.

5. Dissemination and Application of Results.

Expected results of the proposed program will be disseminated in several ways. Contractor will maintain direct contact with national pearl millet programs in developing countries and with the ICRISAT research and out reach programs. Both avenues will permit direct communication among these programs. Kansas State University also had a long association with Andhra Pradesh Agricultural University at Hyderabad, and will use this contact directly.

The planned program will have a number of "products" that can be applied immediately by the developing countries. Improved pearl millet populations and synthetic varieties can be used as high-yielding varieties, used to upgrade local varieties, or the widely-adapted populations can be selected further by national programs in developing countries. Introduced germplasm possessing specific desirable traits - yield potential, drought resistance, high nutritive value, etc. - can also be incorporated into the national millet breeding programs. Techniques developed for screening millet for desirable traits - selection criteria, drought resistance, nutrient-use efficiency, etc. - can also be employed by national pearl millet programs to accelerate their work. Results on effects of processing on nutritive value of pearl millet food products might be used to modify traditional processing methods if that should seem feasible.

Research results will be published in the form of reports to A.I.D. technical papers, etc; copies and reprints of these will be distributed to a mailing list of millet workers in developing countries.

E. Management Considerations.

No unusual management problems are expected to arise in connection with this project. It will be similar in concept and design to other centrally funded crop improvement research projects of TA/AGR.

Noncontract funded inputs will be substantial. These include time of five KSU investigators spending a total of 14 man-months per year on the project. Also there will be cooperation by other staff members, office, and laboratory facilities, as well as use of equipment and extensive field facilities.

The project will be evaluated by a review and evaluation team visit to the campus during the first year of the project, probably during the growing season of 1978. In addition, management evaluations will be conducted each year and technical and managerial considerations will be under constant monitoring by the A.I.D. project manager.

Contractor will clear all manuscripts proposed for publication with the project manager, and will submit an annual report within 45 days of the close of each contract year.

F. Project Background Description.

Previous pearl millet research at Kansas State University has included:

1. Plant Improvement (A.J. Casady, U.S.D.A.Research Agronomist).

During the 1960s, two open-pollinated pearl millet varieties from Uganda were grown in isolation. Seed was harvested from a number of the most agronomically desirable plants. Composited seed from each head was grown interspersed with Tift 239 (dwarf forage type from the U.S.D.A. program). F_1 populations were grown in isolation and allowed to random mate. F_2 populations were grown in isolation and selfed seed from bagged dwarf plants and open pollinated seed from dwarf plants were harvested. F_3 plants from the selfed seed were all of combine height; their grain was used for preliminary nutrition and utilization studies. The open pollinated seed from dwarf plants was composited and grown in isolation and allowed to mate randomly. Seed was harvested from the most agronomically desirable dwarf plants in each isolation. Their seed was

composited and grown and about 2000 dwarf plants were bagged for selfing. Four-hundred selfed heads from plants with good seed set, good head exsertion, large seed size, and good stalk strength were harvested. Grain protein content and seed weights were determined on those lines in the Kansas State University Crop Physiology Laboratory.

Two-hundred lines, representing the best 100 each in protein content and grain weight, were entered in replicated S_1 yield trials during 1973. Also during 1973, introduced lines were examined for stalk strength and top cross hybrids were developed for yield trials. Remnant seed of the top 20 yielding S_1 lines in the 1973 trials was grown in Puerto Rico in 1973-74 for recombination by random mating. The population from combining the top 20 lines was released to plant breeders as RMP1(S)C1. This is apparently the only pearl millet released for grain purposes in the U. S. to date. Seed from the random mating in Puerto Rico was grown in 1974, and 200 selfed heads were selected. Replicated S_1 yield trials were conducted in 1975, and remnant seed of the top 20 yielding lines were grown in Puerto Rico in 1975-76 for recombination by random mating. Also, in 1975 an introduced Senegal population was grown, and 200 selfed heads were selected for replicated S_1 yield trials in 1976.

2. Plant Improvement (W. D. Stegmeier, Fort Hays Experiment Station).

Selection and breeding of pearl millet started in 1971 with varieties, lines, and bulk populations obtained from several sources. Uganda varieties Serere 3A and Serere 17 and bulk populations of their dwarf F_3 derivatives were obtained from Dr. A. J. Casady, Manhattan, Kansas. Dr. G. W. Burton, Tifton, Georgia, supplied seed of several late maturing, tall and dwarf forage inbreds, and 141 plant introduction lines were received from the USDA Plant Introduction Station at Experiment, Georgia. An additional 139 P.I. lines were obtained in 1972 and a bulk of approximately 1450 lines of the world collection of pearl millet was received from Dr. Gary Paulsen, Manhattan, Kansas, in 1974.

The Uganda varieties, particularly selections of Serere 3A, have been backcrossed two and three times to the dwarf form. Over one-hundred BC_2F_4 and BC_3F_3 selections were composited and random-mated in 1975. In 1976, the population will have 2000 or more plants selfed and the best 10 to 20 per cent of the S_1 lines will be grown in replicated yield trials in 1977 followed by recombination of superior lines and another cycle of selection. Selections from many of the plant introductions have been crossed to dwarf derivatives of the Uganda varieties, and inbred lines are being developed.

At the present time, selections of 56 PIs are being converted to dwarf, early-maturing forms through crosses involving the early-maturing, large-seeded PI 185642 and Serere 3A, and with Tift $23DB_1$ and Tift $239DB_2$ contributing dwarfness, tillering ability, and fertility maintenance in

the A_1 and A_2 cytoplasmic male-sterility systems. Approximately two-thirds of the crosses with these 56 PIs will be in the F_2 or F_3 generations in 1976. The remaining PIs of the group of 56 are either receiving their initial crosses or are being placed in three- and four-way crosses in the 1976 spring greenhouse. Some of the progenies will be maintained as inbreds and tested in F_1 hybrid combinations but the majority will be screened for various traits and then placed in genetically broad-based random-mating populations, modified ear-to-row selection systems, or recurrent selection programs. Improved lines will be extracted and tested as parents in F_1 hybrid combinations.

Several selections of PI 185642 have been crossed to Tift $23DB_1$ and Tift $239DB_2$. The DB_1 progenies have been backcrossed to 185642 two times. DB_2 progenies will receive the first backcross this spring. Following initial test crosses of the 185642 DB_1 lines to Tift 23DA, a group of twenty-six BC_1 185642 DB_1 lines have been backcrossed four times into the A_1 cytoplasm. Twelve BC_2F_3 selections of 185642 DB_1 will receive their first crosses into the A_1 cytoplasm this spring.

Several of the 185642 DA_1 lines are being used as female parents in F_1 hybrid combinations using as male parents inbred selections of dwarf Serere 3A derivatives and from crosses of the Serere 3A derivatives and various PIs. Heavy rains at emergence destroyed early planted replicated yield trials of 60 hybrids in 1975, but several of these hybrids planted later in single-row observation plots appeared to equal the yield of the sorghum check. Approximately 50 F_1 hybrids will be yield tested in 1976.

The bulk random-mating population of the 1450 lines of the world collection of pearl millet has been grown in isolation in 1974 and 1975 and will be handled similarly in 1976. Selection pressure consists of the elimination of late maturing genotypes by the shortness of the growing season and lack of moisture in the fall and by selection at harvest for desirable head, seed, and plant characteristics. Germplasm containing dwarfness, early maturity, and large seed size will be introduced in 1977 and eventually this material will be converted to a dwarf, early maturing population.

