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PD-AAF-216-E

PROJECT SUMMARY

A. PROJECT SUMMARY

38p

1. Statistical

Project Title:	Development of Improved Sorghum - Physiology of Yield and Stress Reaction
New or Extension:	Extension for 3 years
Contractor:	University of Nebraska
Principal Investigator:	Dr. Jerry Eastin
Duration:	February 11, 1977 - February 10, 1980
Total Estimated Cost:	$604,000
Funding by Fiscal Years:	FY 77 - $182,000 FY 78 - $211,000 FY 79 - $211,000
Prior Funding:	Life-of-project - $295,000 (FY 76 - 135,000)
Project Manager:	Earl R. Leng, TA/AGR/CP

2. Narrative Summary

This is a proposal to extend research in sorghum physiology, particularly in relation to yield and stress tolerance, which is presently being conducted at the University of Nebraska under a centrally-funded contract, AID-ta-c-1068. The work will be conducted in close collaboration with other centrally-funded contract research at Texas A&M and Purdue universities, as well as with ICRISAT and other international centers where sorghum is a major object of research.

The current project and preceding work funded by other sources have been successful in developing a better understanding of basic physiological processes in sorghum, their relation to yield and stress tolerance, and the possibilities of genetic manipulation to improve performance of breeding stocks. With further work, it is anticipated that this information can be put to practical use for the development of varieties, lines, and populations adapted to cultivation in DCs where sorghum is a major food grain crop.

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Worksheet

IX

PIO/T

DEPARTMENT OF STATE
AGENCY FOR
INTERNATIONAL DEVELOPMENT

PROJECT IMPLEMENTATION ORDER/TECHNICAL SERVICES

1. Cooperating Country: DS Bureau

Page 1 of 1 Pages

2. PIO/T No. 931-0575-3697007

3. ☐ Original or Amendment No. 2

4. Project/Activity No. and Title (931-0575.11)Univ. of Neb. Sorghum Yield Physiology

DISTRIBUTION

5. Appropriation Symbol: 72-1191021.3

6. Allotment Symbol and Charge: 943-36-099-00-22-03

7. Obligation Status: ☒ Administrative Reservation ☐ Implementing Document

8. Project Assistance Completion Date (Mo., Day, Yr.): March 31, 1980

9. Authorized Agent: AID/W

10. This PIO/T is in full conformance with PRO/AG: N/A Date

11a. Type of Action and Governing AID Handbook: ☒ AID Contract (HB 14) ☐ PASA/RSSA (HB 12) ☐ AID Grant (HB 13) ☐ Other

11b. Contract/Grant/PASA/RSSA Reference Number (If this is an Amendment): AID/ta-c-1382

12. Estimated Financing (A detailed budget in support of column (2) is attached as attachment no. N/A)

		(1) Previous Total	(2) Increase	(3) Decrease	(4) Total to Date
Maximum AID Financing	A. Dollars	105,000	—	—	105,000
	B. U.S.-Owned Local Currency				

13. Mission References

14a. Instructions to Authorized Agent: This PIO/T authorizes SER/CM/COD/AN to extend Contract AID/ta-c-1382 with the University of Nebraska for a period of 6 months (from October 1, 1979 to March 31, 1980) in order to provide the time required to complete the scope of work as currently specified. No additional funds are required for this extension. All other conditions remain the same. Article # Voucher Identification: In each instance of Voucher (SF-1034) submission made by the contractor for payment hereunder, the following identification data will appear on the face of the voucher:

Contract: AID/ta/c/1382; Project: 931-0575.11; Project Officer: Robert I. Jackson, DS/AGR/FCP

14b. Address of Voucher Paying Office

Office of Financial Management
Agency for International Development
Washington, D.C. 20523

15. Clearances—Include typed name, office symbol, telephone number and date for all clearances.

A. The project officer certifies that the specifications in the statement of work are technically adequate
DS/AGR/FCP:RIJackson [signature] 11/8/79
DS/AGR/FCP:KMByergo [signature]
Phone No. Date 11/8/79

B. The statement of work lies within the purview of the initiating and approved agency programs
DS/ AGR:DPeterson [signature] Date 11/9/79

C. DS/AGR/FCP:SEngberg [signature] Date
DS/AGR:MMozynski [signature]

D. Funds for the services requested are available
DS/PO:MEgan Noted [signature] Date: Nov 15, 1979

E. DS/PO:MRechcigl [signature] Date 11/14/79
DS/PO:ASilver [signature] 11/14/79

16. For the cooperating country: The terms and conditions set forth herein are hereby agreed to

Signature _____ Date _____

17. For the Agency for International Development

Signature [signature] Date 11/15/79

Title Kenneth Milow
Chief, Program Office

931-0575

No problems. S

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The current project and preceding work funded by other sources have been successful in developing a better understanding of basic physiological processes in sorghum, their relation to yield and stress tolerance, and the possibilities of genetic manipulation to improve performance of breeding stocks. With further work, it is anticipated that this information can be put to practical use for the development of varieties, lines, and populations adapted to cultivation in DCs where sorghum is a major food grain crop.

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The Nebraska group is recognized worldwide as leaders in this aspect of sorghum research, and their assistance and counsel are sought by sorghum investigators in both developed and developing countries. In particular, research workers at ICRISAT and ALAD, as well as at other institutions conducting sorghum improvement, have reported the Nebraska findings to be of significant assistance to their breeding and cultural practice programs, and have strongly urged continuation and intensification of the physiological studies.

B. RESEARCH PURPOSE AND OBJECTIVES

1. Purpose

The overall purpose of this and related projects is to make available to developing countries high-yielding, nutritious varieties of sorghum with multiple resistance to environmental stresses and diseases and insects, together with improved practices for their cultivation.

2. Objectives

The major objectives of the proposed project are:

Objective 1. Investigate the nature of plant stress avoidance and tolerance mechanisms, develop screening techniques and select genotypes which may contribute to the development of sorghums with increased heat, drought, and cold tolerance.

Objective 2. Determine the tillage and production methods best suited for producing high yields with the low energy input under varying environmental conditions.

Objective 3. Investigate genotype differences and inheritance for mineral nutrient uptake and utilization efficiencies under mineral stresses and different cultural practices. Also study effects of mineral nutrients on heat, drought, and cold tolerances, other physiological properties, and plant quality and yield.

Objective 4. Develop and evaluate breeding techniques, especially recurrent selection procedures applied to artificially induced random mating populations. Apply these approaches to increase yield, insect and disease resistance, grain quality, mineral uptake efficiency, and stress tolerance.

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Objective 5. Investigate the influence of pests and pathogens on essential physiological processes in sorghum and attempt to elucidate the plant reaction mechanisms operative in plant resistance and tolerance.

Objective 6. Develop and strengthen linkages with developing country agencies, international and regional centers, and developed country institutions carrying out sorghum improvement programs aimed at DC needs.

C. SIGNIFICANCE AND RATIONALE FOR THE RESEARCH

1. The Development Problem

Sorghum is one of the four most important cereal food grains (along with rice, wheat, and maize). It is particularly significant as a supplier of human food in sub-Saharan Africa, parts of the Near East, the Indian subcontinent, and certain low rainfall areas in Latin America. Wherever sorghum is a major crop, environmental stress is a normal feature of growing conditions, and tolerance to stress is important for the successful cultivation of the crop.

2. State-of-the-Art

Investigations on the physiology of yield and stress tolerance now indicate that breeding for high performance under stress is feasible. It remains to further define the physiological processes and parameters, to work out details of breeding procedures and cultural practices suitable to improve sorghum for DC use, and to put this knowledge to practical use by producing and distributing breeding stocks which will be directly usable under DC conditions.