3. Agronomy and Physiology (G. M. Paulsen, Department of Agronomy).

Pearl millet has been treated like sorghum in previous studies; specific requirements of the species remain to be determined. Prior to 1973, the only yield data available were for a comparison of two pearl millet introductions from Uganda with two sorghum hybrids. (Unpublished data of A. J. Casady.) Good yields were obtained in spite of droughty conditions, and yields of the tall introduced pearl millet varieties were not significantly different from those of the adapted sorghum hybrids.

Yield trials comparing a pearl millet line developed by A. J. Casady, a pearl millet hybrid furnished by G. W. Burton, and maize and sorghum hybrids were conducted at five Kansas locations during 1973. Yields of the pearl millet hybrid, developed for forage use, were low because of its late maturity. However, both millets contained much higher quality protein, particularly in terms of lysine content, than the maize and sorghum. A nitrogen fertility trial comparing dwarf and tall pearl millet lines, an iron nutrition trial comparing pearl millet and sorghum, and a date of planting trial comparing pearl millet and sorghum were also completed during 1973. Pearl millet grain for swine feeding trials was grown on about 2.5 acres; millet and maize were equally acceptable and efficient in the feeding trial.

In physiology studies, besides screening A. J. Casady's breeding lines for protein and seed weight, introduced lines were being screened for desirable traits and photosynthetic efficiency of pearl millet was determined. Approximately 130 lines obtained from the World Collection and personal contacts in Africa and India were included in the screening studies. In the photosynthesis studies, pearl millet had the same efficient photosynthesis system of corn and sorghum, not the inefficient photosynthesis system of other cereals.

4. Grain Composition (R. D. Hoseney, Department of Grain Science and Industry.

Protein content has been 3-4 percent higher in pearl millet lines of A. J. Casady than in sorghum grain produced under similar conditions. The amino acid distribution has also been much better in pearl millet than in sorghum. Lysine, the major limiting amino acid in cereals, averaged 3.6 percent of the protein in pearl millet compared with about 2.0 percent in corn and sorghum. The lysine content of pearl millet is comparable to that of high-lysine corn. Pearl millet lines obtained from other sources have ranges as low as 1.9 percent lysine, indicating considerable genetic variability in that characteristic.

Scanning electron photomicrographs of pearl millet endosperm show both the hard and soft endosperm types similar to those found in corn and sorghum. The soft endosperm is characterized by nearly round starch granules with a thin protein matrix and a large amount of intergranular air spaces. The starch is polygonal in shape and covered with a layer of matrix protein embedded with a large number of spherical protein bodies.

Grain Utilization (A. J. Casady, R. C. Hoseney, C. W. Deyoe, D. B. Parrish, and P. E. Sanford, Departments of Agronomy, Grain Science, and Industry, Biochemistry, and Dairy and Poultry Science).

Starch isolated from pearl millet had the same polygonal shape as starch from corn and sorghum. The granule size was about 12 u diameter

compared to 25 u for corn and sorghum starch. The gelatinization temperature of pearl millet starch ranged from 61 to 71°C, or slightly lower than that of corn and sorghum starch. Pasting characteristics (amylograph) of pearl millet starch are similar to sorghum starch except for a rise in viscosity while holding at 95°C. That may be the result of a lower amylose/amylopectin ratio. Pearl millet starch contains about 12 percent amylose compared to 22 percent for sorghum starch (Badi, S. E. M.S. Thesis, Kansas State University). Malted pearl millet has been relatively high in a-amylase activity (equivalent to barley), but contains essentially no B-amylase activity.

A composite flour (90% wheat, 10% pearl millet) gave bread with excellent loaf volume, crumb grain, and texture. A remarkable feature of the composite flour was that bread characteristics were also excellent when sugar and malted wheat flour were removed from the formula. This is presumably because of high a-amylase activity of the pearl millet flour. The bread has excellent flavor and is nutritionally superior to a 100% wheat flour loaf. This finding should be of particular importance in LDCs where bread is a traditional food but wheat flour and malted wheat flour are imported and sugar is imported or is an important export item.

Procedures have been developed to produce cookies from pearl millet and sorghum flours. The procedure involved hydrating the flour for 3 hours with water followed by air drying and supplementing with soy oil. The cookies have spread and top grain characteristics equal to wheat flour cookies. The cookies are more fragile than those from wheat flour and are slightly more gritty. Mixtures of wheat flour and pearl millet flours (1:1) gave cookies that were not significantly different from 100% wheat flour cookies in eating quality or appearance as judged by a taste panel.

In rat feeding trials, growth was faster on an unsupplemented diet of bajra (pearl millet) than of ragi, corn, or sorghum. Ragi was not deficient in any amino acids; pearl millet was deficient in lysine; corn was deficient in lysine, tryptophan, isoleucine, and valine; and amino acids [Pushpamma, S., D. B. Parrish, and C. W. Deyoe. 1972. Improving protein quality of millet, sorghum, and maize diets by supplementation. Nutrition Rpts. Intern. 5 (2):93-100. (Ph.d. Thesis, Kansas State University).]

At equal protein levels, chick performance was similar on pearl millet and sorghum rations. The amino acid profile, rate of chick gain, and efficiency of utilization of feed were better for pearl millet than for sorghum as a source of energy and protein for broiler-strain chicks (Sanford, P. E., F. Camacho, R. P. Knake, C. W. Deyoe, and A. J. Casady. 1973 62nd Annual Meeting, Poultry Science Association).

G. Project Design and Methods.

Four major objectives will be under study, as outlined in B.2 above. Research methods and techniques to be followed are:

Objective 1. Accelerate improvement of pearl millet grain yield in types suitable for use in developing countries.

a. Improved pearl millet populations and varieties probably have more immediate use than hybrids to farmers and national programs in developing countries. Consequently, major emphasis of the proposed program will be on millet population improvement. Techniques developed for breeding maize are directly applicable to pearl millet; researchers will use a random mating and S progeny selection procedure for the most part. However, other recurrent selection methods and modified ear-to-row selection systems will be used where they are preferable.

Superior germplasm for traits determined to be important must be identified and incorporated into improved pearl millets. Germplasm available from the Germplasm Introduction, Maintenance, and Distribution program will be evaluated for essential traits - nutrient content, yield components, lodging resistance, maturity, etc. - and desirable lines will be added to broadbased random mating populations or used to develop new random mating populations.

Cycles of random mating and S_1 progeny selection will accumulate genes for high yield and high nutrient content. Frequency of genes for low yield, poor nutrient content, site specificity, poor plant type, day length sensitivity, pest susceptibility, lodging, and poor seed set will decrease. The improved millet populations, after being tested in international trials, can be used directly or selected further to produce synthetic varieties or hybrids in developing countries. The wide adaptability of the improved populations as a result of selection and testing over a range of conditions should make them directly and immediately useful to developing countries.

b. Wide adaptability is essential for maximum distribution and utilization of improved pearl millet germplasm and for high grain yields under varying environmental conditions in developing countries. Improved pearl millets have been distributed to several states and developing countries, where they have performed significantly better than existing types. However, lack of resources has limited selection and testing of materials under the range of conditions needed to give them wide adaptability. Present pearl millets, pearl millets available from other programs, and additional improved pearl millets developed under the proposed program must be selected and tested under a greater array of conditions. This will be accomplished by increasing the number of selection sites in Kansas, expanding the comparative programs, and entering the most advanced materials in International Millet Field Trials. The Kansas locations have an annual precipitation of 16 to 34 inches, giving a good range within the state. Wide adaptability of breeding materials will be achieved by introducing and accumulating genes that favor that trait into the synthetic varieties, random mating populations, and hybrid millets developed.

c. Pearl millet hybrids have nearly doubled experimental grain yields in India when the best hybrids were compared with local varieties (Burton, G. W. and J. B. Powell. 1968. Adv. Agron. 20:49-39). However, many of the hybrids lacked wide adaptation and were no better than local varieties when tested over a range of conditions. Poor seed set in some hybrids leads to problems with ergot.