This contract project is part of a centrally-funded A.I.D. program intended to make improved sorghum varieties available to farmers in DCs.

Knowledge regarding these processes and their effects on yield has advanced considerably in the past few years, with the Nebraska research group playing a key role in these advances. It has been found that seed number is a particularly sensitive yield component to environmental effects, and also that seed size is an important manifestation of stress reaction. Under growing conditions usually encountered by sorghum, the number of seeds produced is nowhere near the potential maximum, and seed size seldom attains more than

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seventy-five per cent of its potential. Clearly, if either or both components can be affected by selection for stress tolerance, there is a ready potential for genetic improvement in expected yield level.

Screening techniques for quick measure of stress reaction and tolerance have been partially developed. Perfection of these methods would facilitate the development of improved varieties, lines, and populations, if they were applied to practical breeding programs.

D. LINKAGE AND UTILIZATION PLANS

1. International Research Centers and Networks

The current project already has established linkages and close professional ties with ICRISAT, and had similar linkages with ALAD until operations of the latter organization were disrupted by civil strife in Lebanon. If the new arid lands center (ICARDA) becomes operative, it is expected that similar ties will be developed with it. The University of Nebraska is a working partner in the international sorghum research network, and regularly exchanges research information and germplasm materials with other members of this network. The project is recognized throughout the network as the major source of strength in physiology of yield and stress reaction.

2. Developing Country National and Regional Programs

During the contract extension period, efforts will be made to strengthen direct involvement and contact with selected sorghum research agencies in developing countries. The proposed SAFGRAD project in sub-Saharan Africa is expected to provide a vehicle through which closer contact with sorghum research workers in these countries can be developed. ICRISAT and IITA, as expected major SAFGRAD contractors, will also be involved in developing these relationships. Nebraska can provide a very effective research backstop in physiology and related topics for these programs.

3. Other Centrally-funded A.I.D. Activities with U. S. Institutions

Very close working association has been established between the current project and centrally-funded research programs in sorghum at Texas A&M and Purdue Universities. There is a free exchange of research information, techniques, and seed stocks, which is expected to continue and strengthen during the extension period. Similar relations have been developed with

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Kansas State University, which is proposing a research program with pearl millet. Sorghum research workers from these and other institutions hold a special sorghum research conference once a year (in Texas in 1976), and AID-funded contract personnel regularly meet at least once a year (twice in 1975) to discuss matters of mutual interest.

4. Utilization Plans

The current system of disseminating research findings through publications and reports seems rational and adequate. This system utilizes established information centers, particularly those of ICRISAT and other international and regional agencies, to disseminate information and seed materials to country programs. Reports also are disseminated directly through A.I.D. channels.

E. MANAGEMENT CONSIDERATIONS

No unusual management problems are expected to arise in connection with this project renewal. As of the date of preparing this project statement, nearly 2½ years experience with the present contractor's operations of the existing project have shown high technical capacity, efficient administration, and excellent cooperation with A.I.D. technical and contract staff. Since the project extension contemplates retention of the same principal investigator and administrative arrangements, it is presumed that this excellent performance will continue.

The project will be evaluated in detail by a review and evaluation team during the first year of the contract extension, probably during the growing season of 1977. This evaluation will be conducted by site visit and will include qualified outside consultants. In addition, the project will be administratively reviewed each year, and will be under frequent review by the project manager.

This will be a sole-source procurement contract, since the project will be an extension of ongoing activities and since the present contractor has not only shown excellent performance, but has predominant capability in the field of sorghum physiology.

Personnel inputs from the University of Nebraska and affiliated USDA-ARS staff, funded from sources other than the A.I.D. contract, are estimated at ninety-eight worker months/year of professionals and seventy-two worker months/year subprofessionals and clerical. In addition, several graduate research assistants, not funded by the A.I.D. contract, will be involved in project operations.

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F. PROJECT BACKGROUND DESCRIPTION

1. General Background

Sorghum ranks among the four most important cereals (along with wheat, rice, and corn) as a human food source. Sorghum is particularly important in developing nations where environmental stresses often severely limit crop growth one or more times during the season. Much of the new land which will be brought into production in the next 20 years will be in limiting environments (soil and aerial). Relatively little is known about how to effectively screen for desirable environmental stress reactions in sorghum.

In the work under A.I.D. Contract ta-c-1068, and in earlier work funded by the Rockefeller Foundation, the major objective has been to study the effect of environmental parameters (particularly stress) on essential physiological and developmental processes as they dictate the seed number and seed size components of yield. Two environmental stresses of chief interest are temperature extremes and water deficits. Another area of interest includes soil nutrient deficiencies or toxicities which bear on the efficiency of nutrient uptake and subsequent utilization by the crop. Mineral toxicities are especially prominent in some of the new tropical areas being brought into cultivation. Also insects and pathogens must be recognized as limiting components of the environment. They impose limiting drains to attaining high efficiency in essential physiologic processes which dictate yield.

Cultural practice changes are useful if they improve the water, nutrient, and temperature environments which in turn increase biological efficiency and water use efficiency. Proposed cultural research is closely associated with physiological process research and relates to maximizing soil water retention and minimizing water loss. Successful cultural innovations depend heavily on fitting the right genotype to available resources within a given environment.

Plant breeding programs traditionally have been carried out under relatively optimal conditions to assure full expression of a genotype's potential with the assumption that the best genotypes grown under good conditions will also probably be the best under stress conditions. Reasonable evidence is available to suggest such is not necessarily true. Therefore, effort should be devoted to developing stress screening techniques for breeding programs.

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Developing these screening techniques requires a good basic understanding of environmental stress effects (including pathogens and insects) on photosynthetic and respiratory mechanisms, synthetic processes mediating metabolite utilization in all those essential processes. The overall objective is to better understand the nature of stress induced effects on essential physiological and developmental processes in order to (a) develop screening techniques for efficient genetic manipulation for diverse environments; (b) to improve cultural practices to conserve water and nutrients; and (c) to combine appropriate genetic selections with the best cultural practices to stabilize and/or improve biological and water use efficiencies. A current status report is followed by a more detailed breakdown of these broad objectives.

2. Findings and Accomplishments to Date

The following statement on current status (accomplishments in the past 5 years) is supplemented by pertinent comments inserted in the "time-phased detailed work plans" statement. Comments so inserted permit easier evaluation of investigations planned in view of past experiments and knowledge gained.

a. Physiology Investigations

(1) Environmentally induced grain yield losses can frequently best be analyzed in terms of the seed size and number components of yield. Usually yield losses result most directly from seed number losses. Therefore, a careful study of plant development stages as they relate to differentiation of a high seed number has been made. Investigations reveal (a) that the floret differentiation stage (about 2 weeks after panicle initiation) is extremely sensitive to stress; (b) that either photosynthesis or ability to partially assimilate developing grain in deference to other plant parts, or both, are primary limiting physiological processes; (c) that length of the grain filling period relates to yield capacity and is shortened drastically by stresses; and (d) that seed size seldom achieves more than 75% of its potential capacity under normal conditions. Much research is still needed on how to chemically and genetically manipulate physiological and dependent developmental processes which limit seed number and seed size. Environmental control facilities being constructed will aid these efforts greatly as well as efforts in (2) and (3) below.

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(2) Night temperature elevation 5°C above an approximate optimum reduces grain yield about 25 per cent. A 10°C elevation reduces yield about 50 per cent. Yield reductions are paralleled by seed number reductions. These growth chamber results were consistent in both temperate and cool tolerant sorghums tested. Similar testing needs to be done in the field.

These heavy yield reductions occurred at 22 and 27°C night temperatures which ordinarily would not be considered stress temperature levels (no water stress). Obviously temperature influences on yield (by reducing seed number and grain fill period) are more subtle and more pronounced than expected. Effort should be made to develop a method to temperature type sorghums in terms of tropical, temperate or cool adaptation.

(3) Screening Techniques

(a) A heat test measuring solute leakage (by electrical conductivity) from leaf discs is being tested on lines and populations. It appears to be useful in detecting superior heat tolerant genotypes. Several genotypes have been found and distributed to several developing countries.

(b) A similar test for measuring drought tolerance is being used.

c) Initial evaluation of a field heat test for developing grain has been completed on one genotype and shows grain to be most sensitive about 7 to 10 days after bloom. Ability to discriminate amongst genotypes will be evaluated the next two years.

(d) A cool temperature vigor screening test was conceived in 1975. The growth chamber test correlates positively with early spring field emergence. Utility of the vigor test is being further evaluated this year in Nebraska (3 locations), South Dakota, Minnesota, and Chapingo, Mexico. A student from Mexico is conducting the tests.

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(e) A field temperature typing test based on comparative development rates (heat units required to bloom) at 2 locations (cool and warm) at the same latitude is being tested and appears encouraging.

(f) A root screening technique has been developed and is under test.

(g) A precise method of determining grain physiological maturity has been developed permitting accurate determination of grain fill period length. A population has been evaluated and shown to possess considerable variability (37 to 53 days) for grain fill period. Selection is, therefore, possible.

(4) Essential Physiological Processes

(a) Heat tolerant sorghums can carry on photosynthesis at several degrees centigrade higher than a widely adapted sorghum hybrid. These photosynthesis results correlate positively with screening results from the leaf disc heat test.

(b) Respiration (and life in general metabolic pace) in a cool temperature sorghum is 25 per cent faster than in a temperate sorghum over a range from 10 to 30 C. The cool types reach maximum biological efficiency at a much lower temperature than the temperate types. Metabolic pace dictates biological efficiency, to a degree, and temperature dictates metabolic pace. These facts relate closely to the yield reductions reported in item 1 of this section and point to the import ance of properly fitting a genotype to an environment.

(c) Grain fill period correlates positively with yield. Variability checks within a random mated population ranged from 37 to 53 days indicating length of grain fill can be a selection criterion.

(d) Initial exploratory experiments show differential nutrient uptake and utilization inside the plant.

b. Plant Breeding and Genetics Investigations

These investigations have centered on population development, evaluation of breeding methods using the populations and development of breeder screening methods for both line and population improvement approaches.

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(1) The first random mating U.S. populations (NP3R was the first) using the male sterile gene were developed at Nebraska.

(2) Four of eight unselected populations, including NP3R, yielded 90 per cent or more of the average of RS 626 and RS 671 in 1975. NP3R and NP5R have maintained this average over a four-year period.

(3) The first cycle of improvement using family evaluation schemes in the random mating population NP3R gave gains of 4.4, 5.2, and 7.5 per cent respectively, for half-sib, full-sib, and S_1 progeny testing.

(4) S_1 progeny testing has been used successfully for evaluating and recombining greenbug resistant families resulting in the populations RP1R and RP2B recently released.

(5) Populations are currently being screened jointly by physiologists and breeders for heat tolerance, drought tolerance, cool tolerance, protein content, length of grain fill period, and narrow row spacing for solid stand culture.

G. PROJECT DESIGN AND EXPANDED OBJECTIVES

1. Objective 1. (Thirty-five per cent of total effort). Investigate the nature of plant stress avoidance and tolerance mechanisms, develop screening techniques and select genotypes which may contribute to the development of sorghums with increased heat, drought, and cold tolerance. Genotype adaptation to the prevailing environment is critical and has not received due attention.

   While the responses of plants to environmental stresses have been studied for centuries, little progress has been made in defining specific selection criteria for improved performance under stress conditions other than by empirical means. A knowledge of the mechanisms that contribute to stress resistance and the interactions that occur among the stresses should both shorten considerably the breeding process and result in greater stress resistant genotypes.

2. Objective 2. (Ten per cent of total effort). Determine the tillage and production methods best suited for producing high yields with low energy inputs under varying environmental conditions.

Improved technology and changing environmental and economic events generally result in a need to change conventional cultural practices. Results suggest that reduced tillage and bedding systems require less energy input while still maintaining or even increasing yields. Alterations in temperature and moisture regimes are the primary effects. These strongly influence uptake and utilization of mineral elements. Therefore, work proposed in that area is important.

Nitrogen is particularly limiting in many developing areas. Cultural practices such as crop rotation which include a grain legume may help alleviate the nitrogen problem and provide a high protein human food supplement at the same time. Altering light, temperature, and moisture regimes in a given climate may also best be fitted by specific morphological types. Such aspects as erect leaves and profuse root systems need to be more closely evaluated under different cultural conditions.

3. Objective 3. (Ten per cent of total effort). Investigate genodifferences and inheritance for mineral nutrient uptake and utilization efficiencies under mineral stresses and different cultural practices. Also study effects of mineral nutrients on heat, drought, and cold tolerances, other physiological properties, and plant quality and yield.

Improved and expanded crop production will require the continued use of fertilizer nutrients in environmentally stressed areas, disturbed, or marginal lands. Mineral nutrient scarcities and high costs may limit the amounts used, thus improved plant efficiency for mineral nutrient utilization becomes important, if not imperative, for continued high crop production. Many environmentally stressed, disturbed, or marginal lands have serious mineral element problems and will require plants that are more adapted to these inherent or imposed stress conditions. New cultural practices will likely alter mineral nutrient availabilities and utilization, thus imposing mineral nutrient problems on plants. Sometimes soils have more than adequate amounts of nutrients present in the soil, but these are not available for plant use. Problems of plant nutrition have generally been approached by fertilizer application or soil amendments, or forcing already developed lines into existing soil or cultural conditions, to correct or eliminate mineral nutrient problems. These approaches may not succeed or be economically practical in the future. One method to help solve or overcome some of these problems may be to capitalize on the ability of plants to differentially use mineral nutrients and to grow well under adverse or altered mineral conditions.

Studies have shown that wide diversities exist in plant genotypes for mineral nutrient uptake and use. Large differences in tolerances to toxic elements and wide adaptations to problem soils or cultural practices are also known. Taking advantage of these differences and breeding plants with greater efficiency for mineral uptake and use, better ability to use less available sources of nutrients, and greater adaptability to grow under adverse soil conditions or cultural practices have great potential. Mineral nutrients are also known to be associated with or to alter tolerances of plants to physiological properties, quality, and yield. These approaches hold reasonable promise of helping solve mineral nutrition problems as we acquire a better understanding of the bearing of mineral deficiencies or toxicities on essential physiological processes.

4. Objective 4. (Twenty-five percent of total effort). Develop and evaluate breeding techniques, especially recurrent selection procedures applied to artificially induced random mating populations. Apply these approaches to increase yield, insect and disease resistance, grain quality, mineral uptake efficiency, and stress tolerance.

   Several original unselected populations are known to yield 85-90% of some good adapted F_1 hybrids. Newer, more recently developed populations may exceed this and present relatively favorable take-off points for recurrent selection. Two cycles of family selection with NP3R have demonstrated significant yield gains each cycle with an indication that full-sib family testing and S_1 progeny testing are slightly more efficient than half-sib family testing. S_1 progeny testing and subsequent recombinations have been used successfully to develop greenbug resistant populations and to isolate and concentrate cornborer resistance. Mass selection has made only small gains in increasing grain protein; family schemes should be more successful. Population breeding is particularly advantageous for the DCs in that large amounts of material can be handled with low skilled labor, little hand crossing is required (except for making full-sib families), natural crossing in broad based populations should result in fortuitous genetic recombinations adapted to any environment, and line breeding can be initiated easily at any stage or cycle of the program.