Top cross hybrids, which can be developed most rapidly, will be made and tested against their parents over a range of conditions in Kansas. Additional testing sites will also be used if arrangements can be made. Pearl millet A-lines (cytoplasmic male sterile), B-lines (sterility maintainer) and R-lines (fertility restorer) are also available and are being used. When widely adapted populations are available, they will be used to create widely adapted A-, B-, and R-lines for hybrid development. These hybrids will likewise be tested over a range of conditions in Kansas, and other sites. The lines will also be supplied to national millet programs in developing countries for testing under their conditions.

Objective 2. Determine genetic and environmental variation in seedling vigor, water use, drought resistance, and herbicide susceptibility.

a. Drought resistance is one of the most important attributes required in pearl millet because of its nearly restricted production to the most droughty soils. Breeding for drought resistance is handicapped by lack of good physiological selection criteria, particularly since drought resistance can be imparted by a number of different physiological and morphological traits. A project on drought by D. R. Krieg at Texas is determining physiological traits related to drought resistance in pearl millet and the ICRISAT cereal physiology program is studying root systems, leaf water potential, and leaf desiccation tolerance in drought endurance (Kassam, ibid.). KSU will develop information that adds to these studies by investigating plant-water relations under water-deficit conditions, for a wide variety of genetic material.

b. Seedling vigor problems require excessive use of grain for high planting rates or replanting and cause inadequate stands and low productivity. Genotypes are needed that will establish themselves under adverse conditions. We will screen introduced germplasm S_1 lines in breeding populations to identify lines that have high seedling vigor, determine the magnitude of variation in seedling vigor within populations, and related seedling vigor to seed characteristics that can be easily screened. Standard methods of measuring seedling vigor - root and shoot yield, mechanical and osmotic stress, and adenylate charge - will be compared to determine those that are applicable to pearl millet improvement.

c. Reaction of pearl millet to commercial herbicides will be determined to enable programs in developing countries to select those herbicides that will control local weeds without harming the crop. Weeds markedly

reduce crop yields and compete for scarce water and fertilizer nutrients required by millet. By knowing reaction of pearl millet commercial herbicides, specific herbicides can be used to control specific local weed problems. We will field plot test available commercial herbicides at different rates to determine reaction of pearl millet to them. Emphasis will be on herbicides that are likely to be or become available in developing countries, particularly triazine herbicides, which we have used with good success.

Objective 3. Determine the nutritional quality and digestibility of pearl millet grain and its component proteins and carbohydrates.

a. Pearl millet introductions, populations, S_1 breeding lines and field trials will be analyzed for protein content to maintain the generally high protein content of millet as yields increase. Protein content of pearl millet grain is as important a selection criterion as yield or any other trait.

b. Amino acid profiles, minerals, and certain vitamins will be analyzed to determine variation in these constituents among genotypes and environments. Particular attention will be paid lysine. Many populations and lines analyzed have a high grain lysine content, but some have low lysine content comparable to that in other grains. The high lysine trait probably should be transferred to low lysine lines and populations where it is lacking to upgrade the nutrition of persons in developing countries.

c. Pearl millet grain proteins will be fractionated by a modified Osborne procedure. Amino acid distribution in the isolated proteins will be determined, and the proteins will be characterized by techniques such as SGE, gel filtration, etc. Similar comparisons will be made for low and high lysine lines (already identified). This information, together with scanning electron photomicrographs of grain morphology, will be used in an attempt to develop rapid methods of detecting high lysine lines in the pearl millet breeding program.

d. Milling and other processing procedures will be developed to produce pearl millet flour and food products. Chemical analysis will be used to characterize the nutritional value of the flour and foods and compare it to the whole grain. Emphasis will be on determining how chemical composition and nutritional value are affected by various precooking processing methods. Information will also be obtained on how the chemical composition and nutritive value vary among various component parts of the pearl millet grain.

e. Feeding trials will be extended using rats as primary test animals. Objectives of the trials will be to confirm chemical analysis data and extend the information obtained thus far with rats and chicks. Primary emphasis will be on determining the biological value of traditional foods prepared from pearl millet.

f. Carbohydrate characteristics will be studied by determining effect of enzymes on pearl millet starch, by studying the staling rate of pearl millet starch pastes, and by determining the pentosan content of the grain.

Objective 4. Determine the storage stability of pearl millet grain and meal by determining the factors contributing to grain losses during storage and the factors contributing to the development of rancidity in ground pearl millet.

a. Factors contributing to storage losses to be studied will include microbial growth under various storage conditions, moisture-temperature relations and their connection to storage losses, and the susceptibility of stored pearl millet grain to major insect pests.

b. Rancidity in ground pearl millet tends to develop quickly. This will be studied by characterizing the lipids in ground millet meal, determining changes in lipids during storage under different conditions, and identifying possible simple means of controlling lipid degradation.

H. Time-phased Work Plan.

The following section details the research effort needed to complement pearl millet improvement by ICRISAT and other agencies. The areas where research emphasis are to be applied were identified during consultation and visitation with ICRISAT administrators and scientists. The areas are also those where particular expertise exists at Kansas State University. This plan as presented contains dates based on the assumption that the work could begin with the 1977 crop season.

Objective 1. (25% of the total effort)

a. Population Improvement.

(1) 1977.

(a) Conduct the Cycle 1 S_1 progeny performance of Hays populations 550, 553, and 557A. Trials will contain 100 to 200 S_1 lines of each population.

(b) Produce the Cycle 1 S_0 generation of Hays populations 600, 1002, and 1700. Bag 800 to 1500 plants within each population to produce S_1 seed.

(c) Introduce dwarf plant height, early maturity, B_1 and B_2 male-fertility maintenance, and large seed characteristics into a bulk population composed of the random-mated mass selected progeny of the world pearl millet collection. Seeds harvested from dwarf B_1 and B_2 plants will be maintained separately and designations will be Hays populations WC1 and WC2.

(2) 1977-1978 winter.

(a) Evaluate seedling reactions of selected S_1 lines of Hays populations 550, 553, and 557A to the greenbug aphid, Schizaphis graminum, in cooperation with Dr. T. L. Harvey, Entomologist.

(b) Recombine the top 10 to 15 percent of the lines within Hays populations 550, 553, and 557A in Puerto Rico.

(3) 1978.

(a) Grow the Cycle 2 S_0 generation of Hays populations 550, 553, and 557A to produce seed for S_1 progeny testing.

(b) Conduct the Cycle 1 S_1 progeny testing phase of Hays populations 600, 1002, and 1700.

(c) Mass select within Hays populations WC1 and WC2 tall agronomically desirable F_1 plants.

(4) 1978-1979 winter.

(a) Evaluate seedling reactions of selected S_1 lines of Hays populations 600, 1002, and 1700 to the greenbug aphid, in cooperation with Dr. T. L. Harvey.

(b) Recombine the top 10 to 20 percent of the lines within Hays populations 600, 1002, and 1700 in Puerto Rico.

(5) 1979.

(a) Conduct the Cycle 2 S_1 performance trials of Hays populations 550, 553, and 557A. Initiate inbred line development by self-pollinating agronomically desirable plants.

(b) Produce the Cycle 2 S_0 generation of Hays populations 600, 1002, and 1700.