5. Objective 5. (Ten per cent of total effect). Investigate the influence of pests and pathogens on essential physiological processes in sorghum and attempt to elucidate the plant reaction mechanisms operative in plant resistance and tolerance.

Two of the ways pests and pathogens effect economic losses are (1) by the production of toxins and (2) by draining off assimilates ordinarily used to produce grain. Resistant lines to some pests and pathogens are available for use to investigate the plant reaction mechanisms operative in plant resistance and tolerance. Identification of mechanisms and host-pest or -pathogen interactions may be advantageous for developing screening techniques and/or cultural changes needed to minimize economic loss.

6. Objective 6. (Ten per cent of total effort). Develop and strengthen linkages with developing country agencies, international and regional centers, and developed country institutions carrying out sorghum improvement programs aimed at DC needs.

TIME PHASED DETAILED WORK PLANS

1. Objective 1

a. Investigate genotype differences in response to water stress at different stages of development. Greenhouse and growth chamber pot studies indicate sorghum is the most sensitive to damage during about a 2 week period from stigma and stamen differentiation to bloom. Field results are needed where root systems are more normal to supplement greenhouse and chamber results.

(1) 1977. A number of genotypes will be planted in a rain-out shelter plot where water stress can be controlled.

(2) 1977. Attempt to devise a field screening technique at the Tryon, Nebraska Sandhills Station. Plants will be grown in the sandy soil (essentially hydroponics) and water withheld periodically to screen for drought resistance at various developmental stages. The Sandhills station is at an elevation where nights are quite cool. Arrangements for a similar test at a warmer site are being explored for 1978.

(3) 1978. Field selections will be grown hydroponically and stress controlled with polyethylene solutions. Specific studies will be made on the effects on photosynthesis, stomatal response, yield and yield components at different stages of stress.

(4) 1979. Continue study of stage of development where limited irrigation will be most effective.

(5) 1977, 78. Determine the degree of water stress which generally stops sorghum coleoptile elongation or growth and attempt to devise a screening tool to find genotypes capable of growth at high water stress.

(6) 1977. Considerable greenhouse work is in progress on evaluating the status of carbohydrate reserves in sorghum before grain filling and after grain filling commences under optimal and stress conditions. Use common sorghum genotypes to investigate carbohydrate (assimilate) accumulation and movement from stalks to other plant parts in normal soil volumes as water is withheld. Relate assimilate movement to root activity studies and grain filling problems mentioned in 4 below.

(7) 1977. Study carbohydrate formation, transformations, and patterns of accumulation in stalks of lodging resistant and susceptible types.

1978. Based on first year's interpretations, continue the study similarly and add substudies as necessary depending on results from 1977.

1979. Continue as in 1978.

b. Investigate the effects of both prolonged and short term high temperature stress on photosynthesis, respiration, and subsequent growth and seed development.

(1) 1977. Short term stress will be imposed in growth chamber and greenhouse experiments. Photosynthesis and respiration will be measured before and after the stress.

(2) 1978. Effects of longer term stress will be studied by use of rain-out shelters.

(3) 1979. Screen for stability of photosynthesis to stress.

(4) 1977, 1978. Screen for ability for cell elongation (growth) under high temperatures.

(5) 1977. Initial results of a field heat screening test for sensitivity to heat in developing grain warrant further evaluation. Grain appears most sensitive to damage about 7 to 10 days after bloom. Comparisons will be made on sensitivity to damage using the head heat test and the leaf conductivity method.

1978. Comparative tests for a second field season are anticipated with a test possibly also being conducted at ICRISAT if 1977 results are encouraging.

c. Measure and select for genotypes with high water use efficiency (unit dry matter or grain produced per unit water consumed).

(1) 1977. Develop technique of selection in growth chamber and greenhouse studies.

(2) 1978. Screen large numbers of plants by growth in hydroponic culture.

(3) 1979. Test selections under field conditions.

d. Screen genotypes for possible differences in root development, size, length and top:root ratios.

(1) 1977. Refine technique of growing plants in slender cylinders for root observations and measurements.

(2) 1978. Screen and select plants with large root systems.

(3) 1979. Test selections in the field.

(4) 1978. Attempt to see how root volume and bulk relates to root activity at different developmental stages. Greenhouse studies have shown that a large root of one genotype was not necessarily a more active root than a smaller root from another genotype when grain filling began. Different genotypes partition assimilates to roots and expanding panicles differently when stress occurs. Investigate comparative root function in larger soil volumes and hydroponics using ^{14}C tracer to see if results agree with greenhouse pot experiments. These investigations relate closely to 2e above.

(5) 1979. Continue assimilate partitioning experiments and attempt to influence root function with different chemicals especially during grain filling as it relates to length of the grain filling period and grain yield.

e. Investigate effects of high temperatures on nitrate reductase.

(1) 1977. Make limited measurements on plants at about 3 weeks of age after receiving one heat stress treatment.

(2) 1978. Characterize growth habit at prolonged high temperature exposure. Start screening genotypes for stability of nitrate reductase to high temperatures.

(3) Continue screening.

f. Screen populations for high cellular tolerance to heat and desiccation by the electrical conductivity method with leaf discs.

(1) 1977. Partial screening of one or two populations. Screen random selections of a base population random mated in Nebraska and in Arizona to see if heat tolerance is greater in the Arizona population.

1978. Screen selections from 1977. Start screening other populations.

1979. Use selections for making hybrids. Continue testing and selecting.

(2) 1977. Attempt to correlate the leaf disc conductivity test with the head heat test in 2e.

g. Investigate specific mechanisms for plant hardening to drought and heat stress.

(1) 1977. Measures changes in osmotic potentials or a possible hardening mechanism when exposed to stress.

(2) 1978. Investigate changes in lipids associated with stress conditions.

(3) 1979. Continue studies based on information obtained FYs 1977 and 78.

h. Evaluate temperature influence on biological efficiency and water use efficiency.

(1) 1978, 79. Placing the right genotype in the right temperature environment appears critical based on growth room experiments. About a 25 per cent yield loss results from elevating night temperature 5°C above optimal for temperate and cool tolerant genotypes. A 10°C rise reduces yield 50 per cent or more. Test the effect of elevated temperatures on yield of tropical genotypes suitable for low altitude subtropical areas. Controlled environment facilities under construction will be used for this work.

(2) 1977, 1978, 1979. (a) Cool temperature selections (as for high altitudes in Ethiopia, etc.) have been shown to have about 25 per cent faster metabolic screening techniques by using the same latitude but different altitudes.

(b) Continue testing a combination field-laboratory germination early growth test to evaluate cool tolerance.

(c) Heat test cool tolerant materials available since the high altitude cool tropical areas frequently have hot days.

(d) Characterize metabolic peculiarities of existing cool temperature materials to try to determine mechanisms responsible for cool tolerance. This may help devise better screening procedures for use at ICRISAT, other international centers and in DCs.

(e) Exchange cool tolerant germplasm with interested parties in cooperating institutions.

(3) 1978, 1979. Determine the influence of temperature on water use efficiency. Two factors are involved. First, elevated temperatures cause greater transpiration losses which will be quantified by using environmental control facilities being constructed under the current contract. Second, biological efficiency decreases beyond a certain optimal temperature level peculiar to the adaptation of the genotype. The twofold effects of temperature on water use efficiency will be quantified in order to determine (a) how critical appropriate adaptation is for an area (i.e., what kinds of gains can be expected from proper adaptation) and (b) what the range of reaction among genotypes might be in order to make a reasonable guess on whether or not differences can be manipulated genetically to advantage.

i. Initiate both field and laboratory heat x water stress interaction studies all 3 years as facility construction permits.