(c) Select and self-pollinate desirable dwarf plants segregating within Hays populations WC1 and WC2. These selections are to be evaluated in head rows in 1980. Superior materials will then be grown in random-mating, mass-selected populations.

b. Hybrid Possibilities.

Presently available dwarf, forage-type cytoplasmic male-steriles (A lines) and their inbred fertility maintainer counterparts (B lines) require 77 to 85 days from planting to anthesis. Dwarf, large-seeded, grain-type A and B lines requiring 55 to 70 days to reach anthesis are being developed. Dwarf B_1 and B_2 derivatives of PI 185642 are being used as the recurrent parents in backcrosses to their respective dwarf A_1 and A_2 counterparts.

The development of male-fertility restoration lines having dwarf stature and desirable agronomic characteristics has proceeded concurrently with the development of the cytoplasmic male-sterile lines. Lines ranging from F_3 to F_8 were derived from crosses involving 56 plant introductions, Tift 23 DA_1 and DB_2, Tift 239 DA_2 and DB_2, Serere 3A, Serere 17, and PI 185642. Approximately 135 top crosses were made in 1976 between superior PI 185642 DA_1 lines and R lines.

(1) 1977-1978 Greenhouse.

(a) PI 185642 DA_1 lines ranging from BC_2 to BC_6 will receive a further cycle of backcrossing from their DB_1 counterparts which range from BC_1 F_5 to F_7 and BC_2 F_4 and F_5. The DB_2 lines will be backcrossed for the first time into the DA_2 F_1's.

(b) Advanced generation steriles will be pollinated by selected R lines.

(2) 1978.

(a) Backcrossing of the DB_1 and DB_2 progenies into the A_1 and A_2 cytoplasms will be advanced one generation with appropriate selection pressure applied for male-sterility and desirable agronomic characteristics.

(b) Selected lines will be advanced one generation and superior lines will be crossed to PI 185642 DA_1 lines.

(c) Depending on available quantities of seeds the F_1 hybrids produced in the 1976 field and 1976-1977 greenhouse will be placed in early-planted single-row observation nurseries and replicated yield trials at two locations (upland and bottomland) on the Fort Hays Experiment Station.

(d) Late-planted crossing nurseries will be used to produce sufficient seed of promising hybrids for 1978 observation nurseries and yield trials at several locations across the state.

(3) 1978-1979 Greenhouse.

(a) The DA_1 and DA_2 lines will be advanced one generation by backcrossing to their respective DB lines.

(b) Selected R lines will be grown and topcrossed to DA_1 lines.

(4) 1979.

(a) Superior DA_1 and DA_2 lines will be advanced one generation by backcrossing to their respective DB lines.

(b) New inbred R lines will be crossed to DA_1 and DA_2 lines for observation of their F_1 hybrids in 1979.

(c) Hybrids showing promise in 1977 yield trials will be reproduced in small isolated crossing blocks containing their respective A and B lines. F_1 seed produced in these crossing blocks will be used for additional statewide testing and in regional observation nurseries in other states in 1979.

Objective 2. (25% of total effort)

a. Develop techniques whereby evapotranspiration estimates can be made under various climatic regimes which would then allow soil moisture estimates (water deficit conditions) to be made.

(1) 1977.

Assess the advective contribution to total evapotranspiration by measuring canopy temperatures.

(2) 1978.

Plant millet on the Evapotranspiration Research Field and use weighing lysimeters to measure evapotranspiration.

(3) 1979.

Make energy and radiation balance measurements on millet to assess crop response to water stress.

b. Investigate plant-water relations of different genetic lines under water deficit conditions.

(1) 1977.

Stomatal resistance and xylem water potential will be measured on selected millet lines.

(2) 1978.

Under conditions of water deficit at various growth stages (performed under a rainout shelter or restricted root zone), compare stomatal resistance, xylem potential, and leaf temperature of selected millet lines.

(3) 1979.

Select and test criteria best suited for screening for drought resistance.

c. Identify seed and seedling characteristics which are associated with field performance of millet.

(1) 1977.

Standard germination and vigor tests, e.g. accelerated aging ammonium chloride treatment and cold tests, will be used on millet seed lots and correlated with field establishment under a range of climatic conditions.

(2) 1978.

The most promising vigor tests will be continued with as a wide a range of genetic material as can be obtained and where possible seed lots of the same genetic material produced in either different locations or in different years.

(3) 1979.

Materials developed in Objective 1 will be screened using the best vigor test obtained in the first two years of testing. Those showing excellent vigor will be tested under field conditions to verify their establishment capability.

d. Identify herbicide susceptibility of pearl millet to those herbicides commonly used on grain sorghum.

(1) 1977.

Herbicides which normally are used on grain sorghum and those which might be used on crops which would be expected to be grown in rotation with millet will be applied to millet using the rates and time of application of the herbicides as they would be utilized on sorghum.

(2) 1978.

Based on results on the 1977 experiments, selected herbicides would be applied to pearl millet with rates and times of applications varied to assess the sensitivity of pearl millet to these herbicides.

(3) 1979.

Materials from the breeding section (Objective 1) would be subjected to the herbicides studied in the previous two years to determine the possibilities of selection for genetic response to herbicides.

Objective 3. (40% of the total effort)

a. Determine if genetic variability in digestibility occurs within pearl millet.

(1) 1977.

Pearl millet proteins will be fractionated and characterized amino acid distributions will be determined paying particular attention to variations in lysine content among and within populations.

(2) 1978.

Rat feeding studies on traditional foods prepared from pearl millet will be conducted to determine total digestible matter and protein digestibility.

(3) 1979.

Determine if any antidigestibility factors or morphological barriers to enzymatic attack exist by using enzyme digestion techniques and scanning electron microscopy.

b. Determine the nutrient composition and availability of nutrients in pearl millet.

(1) 1977.

Pearl millet lines grown under a number of environmental conditions will be analyzed for minerals, vitamins, and amino acids.

(2) 1978.

Milled fractions obtained from pearl millet will be analyzed for minerals, vitamins, and amino acids.

(3) 1979.

Chemical and biological assays will be used to determine the retention and availability of nutrients before and after processing millet into food.

c. Characterize the carbohydrates of pearl millet to determine their susceptibility to hydrolytic enzymes and their influence on food quality and digestibility.

(1) 1977.

Determine the susceptibility of pearl millet starch to enzyme attack.

(2) 1978.

Studies on the staling rate of starch pastes made with millet starch.

(3) 1979.

Determine the amount and types of pentosans in pearl millet.

Objective 4. (10% of total effort)

a. Determine what factors contribute to the losses of pearl millet grain during storage.

(1) 1977.

Moisture isotherms for pearl millet will be determined.

(2) 1978.

The effect of storage conditions on microbial growth will be determined.

(3) 1979.

Determination of the susceptibility of stored millet to grain insects.

b. Investigate the factors contributing to the rapid development of rancidity in millet meal during storage.

(1) 1977.

Determining and characterizing the lipids in millet meal.

(2) 1978.

Determination of the types of changes occurring in lipids during the storage of millet meal under varied environmental conditions.

(3) 1979.

Identification of possible conditions which might control lipid degradation.

I. Contractor Internal Management and Facilities.

1. Local Research Organizations Involved.

a. Department of Agronomy, H. S. Jacobs, Head

b. Department of Grain Science and Industry, Charles W. Deyoe, Acting Head

c. Fort Hays Branch Experiment Station, William Phillips, Acting Superintendent

d. Kansas Agricultural Experiment Station, F. W. Smith, Director

e. USDA, ARS, Manhattan, Kansas, M. G. Eversmeyer, Research Leader.