2. <u>Objective 2</u>

a. Compare minimum till bedding with normal surface planting utilizing corn and sorghum for comparative purposes.

1977. Complete a 3 year sorghum test and the second year of a corn test.

1978. Complete the third year of a corn test and summarize all data for publication.

b. Study normal and minimal tillage alternatives coupled with different planting methods under dryland conditions.

1977. Continue yield comparisons of several minimum till operations with normal surface cultivation and planting.

1978. Partially monitor water status in addition to yield in selected treatments.

1979. Continue 1978 and 1979 experiments, summarize, and interpret data.

c. Compare sorghum yields in a grain legume (soybean) rotation to conventionally fertilized sorghum with respect to nitrogen utilization.

1977. Continue the third cycle of a five-year study to determine and compare soil moisture and nitrogen status along with grain yield.

1978. If yield and nitrogen utilization results in the soybean-sorghum rotation appear favorable, trials with other grain legumes should be initiated in selected DCs.

1979. Continue and terminate the experiment. Interpret and publish the results.

d. Determine the influence of erect and normal leaf type sorghums in different stand geometries on light interception and grain yield. Results thus far indicate a linear relationship between photosynthetically active radiation and grain yield.

1977. Conclude an investigation using erect leaf hybrids in different row spacings and spacings within rows.

Objective 3

a. Evaluate and screen sorghum lines and populations for differential responses to mineral elements and Al tolerance in soils and nutrient solutions.

1977. Continue screening and refining screening methods for differential responses to P and Fe by growing plants on problem soils low in P and Fe.

Initiate screening of sorghum for differential responses to Zn and Mg in low Zn and Mg soils.

1978. Initiate screening sorghum for differential Al tolerance in nutrient solutions (bulk tanks).

Initiate screening sorghum for P and Fe in nutrient solutions (bulk tanks) and compare soil results in order to evaluate methods and to accelerate and improve methods for screening for mineral nutrient efficiency. (This methodology can and will be used for testing differential responses of plants to any element.)

1979. Continue to screen lines and improve on screening methods.

b. Investigate the inheritance of mineral nutrient utilization and evaluate these traits when incorporated into hybrids.

1977. Screen lines for mineral efficiency as given in Objective 1 and make some crosses of plants that show differences in P and Fe.

1978. Make crosses of plants showing differential responses to minerals and test S_1's made previously.

1979. Continue making crosses and testing for the inheritance of mineral nutrient utilization traits. Test some lines on soils known to have mineral problems.

c. Investigate mineral element relationships and differential responses of genotypes to heat, drought, and cold tolerances, grain protein, yield, and certain physiological and quality factors.

1977. Continue field studies to relate "mineral use"[a] especially N, P, and K) by sorghum genotypes showing different grain protein contents.

Initiate greenhouse studies on "mineral use" by sorghum genotypes showing differential heat and drought tolerance.

1978. Initiate more detailed studies on relationships of mineral nutrients and their distribution in several sorghum lines showing wide variations in grain protein.

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[a] The term "mineral use" means mineral nutrient uptake, distribution, accumulation, and utilization and in some cases metabolism.

Continue "mineral use" studies with sorghum showing differential heat and drought tolerance.

Initiate growth room studies on "mineral use" by sorghum genotypes showing differential cold tolerance.

1979. Continue detailed studies on significant findings of mineral nutrient relationships for lines showing variations in grain protein.

Continue studies on "mineral use" by sorghum showing differential heat, drought and cold tolerance and initiate studies on the effects of heat, drought, and cold stress on "mineral use" by sorghum lines.

Initiate studies on effects of minerals and their use on respiration, photosynthesis, and other physiological processes and on certain quality factors.

d. Evaluate sorghum genotypes for "mineral use" when grown under different cultural practices.

1977. Continue field studies on "mineral use" of sorghum grown under different mulch densities.

1978. Follow up on significant findings of mulch density effects on "mineral use".

Initiate studies on effects of different tillage systems, planting dates, and maturity date on "mineral use".

1979. Continue studies on tillage and agronomic practices effects on "mineral use".

Follow up on any significant findings from mulching, tillage, and other practices on "mineral use".

e. Evaluate sorghum genotypes for root growth in hydroponics and study relationships of "mineral use" in roots and various top parts.

1977. Continue greenhouse studies of sorghum in hydroponicson "mineral use" by and mineral element effects on root, leaf, stalk, panicle, and grain growth and yield.

1978. Follow up on significant findings of mineral effects on roots and top parts and relationships of minerals to the growth processes of sorghum.

Initiate studies on the effects of temperature and osmotic concentrations (drought stress) on roots and top part growth and yield.

1979. Continue studies on the effects of mineral elements on roots and top part growth and yield and relate these effects to other physiological processes (respiration, photosynthesis, translocation, and distribution of metabolites).

4. Objective 4

a. Yield test base populations.

1977. Test populations NP1BR through NP18B for yield potential.

1978. Test improved populations of interest with certain older populations as checks.

1979. Same as 1978; add new populations.

b. Continue recurrent family selection study.

1977. Select third cycle S_1's in NP3R and NP5R and make up third cycle half-sib and full-sib families in NP3R.

1978. Conduct third cycle family yield trials.

1979. Same as 1978 or recombine selections for fourth cycle.

c. Evaluate families from NP3R brown unselected under dryland and irrigation for 5 years.

1977. Select S_1's from both subpopulations.

1978. Yield test S_1 families.

1979. Repeat yield test or recombine selected S_1's from each subpopulation.

d. Develop new high protein populations carrying ms_3.

1977. Select third cycle S_1's from NP7BR and first cycle S_1's from NP17R and NP18B.

1978. Yield test and measure protein in S_1 families.

1979. Composite and random mate selected families.

e. Continue development of drought resistant population.

1977. Make third cycle selections from NP9BR in Arizona under limited water conditions.

1978. Recombine selected S_1's in Nebraska.

1979. Increase and release.

f. Continue development of high quality yellow endosperm populations.

1977. Screen S_1's from NP12B and NP13R in Kansas for MDMV.

1978. Recombine selected S_1's.

1979. Increase and release.

g. Develop new high quality greenbug resistant populations.

1977. Cross NP12B x NP14B and NP13R x NP15R.

1978. Random mate and screen for greenbug resistance and grain quality.

1979. Recombine selected families.

h. Continue development of corn borer resistant population.

1977. Recombine resistant S_1's from second cycle screening of NP11BR in Iowa.

1978. Select new S_1's.

1979. Screen third cycle material in Iowa.

i. Develop population with multiple insect resistance.

1977. Screen nontesta greenbug resistant S_1's from NP14B in Iowa for corn borers.

1978. Recombine selected S_1's.

1979. Selected new S_1's resistant to both insects.

j. Evaluate population bred for cold tolerance.

1977. Select S_1's from NP16BR.

1978. Screen in laboratory and field.

1979. Recombine selected S_1's.

k. Develop populations with improved mineral efficiency (e.g., P).

1977. Perfect techniques for screening large numbers of families.

1978. Screen S_1 progenies from greenbug resistant and/or yellow endosperm populations for mineral efficiency.

1979. Recombine selected families.

5. Objective 5

a. Greenbug investigations. Studies under way have given some information on content of honeydew produced by greenbug infested plants. Studies involve biological reactions in sorghum to extracts from both honeydew and greenbugs. It is desirable to discover the mechanisms of resistance since greenbug biotype changes will in time undoubtedly render current resistance sources unuseable.

1977. Conduct experiments to crudely estimate the amount of assimilate drain caused by greenbug infections. Such an estimate may be useful in determining whether assimilate drain is likely to account for some portion of greenbug damage or whether a toxin may be the primary problem.