2. Available Facilities.

Equipment necessary for the proposed project is available with the exception of adequate harvesting and protein characterization equipment. A protein fractionation centrifuge for that purpose is requested. Facilities already available include cereal chemistry and physiology laboratories, Beckman 120 B amino acid analyzers, macro- and micro-Kjeldahl equipment, four walkin growth chambers, adequate greenhouse space, spectrophotometers, balances, centrifuges, grinders, etc. The Department of Grain Science and Industry has complete milling and processing facilities available for all aspects of the proposed work. The Evapotranspiration Research Field Site is available for water use efficiency studies. The Research Field is equipped with two weigh lipimeters and a high resolution data acquisition system.

An IBM 370/158 system and ETEC scanning electron microscope to be used for the proposed research are available in other departments of the University. User fees are required for their operation, however.

Field facilities and equipment for breeding nurseries, screening lines and introduced germplasm, conducting agronomic trials, and producing grain for feeding trials are available at Manhattan and outlying stations. Annual precipitation at these stations ranges from 42 inches in the southeast to 16 inches in the southwest, giving a wide range of environmental conditions for the studies. The Fort Hays Branch Experiment Station, where much of the Kansas off-campus research will be conducted, is one of the largest dry-land stations in the world.

Kansas State University holds a seed import permit for pearl millet and sorghum, issued by APHIS to L. K. Edmunds, ARS, USDA, and Kansas State University. Under this permit, seed from presently restricted sources in Africa and Asia is channeled through APHIS to Kansas State University for grow-out under quarantine in an isolated greenhouse on the campus. Present capacity, depending on amount of replication desired and occasional service to related programs at other land grant institutions, should allow up to 50 entries per year. It is anticipated that such capacity will be sufficient.

J. Key Project Personnel. (Salaries to be paid by KSU)

1. Richard L. Vanderlip (Principal Investigator)

a. Education.

Institution	Year	Degree	Field
Kansas State University	1960	B.S.	Agronomy
Iowa State University	1962	M.S.	Agronomy
Iowa State University	1965	Ph.D.	Agronomy

b. Experience.

Graduate Research Assistant, Iowa State University, 1960-62
Graduate Research Associate, Iowa State University, 1962-64
Assistant Professor of Agronomy, Kansas State University, 1964-69
Associate Professor of Agronomy, Kansas State University, 1969-76
Associate Professor of Agronomy (Sabbatical), Texas A&M University, 1974-1975
Professor of Agronomy, Kansas State University, 1976-present

c. Principal Publications.

(1) Vanderlip, R. L. 1968. How plant populations affect yields of corn hybrids. Kans. Ag. Expt. Sta. Bul. 519.

(2) Brown, M. J. and R. L. Vanderlip. 1969. Relationship of Palmer drought variables to yield of winter wheat. Agron. J. 61:95-98.

(3) Vanderlip, R. L. 1972. How a sorghum plant develops. Kans. Ext. Cir. 447.

(4) Windscheffel, J. A., R. L. Vanderlip, and A. J. Casady. 1973. Performance of 2-dwarf and 3-dwarf grain sorghum hybrids harvested at various moisture contents. Crop Sci. 13:215-219.

(5) Vanderlip, R. L., F. E. Mockel, and H. Jan. 1973. Evaluation of vigor tests for sorghum seed. Agron. J. 65:486-488.

(6) Jacques, G. L., R. L. Vanderlip, and Roscoe Ellis, Jr. 1975. Growth, nutrient accumulation and distribution in grain sorghum. II. Zn, Cu, Fe, and Mn uptake in distribution. Agron. J. 67:611-616.

Approximately 30 additional publications on corn and sorghum production and management.

d. Amount of time on project.

Twenty percent.

2. Edward T. Kanemasu

a. Education.

Institution	Year	Degree	Field
Montana State University	1962	B.S.	Soils
Montana State University	1964	M.S.	Soil Physics
University of Wisconsin	1969	Ph.D.	Environmental Physics

b. Experience.

Graduate Research Assistant, Montana State University, 1963-1964
Biometeorology Fellow, University of Wisconsin, 1964-1969
Assistant Professor of Agronomy, Kansas State University, 1969-1974
Associate Professor of Agronomy, Kansas State University, 1974-present
Chairman, Western Regional Technical Committee (W-67) 1976
Chairman, Remote Sensing Subcommittee of Great Plains Council on Evapotranspiration (GPC-1) 1974-1976.
Associate Editor, Agronomy Journal, 1977-present.

c. Principal Publications.

(1) Kanemasu, E. T., C. B. Tanner, and G. W. Thurtell. 1969. The design, calibration and field use of a stomatal diffusion porometer. Plant Physiol. 44:881-885.

(2) Teare, I. D. and E. T. Kanemasu. 1972. Stomatal diffusion resistance and leaf water potential of soybean and sorghum. New Phytol. 71:805-810.

(3) Kanemasu, E. T. and G. F. Arkin. 1974. Radiant energy and light environment of crops. Agric. Meteorol.14:211-225.

(4) Kanemasu, E. T. 1975. Editor. Measurement of Stomatal Aperture and Diffusive Resistance. Washington State Univ. Bul. 809. 38pp.

(5) Kanemasu, E. T. and C. K. Hiebsch. 1975. Net carbon dioxide exchange of wheat, sorghum, and soybean. Can. J. Bot. 53:382-389.

(6) Kanemasu, E. T., L. R. Stone, and W. L. Powers. 1976. Evapotranspiration model tested for soybeans and sorghum. Agron. J. 68:569-572.

Approximately 40 additional publications on plant-water relations and agricultural meteorology.

d. Amount of Time on Project.

Ten percent.

3. W. D. Stegmeier

a. Education.

Institution	Year	Degree	Field
Colorado State University	1956	B.S.	Agronomy
Colorado State University	1959	M.S.	Field Crops
South Dakota State University	1968-71	-	Agronomy

b. Experience.

Research Assistant, Colorado State University, 1956-58
Instructor, Garden City Experiment Station, KSU, 1958-64
Assistant Professor, Garden City Expt. Sta., KSU, 1964-68
Research Assistant, South Dakota State University, 1968-71
Assistant Professor, Fort Hays Experiment Station, KSU, 1971
Assistant Professor, Fort Hays Experiment Station, KSU, 1971-

c. Amount of Time on Project.

Forty percent.

4. L. K. Edmunds

a. Education.

Institution	Year	Degree	Field
University of Wisconsin	1953	B.S.	Dairy Husbandry
University of Wisconsin	1958	Ph.D.	Plant Pathology

b. Experience.

Graduate Research Assistant, University of Wisconsin, 1955-58
Research Associate, University of Wisconsin, 1958-60
Research Plant Pathologist, USDA, ARS, 1960-Present

c. Principal Publications.

(1) Edmunds, L. K. 1963. Use of sporidial hypodermic injection to test sorghum for head smut resistance. Plant Disease Reptr. 47:909-913.

(2) Edmunds, L. K. 1964. Combined relation of plant maturity, temperature and soil moisture to charcoal rot development in grain sorghum. Phytopathology 54:514-517.

(3) Edmunds, L. K., M. C. Futrell, and R. A. Frederiksen. 1970. Sorghum diseases. In Sorghum Production and Utilization, J. A. Wall and W. M. Ross (Editors). AVI Pub. Co., Westport, Conn.

(4) Edmunds, L. K. and C. L. Niblett. 1973. Occurrence of panicle necrosis and small seed as manifestations of maize dwarf mosaic virus infection in otherwise symptomless grain sorghum plants.