1977. Continue the study of various sorghum biological reactions to greenbug and honeydew extract compounds which may be toxins.

1978. Continue mechanism of resistance and/or tolerance research based on 1977 investigation results.

b. Develop simple, rapid, and reliable methods for selecting disease resistant genotypes by using toxic metabolites produced by fungal and bacterial pathogens.

1977. Screen sorghum pathogens for those which in culture synthesize toxic metabolites that reproduce a portion or the complete disease symptoms. (Present evidence indicates that such toxins are produced by Periconia circinata (root/crown rot), Helminthosporium turcicum (leaf blight), Fusarium moniliforme (root/stalk rot), and Pseudomonas syringae (bacterial leaf spot).)

1978. Develop effective procedures for obtaining relatively purified toxin preparations and for bioassaying the toxins.

1979. Continue developing toxin preparation procedures and hopefully screen a large number of standard genotypes as well as experimental material for their response to toxin and correlate with their disease reaction in the greenhouse and field, and select potential sources of resistance.

c. Determine the critical physiological and biochemical effects of environmental stresses that predispose sorghum to diseases and the consequential effects on activation and growth of fungal pathogens.

1977. Investigate the ability of soil borne pathogens (e.g. Fusarium moniliforme and Macrophomina phaseoli) to survive and grow under a wide range of water potentials and temperatures as these conditions relate to stalk rot and charcoal rot.

1978, 1979. Examine leaf and stalk tissue of heat and drought stressed plants for accumulation of amino acids (e.g. proline) and for evolution of ethylene; determine the effect of these responses on germination of spores and sclerotia and on growth rate of the fungal pathogens.

d. Determine the qualitative and quantitative effects of foliar, root, and stalk diseases on physiological efficiency of the developing sorghum plant.

1977. Measure the effect of foliar diseases on stomatal response of, and CO_2 fixation by, diseased tissue.

1978. Measure the effect of root rots on foliar stomatal response and translocation rates in diseased plants.

1979. Relate the magnitude of these effects to the amount of disease and consequential effect on dry matter accumulation and grain yield.

e. Screen random mated populations for disease reaction and attempt to detect and define the drift in patterns of resistance/susceptibility to pathogens.

1977, 78. Inoculate random mated populations under controlled conditions in the greenhouse with sorghum pathogens (e.g. Sphacelotheca reiliana, races 1 and 3 (head smut), H. turcicum (leaf blight), Gloeocercospora sorghi (Zonate leaf spot), Ramulispora sorghi (sooty stripe), etc) and record frequency and intensity of disease within the populations as their development progresses.

1979. Continue the above approach and establish the effect of the random mating process on the change in disease resistance and susceptibility.

I. GENERAL APPRAISAL

This project is rated by TA/AGR as being of high priority, and its extension for three years has been included in TA budget plans and congressional presentations. The present proposal is sound in design and the cost estimates are appropriate to the proposed level of effort.

The ongoing project was reviewed by a team from AID/W and three leading sorghum research specialists from the commercial industry in September 1975. Also present were two leading sorghum experts from international centers. In the review, it was concluded that the University of Nebraska was the world leader in research on sorghum physiology, and the experts from the international centers made particularly strong positive statements regarding the importance of the Nebraska research to their development programs aimed directly at DC problems.

The strength of the Nebraska program was further emphasized in 1976 when the Nebraska legislature voted, and the Regents of the University accepted, a special budgetary supplement for support of the recognized "Center of Excellence" in sorghum physiology, led by the Principal Investigator of the AID funded project. This financial support insures the continuation and expansion of the basic research program, to which the AID funded project is joined for support of research directed toward sorghum improvement for the developing countries.

Progress during the present contract, to date, has been excellent, and it is anticipated that all contract objectives will have been met at the conclusion of the alloted time. The extension will permit further development of basic research in stress physiology and the control of yield, and should provide a sound basis for applying the information obtained to practical plant breeding programs with a focus on the needs of sorghum growing DCs.

J. ENVIRONMENTAL CONSIDERATIONS

No adverse environmental problems are anticipated from the proposed renewal of this research project, nor from the adoption of the improved germplasm and cultural practices. The main thrust of this project is the elucidation and application of physiological principles to the improvement of sorghum for DCs.

This activity is not 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 Threshold Decision is negative, constituting a Negative Determination, 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.

K. CONTRACT BUDGET AND LIFE-OF-PROJECT COST ESTIMATES

INPUTS	FY 77 W/M	FY 77 $	FY 78 W/M	FY 78 $	FY 79 $	TOTAL LIFE OF PROJECT COSTS $
1. Salaries	232*	61,000	254	84,000	90,000	235,000
2. Fringe Benefits	62	2,800	84	3,000	3,500	9,300
3. Indirect Costs (64.3%)	62	39,200	84	54,000	57,500	150,700
4. International Travel		7,000		8,000	8,000	23,000
5. Domestic Travel		1,000		1,000	1,000	3,000
6. Equipment		29,000		10,000	-	39,000
7. Materials and Supplies		20,000		25,000	25,000	70,000
8. Other Direct Costs**		20,000		23,000	23,000	66,000
9. Publications		2,000		3,000	3,000	8,000
Totals by Inputs		$182,000		$211,000	$211,000	$604,000

OUTPUTS					
1. Stress Physiology Studies		63,700		73,850	73.850	211,400
2. Production Practices		18,200		21,100	21,100	60,400
3. Mineral Nutrient Studies		18,200		21,100	21.100	60,400
4. Breeding Techniques and Studies		45,500		52,750	52,750	151,000
5. Pest and Pathogen Reaction Studies		18,200		21,100	21,100	60,400
6. Linkages and Utilization		18,200		21,100	21,100	60,400
Totals by Outputs		$182,000		$211,000	$211,000	$604,000

* Includes 98 W/M professional and 72 W/M subprofessional and clerical noncontract funded
** Include winter nursery costs

AID 1020-28 (1-72)

PROJECT DESIGN SUMMARY
LOGICAL FRAMEWORK

Life of Project:
From FY 77 to FY 80
Total U.S. Funding
Date Prepared: 6/11/76

Project Title & Number: Physiology of Yield and Stress Reaction

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 major food crops in DCs. 2. Improvement in nutritional quality of major DC food crops.	1. Official production and population statistics (FAO, Foreign Agricultural Service estimates). 2. Nutritional quality surveys in DCs.	Assumptions for achieving goal targets: 1. DCs will actively attempt to expand food crop production. 2. Nutritional quality can be improved without major constraints on yield.
Project Purpose: To make available to DCs high yielding, nutritious varieties of sorghum with multiple resistance to moisture and temperature stresses, diseases and insects, together with improved practices for their cultivation.	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 sorghum effectively assumed by DC agencies and international institutions and linked by communications network.	1. Publication and reports of LDC governmental agencies; on-site inspections of seed supply. 2. On-site inspection and review by AID/W personnel and consultants.	Assumptions for achieving purpose: 1. Solutions can be found to major constraints. 2. Agriculture extension services are able and willing to promote proven p[illegible]es. 3. DC research [illegible]tions develop adequate capabilities.
Outputs: 1. Determination of the nature of stress tolerance and avoidance, and other physiological traits useful in plant breeding. 2. Development of breeding populations useful for DCs. 3. Establishment of effective linkages with internation and DC agencies.	Magnitude of Outputs: 1. Not quantifiable. 2. At least 2 populations per agro-climatic region. 3. Linkages with 2 international centers and at least 10 DC institutions.	1. Reports by contractor. 2. Reports by contractor, communications and reports from Missions, international centers, and DC institutions 3. Contractor reports, communications from DC institutions and international centers.	Assumptions for achieving outputs: 1. Research is successful. 2. Research is successful and DCs are interested in material. 3. Cooperation by international centers and DC institutions.
Inputs: 1. AID/W provides financial support and project guidance. 2. Contractor provides qualified personnel and backstopping facilities. 3. Participating personnel and cooperation provided by 1) DCs, 2) USAIDs, and 3) international organizations.	Implementation Target (Type and Quantity) 1. AID/W funding at approximately $200,000/year. 2. 230-250 worker/months/year technical personnel; adequate laboratory facilities; 5 or more acres field research area. 3. Not directly quantifiable.	1. AID/W records. 2. Contractor reports, on-site inspections. 3. USAID reports, on-site verification.	Assumptions for providing inputs: 1. AID/W funding will be available on schedule and in quantity agreed upon. 2. Contractor will have necessary qualified personnel; university facilities will be available to project. 3. International organizations, USAIDs, and DCs will have personnel and resources to support this activity.

Attachment A

WORK PLANS

1. Work Plan for the University of Puerto Rico

   a. Continuation of the sorghum conversion program started by the USDA in cooperation with Texas A&M in 1963.

Concentration will be on that component of the work which deals with evaluation and screening for tropical and subtropical conditions, i.e., examining that part of the germplasm which would normally be discarded by U.S. breeders. This project involves the transfer of germplasm from the tall exotic tropical, day-length sensitive varieties into day-length insensitive, short stalked types. The main objective of the project is to make available to the sorghum breeders in the tropical and subtropical zones a vast amount of germplasm which combines the U.S. germplasm with that from tropical varieties. A by-product of this work will be to feed back to the breeders in the tropics, populations and cultivars which in many instances can be directly released as improved varieties or be used in their breeding programs.

Puerto Rico is ideally located (18° north latitude) as the site of the conversion program. The day-length between September and February is short enough for the early heading of exotic varieties and the temperature is favorable for optimum plant growth throughout the year.

In 1971-72 twenty-six new varieties were added to the conversion program which brought the total number of varieties up to 1,085. Seed of 63 converted lines were released in 1969 and the conversion of 134 others has been completed in 1972. When a release is made for international breeding programs it is accompanied by a complete description of its morphological characters as well as what is known regarding its reaction to numerous diseases and insects.

Work is being initiated to combine similar converted lines into special populations, thereby greatly reducing the numbers which breeders will have to handle to satisfy the progressively changing needs of breeders worldwide. Up-to-date circulars will continue to be prepared for worldwide distribution describing the materials currently available in the conversion program as well as the population program and inviting breeders to have their names placed on a mailing list. Each year a list of available breeding materials will be distributed and seed will be sent upon request. Because of the lack of storage facilities in Puerto Rico, seed from the conversion program is held at Lubbock, Texas for distribution. As storage facilities are developed at the Federal Station seed will be maintained and sent only from Puerto Rico.

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b. Continuation of the development of sorghum populations.

Nearly all sorghum varieties in the U.S. have been [illegible] crosses between kafirs and milos and to a limited extent [illegible] the feteritas and [illegible]. From each combination [illegible] good varieties and lines with a minimum of effort. [illegible] groups must have germplasm which could make a contribution to the development of new varieties, their use has been limited because progeny from their crosses has not been productive.

The development of populations offers an efficient breeding tool whereby the germplasm from a number of sources can be combined with a minimum effort and from which genotypes adapted to a number of environments can be selected. The value of such a scheme has been demonstrated by the corn breeders. Since sorghum is mostly self-pollinating (90%), genetic sterility is used to promote cross-breeding.

As an example, a population is being developed in Puerto Rico specifically for the use of breeders in the tropics. Forty-two elite west African varieties have been crossed on to a genetic sterile developed in northern Nigeria. The second generation from these crosses is being planted this fall in a plot under short days in order that all will head simultaneously. A fourth of the heads will be male sterile and will be tagged and pollinated at random by all of the fertile plants in the 42 crosses. The seed from these sterile plants will be harvested and bulked and a second planting can be made in January when the steriles in this planting will again be tagged and harvested.

After three cycles of random mating, three to five acres will be planted from which desirable fertile plants will be selected. After adequate screening (one to four years depending on the complexity of hereditary factors), this population will be made available to breeders in the tropics and could also be used in the temperate zones. Since this population includes germplasm which will give plants with a range in maturity, plant height, disease and insect resistance, tolerance to striga, grain quality, etc., breeders should be able to easily isolate varieties adapted to a number of environments.

In 1971/72 twelve different breeding populations from Kansas, Nebraska, and Puerto Rico were in various stages of development at the Federal Station. In the cooperative work with the States it is possible to grow two crops from September to June and a third in the States, completing three cycles of random mating per year. Without the facilities available in Puerto Rico population breeding would take three times longer to do the same job in the United States.

After three cycles of random mating, a year will be required to select elite germplasm by recurrent selection. These selections can then be put through a second series of random matings to recombine the germplasm.

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c. Maintaining and increasing the seed of the World Sorghum Collection.

[illegible] there are over 16,000 items in the world sorghum collection. The Federal Government [illegible] responsibility [illegible] introducing these collections into the U.S. and maintaining seed for storage at the Federal Station and the National Seed Storage Laboratory, Fort Collins, Colorado. This is an expensive operation but essential if the world germplasm is to be maintained in the Western Hemisphere. In addition to planting and cultivating, all seed must be from bagged heads to be sure of its purity. Each item is examined in the field and a number of morphological characters described as well as their reaction to rust and other diseases. At present no agency has the responsibility of assembling and cataloging the data being collected at a number of places in the world. It is expected that this will be done by ICRISAT at Hyderabad, India, to eventually accumulate in Puerto Rico a "bank" of elite breeding stocks from which breeders in the Western Hemisphere may draw.

It is expected that about $20,000 will be required to speed up the work of increasing seed and collecting information on the world collection. Nurseries are to be planted near Ponce where the rainfall during November-April is less than 10 inches and the crop is dependent upon irrigation. This will assure getting the best quality of seed available. The rainfall on the Federal Experiment Station and the University's Experiment Station at Isabela is considerably higher, which promotes fungus growth on the seed. The operation at Ponce will require a technical assistant being posted there two or three months to supervise the work.

To date there is a backlog of over 2,000 items to grow and it is expected that a large number of additional items will be received as collection is resumed under ICRISAT. Although the new collections will be grown at Hyderabad, they must also be grown at other locations to identify their reaction to diseases and insects.

d. Development of ways to produce seed of sorghum hybrids.

(1) Sorghum breeders are concerned over what would happen to the hybrid sorghum industry if a disease should develop which is associated with the milo-type sterile cytoplasm such as the relationship of the southern corn blight and T-sterile cytoplasm in corn.

Texas workers plan to make reciprocal crosses between the 63 converted lines and to study the segregating population for other possible sources of sterility factors. Concurrently the same crosses will be attempted between the exotic parents at Puerto Rico.

(2) A second source of sterile cytoplasm is available from crosses with the variety 9E from Ghana. Sterility is expressed in non-dehiscent anthers. This type would be difficult to use commercially because of the problem of distinguishing normal and non-dehiscent anthers,

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but could be used in an emergency. The feteritas serve as restorers and breeding will be continued to develop a group of other fertility-restorer lines.

2. Work Plan for the University of Nebraska

a. Incorporate yellow endosperm lines into a Nebraska-developed random-mated population.

Interest in the yellow endosperm lines, which are being used in this phase of the improvement work, is attributed to (1) higher feed value, (2) vigorous root systems (possibly the result of a stress avoidance mechanism), (3) good stomatal control of loss of water, and (4) large seed size. Evidence from other research stations suggests that yellow endosperm types are nutritionally superior to the red and brown grained types because of their Vitamin A for human consumption and lack of tannin.

b. Develop suitable selection techniques and breeding methods for use with random-mating populations destined for the tropical environments.