(5) Edmunds, L. K., R. L. Voigt, and F. M. Carasso. 1964. Use of Arizona climate to induce charcoal rot in grain sorghum. Plant Disease Reptr. 48:300-302.

(6) Edmunds, L. K. and N. Zummo. 1975. Handbook of sorghum diseases in the United States and their control. U. S. Dept. Agr. Handbook Series No. 468.

Approximately 20 additional publications on sorghum diseases and their control.

d. Amount of time of Project.

Five percent.

5. R. C. Hoseney

a. Education.

Institution	Year	Degree	Field
Kansas State University	1957	B.S.	Grain Science
Kansas State University	1960	M.S.	Grain Science
Kansas State University	1968	Ph.D.	Grain Science

b. Experience.

Research Chemist, U. S. Department of Agriculture, 1956-1970
Associate Professor, Kansas State University, 1971-1975
Professor, Kansas State University, 1975-Present
Consultant, The Pillsbury Company, 1973-Present
Associate Editor, Cereal Chemistry, 1973-Present

c. Principal Publications.

(1) Hoseney, R. C., K. F. Finney, and Y. Pomeranz, 1966. Changes in urea-dispersability of wheat protein during maturation. J. Sci. Food and Agric. 17:273.

(2) Hoseney, R. C. and K. F. Finney. 1971. Functional (breadmaking) and biochemical properties of wheat flour components. XI. A review. Baker's Digest 45(4):30.

(3) Wassom, C. E. and R. C. Hoseney. 1973. A scanning electron microscope for selecting high lysine corn. Crop Sci. 13:462.

(4) Robutti, J. L., R. C. Hoseney, and C. W. Deyoe. 1974. Modified opaque-2 corn endosperm. I. Protein distribution and amino acid composition. Cereal Chem. 51:163.

(5) Robutti, J. L., R. C. Hoseney, and C. E. Wassom. 1974. Modified opaque-2 corn endosperm. II. Structures viewed with a scanning electron microscope. Cereal Chem. 51:173.

(6) Hoseney, R. C., A. B. Davis, and L. H. Harbors. 1974. Pericarp and endosperm structure of grain sorghum shown by scanning electron microscope. Cereal Chem. 51:552.

Approximately 45 additional publications on cereal chemistry and processing.

d. Amount of Time on Project.

Twenty-five percent.

6. Elizabeth Varriano-Marston

a. Education.

Institution	Year	Degree	Field
University of Minnesota	1968	B.S.	Home Economics
University of Minnesota	1971	M.S.	Food Research
University of Minnesota	1975	Ph.D.	Food Science

b. Experience.

Nutritionist, Detroit Memorial Hospital, 1971-1972
Scientist, The Pillsbury Company, 1975-1976
Assistant Professor, Kansas State University, 1976-present

c. Principal Publications.

(1) Marston, E. V., Davis, E. A. and Gordon, J. 1974. Mineral retention in vegetables as affected by phosphates in water. H. E. Res. J., 2:147.

(2) Varriano-Marston, E., Davis, E. A., Hutchinson, T. E. and Gordon, J. 1976. Scanning electron miscroscopy of aged free and restrained bovine muscle. J. Food Science, 41:601.

(3) Varriano-Marston, E., Hutchinson, T. E., Davis, E. A. and Gordon, J. 1977. Applications of cryomicrotomy to the preparation of frozen hydrated muscle tissue for transmission electron microscopy. J. Microscopy (in press).

(4) Varriano-Marston, E., Hutchinson, T. E. Davis, E. A. and Gordon, J. 1977. Postmortem aging in muscle. A comparison of two preparation procedures for electron microscopy. J. Food Science (in preparation). To be presented at 1977 IFT Annual Meeting, Philadelphia.

(5) Varriano-Marston, E. 1977. A comparison of preparation procedures for scanning electron microscopy of flour-water mixtures. Presented at 1976 AACC meeting, New Orleans. Submitted to Cereal Chem.

Approximately 20 additional in-house publications while with The Pillsbury Company.

d. Amount of Time on Project.

Twenty-five percent.

K. General Appraisal.

This project has been given top level priority by the Crop Production Division and Office of Agriculture. In addition to the need for developing improved pearl millet varieties for the DCs, the strong support to be provided ICRISAT's pearl millet program is considered essential. Support for SAFGRAD also can be provided.

Less research and breeding work has been conducted with pearl millet than with any of the other major cereal crops. In the United States, only four universities have any significant research in progress on this crop and only one (Kansas State University) is devoting more than one full time equivalent research scientist's time to the crop.

The proposing institution has a strong staff with excellent experience in most of the developing countries. Equipment needed for the proposed project is available with the exception of adequate protein characterization equipment. A protein fractionation centrifuge for that purpose will be requested. Facilities already available include cereal chemistry and physiology laboratories, Beckman 120 B amino acid analyzers, macro- and micro-Kjeldahl equipment, four walk in growth chambers, adequate greenhouse space, spectrophotometers, balances, centrifuges, threshers, grinders, etc. The Department of Grain Science and Industry has complete milling and processing facilities available for all aspects of the proposed activities.

An IBM 360/50 system and ETEC scanning electron microscope are available in other departments of the university. User fees are required for their operation.

Field facilities and equipment for breeding nurseries, screening lines and introduced germplasm, conducting agronomic trials, and producing grain for feeding trials are available at Manhattan and outlying stations. The Fort Hays Branch Experiment Station, where much of the off-campus research will be conducted, is one of the largest dryland stations in the world.

The proposal is sound in design and cost estimates are appropriate in the level of effort intended. The three-year time framework proposed for the initial project is recognized as too brief to reach full results, and it should be anticipated that extension would be desirable if progress is made as anticipated. Alternatively, this project may become part of a larger collaborative research program.

A detailed review of the project should be conducted at the end of the second project year to assess progress and to determine the need for possible extension.

L. Environmental Considerations.

Since this project involves only controlled experimentation on small plots, and is therefore of limited scope and under strictly controlled conditions, it has been determined that it will not result in a major federal action which will have a significant effect on the human environment. Therefore, an Environmental Impact Statement or an Environmental Assessment will not be required.

A negative Determination for this project is attached.

M. Contract Budget and Life-of-Project Cost Estimates

Inputs	Year 1 M/M	Year 1 $(000)	Year 2 M/M	Year 2 $(000)	Year 3 $(000)	Total $(000)
1. Salaries	134	89.2	134	96.6	104.4	290.2
2. Fringe Benefits		11.5		12.3	13.3	37.1
3. Indirect Costs (53.3%)		53.7		58.0	62.7	174.4
4. Travel and per diem						
a. Domestic		4.0		6.0	8.0	18.0
b. International		16.0		18.0	20.0	54.0
5. Equipment		51.0		-	-	51.0
6. Materials and Supplies		30.0		40.0	40.0	110.0
7. Other direct Costs		4.6		8.1	12.6	25.3
8. Publications		2.0		4.0	4.0	10.0
TOTALs		262.0		243.0	265.0	770.0

Outputs						
1. Breeding materials and information		65.5		60.8	66.3	192.6
2. Agronomic information		65.5		60.7	66.2	192.4
3. Nutritional information		104.8		97.2	106.0	308.0
4. Storage quality information		26.2		24.3	26.5	77.0
TOTALs		262.0		243.0	265.0	770.0

AID 1020-24 (1-72)

PROJECT DESIGN SUMMARY
LOGICAL FRAMEWORK

Life of Project:
From FY 77 to FY 79
Total U.S. Funding $270,000 - three years
Date Prepared: April 1977

Project Title & Number: Improvement of Grain Yield and Quality in Pearl Millet for Semiarid Areas #931-17-130-632

NARRATIVE SUMMARY	OBJECTIVELY VERIFIABLE INDICATORS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
Program or Sector Goal: The broader objective to which this project contributes: To increase quantity and nutritional value of food crops in developing countries.	Measures of Goal Achievement: 1. Significant increase in per capita production of pearl millet in the DCs. 2. Improvement of nutritional quality of pearl millet.	1. Official production and population statistics (DCs, FAO, Foreign Agricultural Service estimates. 2. Improvement of nutritional quality surveys in DCs.	Assumptions for achieving goal targets: 1. Staffing with highly competent professional staff. 2. Active cooperation of agencies concerned, including ICRISAT. 3. Continuing interest in pearl millet as human food. 4. Nutritional quality can be improved without major constraints on yield. 5. No abnormally dry weather conditions in millet producing areas.
Project Purpose: To utilize linkages and cooperation between U.S. institutions, ICRISAT, and developing country research and extension agencies to improve production of pearl millet and to extend that improvement to the rural population.	Conditions that will indicate purpose has been achieved. End of project status. 1. New, superior varieties available to farmers in DCs. 2. Research and development activities in pearl millet effectively assumed by DC agencies and international institutions and linked by a communications network.	1. Publications and reports of DC governmental agencies; on-site inspections of seed supply and planted acreages. 2. On-site inspection and review by AID/W personnel, contractors, and consultants, ICRISAT reports.	Assumptions for achieving purpose: 1. Contractor and cooperating groups can find solutions to major constraints. 2. Local extension services are able and willing to promote proven practices. 3. DC, regional and international research institutions develop adequate capabilities.
Outputs: 1. Breeding stocks useful for further DC breeding programs. 2. Widely-adapted, stress-tolerant variation suitable for use under marginal conditions. 3. Diverse genetic material and techniques for use in ICRISAT's improvement programs. 4. Well trained staffs for developing countries. 5. Effective research and informational linkages among international agencies. 6. Training and technical assistance services to supplement efforts of ICRISAT.	Magnitude of Outputs: 1. At least two superior varieties per agroclimatic region. 2. Minimum one test sited in each major pearl millet growing DC. 3. Total of 10 DC trainees trained at KSU. 4. Linkages with at least two international centers and at least 8 DC institutions.	1. Reports by contractor. 2. Reports by contractor, USAIDs, DCs, cooperators, and ICRISAT. 3. Same as above. 4. Contractor reports. 5. Communications and reports from DCs, contractor, and international and regional agencies.	Assumptions for achieving outputs: 1. Research findings will be available and DCs will request assistance. 2. DCs will cooperate. 3. Interest and resources exist in the DCs. 4. Collaboration of ICRISAT and other international institutions. 5. DCs possess or are willing to train qualified personnel.
Inputs: 1. AID/W provides financial support and project guidance. 2. Contractor provides qualified personnel, facilities, coordination & training. 3. Participating personnel and cooperation provided by 1) DCs, 2) USAIDs, 3) other U. S. institutions, and 4) ICRISAT.	Implementation Target (Type and Quantity) 1. AID/W funding of approximately $265,000/year. 2. KSU provision of at least 14 w/m per year professional staff without charge to project. 3. KSU provision of required field, laboratory, and office facilities.	1. AID/W records. 2. Contractor reports and on-site inspections. 3. USAID reports and on-site verification.	Assumptions for providing inputs: 1. AID/funding will be available on schedule. 2. Contractor will have qualified personnel and facilities available to the project. 3. ICRISAT, other international agencies, USAIDs, and DCs will have personnel and resources to support this activity.

OPTIONAL FORM NO. 10
JULY 1973 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

TO : Files

DATE: June 10, 1976

FROM : AA/TA, Curtis Farrar

SUBJECT: Negative Environmental Determination for Research Project on Pearl Millet

Environmental aspects of the proposed project "Agronomic and Nutritional Improvement of Pearl Millet for Semiarid Areas" have been examined. Although most of the activities of this proposed research and development project will take place in the United States, no adverse environmental problems are anticipated to arise from execution of the project. Neither are adverse effects in developing countries expected to result from adoption of the research results in the field. Such adoption should, on the contrary, lead to energy conservation per unit of production, and to decrease in possible needs for pesticides as resistant varieties are put into use.

This activity is <u>not</u> deemed a Major Federal Action (Section 1500.6, CEQ Guideline) because the project will have no significant effects which adversely affect such aspects of the human environment as air, water, land, flora, fauna, or socioeconomic conditions.

The <u>Threshold Decision</u> is negative, constituting a <u>Negative Determination</u>, because project activities are restricted to controlled experimentation exclusively for the purpose of research, and as such the project is confined to small areas which are carefully monitored.

Clearance:

TA/AGR, WVonSpiegelfeld
TA/AGR, LFHesser

5010-110

Buy U.S. Savings Bonds Regularly on the Payroll Savings Plan

SUBJECT: Issues concerning the proposed research program titled: "Improvement of Grain Yield and Quality in Pearl Millet for Semi-Arid Areas"

1. The project statement should more clearly outline the relationship of Kansas State University and ICRISAT. The investigators should be made aware of Dana Dalrymples' report of his visits to the International Research Centers in Asia (Feb. 26-Mar. 16, 1977) which included ICRISAT. At this time it is not clear what cooperative arrangements have been made to prevent overlapping research.

2. Are the 4 objectives realistic goals for a three year project? A more detailed discussion of methods to be utilized in evaluating the progress of the project is needed.

3. Some reference concerning the endorsement and evaluation of this proposal from the various AID Bureaus would help evaluate this research programs' probability of success in meeting the needs of the LDC's.

4. The negative determination as discussed under Environmental Considerations (p. 31) is not attached and should be.

5. Some description of the capital equipment to be purchased should be included.

6. Storage losses of millet are to be examined but are restricted to insect pests. Other stored grain pests such as mold, fungi, rats, etc. should also be examined. However, since AID already funds a project in pest management (GTS), maybe this part of the proposal could be dropped.

7. Various seedling reactions to attack by the greenbug aphid will be examined. Why is this species the only one to be examined and how do the insect pest species in Kansas relate to the insect pest situation in the LDC's in terms of both species and population densities?

8. It appears that this research program is an ongoing project which began some time ago. Was this project funded before and if so, what new research has been added to this proposal?

9. Are there any plans at the present time for some of the field research in this project to be carried out in the LDC's? Enviromental parameters will be greatly different in the LDC's than those found at KSU.

10. On page 12 of the proposal, the investigators state, that through random breeding and artifical selection, they will accumulate high yield and high nutrient content strains of millet and reduce genes for low yield, day-length sensitivity, pest susceptibility, etc.

The Principle of Allocation (see Martin Cody, etc.) suggests that in nature energy budgets for individuals are limited and energy will be allocated to meet the overall ecological demands on the growth, development and reproduction of that individual. Breeding selectively for yield, fiber content, etc. often times is achieved at the cost of reducing energy available for some other biological component such as pest resistence, disease resistence, stem length, etc.

Thus, problems of ergot fungus (p.4) and strains of millet lacking wide adaptability (p.13) as discussed in the proposal may in fact be due to this allocation principle and are a negative response in the plant which was selectively bred only for high yield. This co-evolutionary relationship should be brought to the attention of the investigators as a possible project complication.