Particular emphasis will be placed on determining what the correlation is between length of the grain filling period and the yield of grain.

c. Evaluate the utility of limited till bedding practices for sorghum on upland soils, and later on wet soils.

Use of such practices on wet soils may produce better stands and growing conditions as well as reduce the number of tillage operations required and consequently expense. Hopefully, water loss will be lessened as the tillage is decreased. When soil is wet, sorghum must be planted on beds so that root aeration may be improved.

d. Develop screening techniques applicable to random-mating population for stress tolerance and stress avoidance mechanisms.

e. Investigate survival mechanism operative in environmentally stressed plants in the more marginal crop production areas of the tropics.

f. Develop screening methods for early season cool tolerance growth capability. Germplasm development is being coordinated with CIMMYT.

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

h. Publication of results in an Annual Report and in appropriate Journals or circulars.

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3. Work Plan for Texas A&M University

a. Preliminary Disease Screening.

Approximately 1,000 previously non-screened exotic sorghum introductions and partially converted exotic lines will be evaluated each year for downy mildew, head smut and foliage diseases in Beeville area nurseries. Also screened in these nurseries will be about 2,000 fourth and fifth generation breeding lines derived by crossing disease-resistant converted and partially converted lines with U.S. elite lines. Partially converted and converted and selected exotic sorghum lines will be evaluated for maize dwarf mosaic (MDM) and lodging resistance (root, crown and stalk rot) at Lubbock, Texas. Exotic sorghums with high levels of disease resistance will become candidates for conversion.

b. All Disease Nursery (ADN).

The ADN, composed primarily of partially converted and converted sorghums with promising resistance to two or more major sorghum diseases, is grown in several areas,at no cost to the project, to provide maximum exposure to a wide variety of diseases. In 1972 the ADN contained 70 entries; the 12 proposed Texas-USDA cooperative locations for the ADN are:

Location	Principal Diseases
Wharton, Texas	MDM
Berclair, Texas	Head smut
Berclair, Texas	Downy mildew
Experiment, Georgia	Anthracnose, rough spot
Meridian, Mississippi	Foliage diseases
Verona, Mississippi	Head molds
College Station, Texas	Misc. diseases (artificial inoculations)
Friona, Texas	Periconia root rot
Lubbock, Texas (Early)	Charcoal rot, lodging, rust
Lubbock, Texas (Late)	Charcoal rot, lodging
Lubbock, Texas	MDM
Springlake, Texas	Rust, lodging (greenbug and mite associated)

c. International Disease Nursery (IDN).

The IDN is composed of 30 sorghum entries selected from ADN which have broad-based disease resistance and must be further challenged and evaluated in other areas of the world. Both the ADN and the IDN will be updated as new and improved lines or synthetic populations become available. The IDN was grown in eighteen locations in 1972; however, it is anticipated that only a few key locations will be necessary in the future. Many cooperators request seed of this nursery for their own observations -- disease evaluations may or may not be made to our specifications under such conditions. Travel to visiting nurseries will be confined to key locations.

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The following were nursery locations in 1972; those with asterisks are key nursery sites proposed for 1973. Those with double asterisk will be directly coordinated with the international research centers.

Location	Proposed Number of Nurseries	Diseases Evaluated
Argentina *	2	downy mildew, head smut, anthracnose, MDM
Brazil	1	misc.
Colombia **	1	misc., MDM
Ethiopia		downy mildew, head smut
Egypt *		downy mildew, head smut
Hawaii*	1	rust, bact. stripe, foliage diseases
India *	3	misc.
Bergamo, Italy (EUCARPIA) *	5	misc., MDM
Poza Rica, Mexico**	1	rust, bact. leaf spot, Helminthosporium
Tampico, Mexico**	2	rust, Helminthosporium, grey leaf spot
Nigeria**	1	downy mildew, smuts, striga
Panama	1	rust, bact. leaf spot, Helminthosporium
Puerto Rico*	1	rust
Weslaco, Texas *	1	misc.
Houma, Louisiana *	1	rust
Venezuela*	2	anthracnose
Uganda (Serere)**	1	downy mildew, smuts, striga

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Although not specifically designed for insect studies, when present and severe, observations will be recorded for resistance to limiting insects as shoot fly, green bug, midge, and stalk borers.

d. Lodging nurseries.

Because of the complex interaction among plant characters, pathogens and environment, it is planned to superimpose (by both natural and artificial inoculations) root, crown and stalk-rotting pathogens in the sorghum lodging nurseries. Potentially superior lines are further evaluated as hybrids. In 1972, the Statewide Lodging Test (SLT), composed of 25 lines with superior resistance to lodging, was grown at 19 locations; probably as many nurseries will be grown again in 1973.

Several sites are necessary in order to insure differentiating levels in such diseases as: Periconia root rot (2 races seem apparent); anthracnose red rot; charcoal rot, and Fusarium stalk and crown rot. Notes are also taken on other types of lodging such as weakneck, stalk breakage following a freeze, and root lodging. Entries for evaluation in the SLT will be obtained from yellow endosperm breeding lines and partially converted exotic sorghums that have a high degree of resistance to natural lodging and charcoal rot at Lubbock. Preliminary lodging tests are grown at Lubbock to screen new materials for inclusion in the SLT.

e. Population Breeding Approach.

(1) Diseases: Three populations (multiple disease-resistant, downy mildew-resistant and a broad base population) are currently being developed. These populations will undergo two generations of random mating in Puerto Rico during the winter of 1972-73 and probably one additional random mating at Lubbock during the summer of 1973. The first populations should be available for distribution by 1974. Because of the many diseases involved, it is anticipated that the random-mating population approach will materially simplify the incorporation and maintenance of specific sources of resistance into existing germplasm pools, as well as enhance the chances of selecting multiple disease-resistant types. For example, very few of the lodging-resistant lines have good resistance to downy mildew and head smut; similarly, some of the multiple disease-resistant sorghums are susceptible to grey leaf spot and Helminthosporium blight.

(2) Insect Resistance: Sorghum lines resistant to the greenbug will be incorporated into a random-mating, multiple disease-resistant population. The population will undergo two generations of random mating in Puerto Rico during the winter of 1972-1973 and one during the summer at Lubbock. These populations will then be available for selection under conditions of natural greenbug infestation at or near Lubbock.

Partially converted and converted exotic lines that are resistant to insects native to their place of origin will also be integrated into random-mating, multiple disease-resistant populations in 1973. Insects

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considered here are the shoot fly, stalk borers and midge. These populations will then be random-mated for eventual distribution throughout the world for use in sorghum improvement.

f. Resistance to Midge.

A U.S.-financed program for evaluating widely different sorghums for resistance to sorghum midge is headquartered in the Lubbock area. Evaluation studies are currently underway in all areas of the state where midge populations are normally high. Since sorghum midge causes severe losses in nearly all sorghum growing regions of the world and there are few known sources of resistance, this project has a high priority. The program will initially emphasize methods for screening and detecting resistance. Because of the nature of the pest, such mechanisms of resistance as antibiosis may have been overlooked in the past. Methods for determining mechanisms of resistance, and the value of each type will be evaluated.

Initial experiments will involve artificial inoculations of varying midge numbers, which will provide information on the degrees of susceptibility, influence of midge numbers, and effect of the plant on midge development. Sources of midge resistance, like those of greenbug resistance, which meet height and maturity class qualifications, will be included in the random-mating population. Advancements resulting from this work will be incorporated into breeding programs in Puerto Rico for use in the tropics.

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