PPC/FDL

Proj. 9311040
BN-

AGENCY FOR INTERNATIONAL DEVELOPMENT
PROJECT AUTHORIZATION AND REQUEST FOR ALLOTMENT OF FUNDS PART I

1. TRANSACTION CODE: A (A = ADD, C = CHANGE, D = DELETE)

PAF

2. DOCUMENT CODE: 5

3. COUNTRY/ENTITY: TA/BUREAU/AGR—Research RDA#2

4. DOCUMENT REVISION NUMBER: Original

5. PROJECT NUMBER (7 digits): 931-1040

6. BUREAU/OFFICE: A. SYMBOL: TAB; B. CODE: 08

7. PROJECT TITLE (Maximum 40 characters): Pearl Millet Improvement

8. PROJECT APPROVAL DECISION — ACTION TAKEN: A - APPROVED; D - DISAPPROVED; DE - DEAUTHORIZED

9. EST. PERIOD OF IMPLEMENTATION: YRS. 03 QTRS.

10. APPROVED BUDGET AID APPROPRIATED FUNDS ($000)

A. APPROPRIATION	B. PRIMARY PURPOSE CODE	PRIMARY TECH. CODE C. GRANT	PRIMARY TECH. CODE D. LOAN	E. 1ST FY 77 F. GRANT	E. 1ST FY 77 G. LOAN	H. 2ND FY ___ I. GRANT	H. 2ND FY ___ J. LOAN	K. 3RD FY 79 L. GRANT	K. 3RD FY 79 M. LOAN
(1) FN	111 J	963			505			265	
(2)									
(3)									
(4)									
			TOTALS		505			265	

A. APPROPRIATION	N. 4TH FY ___ O. GRANT	N. 4TH FY ___ P. LOAN	Q. 5TH FY ___ R. GRANT	Q. 5TH FY ___ S. LOAN	LIFE OF PROJECT T. GRANT	LIFE OF PROJECT U. LOAN
(1)					770	
(2)						
(3)						
(4)						
TOTALS					770	

11. PROJECT FUNDING AUTHORIZED (ENTER APPROPRIATE CODE(S)) 1 = LIFE OF PROJECT; 2 = INCREMENTAL, LIFE OF PROJECT — A. GRANT: 2; B. LOAN:

C. PROJECT FUNDING AUTHORIZED THRU FY 79

12. INITIAL PROJECT FUNDING ALLOTMENT REQUESTED ($000)

A. APPROPRIATION	B. ALLOTMENT REQUEST NO. ___ C. GRANT	D. LOAN
(1) FN	505	
(2)		
(3)		
(4)		
TOTALS	505	

13. FUNDS RESERVED FOR ALLOTMENT

TYPED NAME (Chief, SER/FM/FSD)

SIGNATURE

DATE

14. SOURCE/ORIGIN OF GOODS AND SERVICES: 000 941 LOCAL OTHER ___

15. FOR AMENDMENTS, NATURE OF CHANGE PROPOSED

N/A

FOR PPC/PIAS USE ONLY	16. AUTHORIZING OFFICE SYMBOL	17. ACTION DATE MM DD YY	18. ACTION REFERENCE (Optional)	ACTION REFERENCE DATE MM DD YY

AID 1330-6 (7-78)

#2

PROJECT AUTHORIZATION AND REQUEST

FOR ALLOTMENT OF FUNDS PART II

ENTITY : TA/Bureau

PROJECT : Pearl Millet Improvement

PROJECT NUMBER: 931-1040

I hereby authorize grant funds not to exceed $770,000 for a three-year contract to be negotiated with Kansas State University for research on "Pearl Millet Improvement".

The research proposed in this project is intended to augment and assist but not duplicate the efforts of ICRISAT, as well as developing countries'(DC) regional and country programs. Emphasis will be on the development of high yielding widely adapted populations, investigating the feasibility of hybrids in developing countries, solving principal problems in plant breeding and production, and increasing nutritional qualities of pearl millet food products in the developing countries. Improved germplasm, breeding, selection and production techniques, nutritional and processing knowledge, and other information will be distributed to developing countries through international agencies and local national programs.

This project will be incrementally funded with $505,000 for the first two years, FY 1977 and FY 1978 of the contract. The final amount, $265,000 will be funded for the third year subject to the availability of funds. The first in-depth evaluation of the project is scheduled for March, 1979. This project was reviewed and endorsed by the Research Advisory Committee in their July 14, 1977 meeting and recommended for approval, subject to three provisions (attached hereto as attachment 3) which shall be incorporated in the project.

Attachments:
1. Memorandum from TA/AGR, L. Hesser to AA/TA, C. Farrar, July 19, 1977
2. Project Paper
3. RAC recommendations

M S Bilder for C Farrar
Curtis Farrar
Assistant Administrator
for Technical Assistance
Date: AUG 23 1977

Clearances:
TA/RES, MRechcigl Date: 8/1/77
TA/PPU, KMilow Date: 8/19/77

References:
1. Research Project Statement (Attached)
2. Minutes of RAC Meeting, July 14, 1977

OPTIONAL FORM NO. 10
JULY 1973 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

TO : AA/TA, Dr. Curtis Farrar

DATE: July 19, 1977

THRU : TA/PPU, Mr. Robert Simpson

FROM : TA/AGR, Dr. Leon F. Hesser

SUBJECT: Project Authorization and Request for Allotment of Funds, Part I and II: "Pearl Millet Improvement" - Kansas State University

Problem: Your approval of the attached Project Authorization and Request for Allotment of Funds is requested.

Discussion: Kansas State University has submitted an unsolicited proposal to conduct research on pearl millet, which has been developed into the project paper. The proposing institution has a strong staff with excellent experience in addressing problems of developing countries. It has the only substantial research program on pearl millet for grain in the United States, and maintains close liaison with all the other pearl millet research workers in the U. S.

Field facilities and equipment for breeding work, agronomic trials, and production of grain for utilization studies are amply available at Manhattan, Fort Hays, and branch experiment stations. Excellent laboratory facilities and equipment are readily available for the proposed utilization and storage trials. The participating staff is highly competent and has available time to conduct the proposed studies.

The proposal has been reviewed by TA/AGR and meets the requirements of an unsolicited proposal contained under AID PR 7-4.5301 (e). Therefore, it is recommended that a contract be awarded to Kansas State University without consideration of other sources.

The RAC recommended at the meeting of July 14, 1977 that this activity be approved as proposed with the three provisions: "(1) That a major initial effort be directed toward production of high yielding synthetic varieties; (2) That there be free exchange of breeding materials and information between KSU and ICRISAT; and (3) That the field outreach aspects be primarily the responsibility of ICRISAT". These points have been incorporated into the PIO/T.

Enclosures
a/s

5010-110

Buy U.S. Savings Bonds Regularly on the Payroll Savings Plan

Summary of RAC Recommendations - July 14-15, 1977

Improvement of Grain Yield and Quality in Pearl Millet for Semiarid Areas (New) - Kansas State University. Duration of project, 3 years; estimated cost, $770,000. *Peterson, Ludington, Moss, Swanson.

Recommendation: That the project be approved as proposed, with the recommendation: (1) that a major initial effort be directed toward production of high yielding synthetic varieties; (2) that there be free exchange of breeding materials and information between KSU and ICRISAT; and (3) that the field outreach aspects be primarily the responsibility of ICRISAT.

Note: With AID's commitment to help the world's poorest people, RAC felt research on pearl millet should be given a high priority since this crop is the staple food in the poorest LDCs of Africa and Asia. RAC felt that Kansas State University was an excellent choice as a contractor since they have over six years of research experience with pearl millet as well as excellent facilities, the proper growing climate, and a highly qualified staff. The RAC, however, recommended that a training component be built into the proposal as well as forward plans for an applied outreach program after the completion of the research phases.

*RAC review Subcommittee; chairman underscored