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ANNUAL REPORT

ON

DEVELOPMENT OF IMPROVED HIGH-YIELDING SORGHUM CULTIVARS

February 12, 1975 - February 11, 1976

REPORT NO. 2

prepared by

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Contract AID/ta-c-1068

Submitted to:

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REPORT SUMMARY

A. 1. Project Title and Contract Number: Development of Improved High-Yielding Sorghum Cultivars. Project No. 931-17-130-575. Contract AID/ta-c-1068.

2. Principal Investigator, Contractor and Mailing Address: Jerry D. Eastin, 102 Kiesselbach Crops Research Laboratory, University of Nebraska, Lincoln, Nebraska 68583.

3. Contract Period (as amended): from February 12, 1974 to February 11, 1977.

4. Period covered by Report: from Febraury 12, 1975 to February 11, 1976.

5. Total A.I.D. funding of contract to date: $295,000.

6. Total expenditures and obligations through previous contract year: $49,720.12.

7. Total expenditures and obligations for current year: $48,723.60 spent plus $670.43 estimated encumberance.

8. Estimated expenditures for next contract year: $195,885.85.

B. Narrative Summary of Accomplishments and Utilization. Grain sorghum is a major food source in many LDC's. Hence the yield per acre of a quality energy and protein source is critical. Climate in the LDC's of interest is usually characterized by environmental extremes (temperature and water) as is often the case in the Great Plains of the U.S.A. The twin problems of maximizing yield and, perhaps more important, of stabilizing yield over the years is critical. The combined disciplines of physiology, breeding, nutrition, entomology and pathology are being brought to bear on these problems.

Principal accomplishments during this current report period are (1) further random mating of yellow endosperm populations (B & R); (2) selection within populations for grain fill period length, testing for testa presence as part of a quality program, selection of obvious good agronomic types; (3) initiated testing for a hydroponic root selection technique; (4) determined that the heat tolerance disc test can separate poor and good tolerance in terms of photosynthetic capacity at high temperatures; (5) initiated tests on a field heat tolerance test during grain fill; (6) quantitated yield loss due to various degree of lodging; (7) conducted cultural experiments minimizing tillage and water loss; (8) conducted rotation experiments to check the influence of a grain legume on nitrogen availability to sorghum; (9) determined that genotypes can be selected which have a 25% difference in metabolic rate from 10 to 27 C; (10) initiated tests on cool temperature screening techniques; (11) initiated screening tests for differences in uptake and utilization efficiency of nutrients; did considerable research on environmental control facilities; (13) training students from Mexico, India, Uganda, The Phillipines, Nigeria and the U.S.

Past accomplishment providing a foundation for accomplishments listed above include (1) synthesis of many random mating populations; (2) development of the heat and drought tolerance tests using leaf discs; (3) complete definition of developmental sequences in sorghum; (4) related developmental sequences to generating the seed number and seed size components of yield; (5) related water stress at various stages to seed number loss and yield reduction in the greenhouse - much field work remains to be done; (6) made initial growth room studies in temperature influence on yield.

A. GENERAL BACKGROUND

Authorities generally agree that increasing world food needs created by rising populations are creating severe pressure on world food production capacity. Crop improvement progress will have to accelerate if production is to keep pace with demand, especially in developing nations.

Sorghum ranks fourth among cereals (behind wheat, rice and corn) as a human food source. Sorghum is particularly important in those developing nations where environmental stresses often severely limit crop growth one or more times during the season. Relatively little is known about how to effectively screen for desirable environmental stress reactions in sorghum.

The purpose of this project is to study the nature of environmental parameter (particularly stress) effects on essential physiological processes, related developmental processes and the resulting seed number and seed size components of yield. Environmental stresses of chief interest are temperature extremes and water deficits. A more recent related area of interest includes soil nutrient deficiencies or toxic excesses which bear on the efficiency of nutrient uptake and subsequent utilization by the crop.

Plant breeding programs traditionally have most often been carried out under relatively optimal conditions to assure full expression of a genotype's potential under the assumption that the top genotypes under good conditions will probably be the top under stress conditions. Reasonable evidence is available to suggest such is not necessarily always true. Therefore, effort

should be devoted to developing stress screening techniques for breeding programs.

Developing these screening techniques will require a good basic understanding of environmental stress effects on photosynthetic and respiratory mechanisms, synthetic processes associated with both, and translocation processes mediating metabolite transport interconnecting all those essential processes. The overall project objective is to better understand the nature of stress induced effects on essential physiological and developmental processes in order to (1) develop screening techniques for efficient genetic manipulation and (2) to improve cultural practices to conserve water while stabilizing and maximizing yields under some given set of environmental conditions. A more detailed breakdown of these broad objectives follow.

B. STATEMENT OF PROJECT OBJECTIVES AS STATED IN THE CONTRACT

Basically investigations are geared to understanding growth and development of the sorghum crop well enough to manipulate the crop toward fairly stable yields consistent with the environmental limitations or resources of a given production area. Sustained progress toward steadily increasing yield depends on (1) progress in current applied investigations bearing directly on improving cultural practices and genetic manipulation and (2) on basic studies on essential physiological processes which designed to develop new plant breeder screening techniques and cultural practices. Both types of investigations are included. Objectives itemized in the contract follow:

1. Incorporate yellow endosperm lines into a Nebraska-developed random mated population. Yellow endosperm lines are being incorporated into good yielding germplasm in current random mating populations because of 1) potentially higher food value, 2) extensive vigorous root systems which may function in a water stress avoidance capacity and 3) potential for gain in the seed size component of yield.
2. Develop suitable selection techniques and breeding methods for use with random mating populations destined for the tropical environments. Grain yield, when grain number and size are not limiting, is a function of plant metabolic efficiency and length of the grain filling period. Particular emphasis will be placed on determining what the correlation is between length of the grain filling period and the yield of grain. A random mating population shall be selected and evaluated for variability in length of grain filling period.
3. Cultural investigations include evaluating the utility of soil bedding as a limited tillage practice for sorghum on upland 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 subsequently reduce expense. Hopefully, water loss will be lessened as the tillage is decreased.
4. Develop screening techniques applicable to random mating populations for stress tolerance and stress avoidance mechanisms. A simple heat test will be used to evaluate germplasm from many sources including populations for heat and drought tolerance.

5. Investigate plant reaction survival mechanisms operative in environmentally stressed plants in the more marginal crop production areas of the tropics. An attempt shall be made to develop additional screening methods.
6. Develop screening methods for early season cool tolerance growth capability. Germplasm development shall be coordinated with CIMMYT.
7. Conduct analysis of energy requirements of sorghums for the developmental stages including the periods from planting to panicle initiation, panicle initiation to bloom, and to physiological maturity.
8. Publish research results.
9. Meet once a year with other AID financed institutions involved in sorghum improvement to review results, exchange information, etc.
10. Provide better control of environmental variables to facilitate research.
11. Initiate investigations on genotype differences on nutrient uptake and utilization efficiency.

C. CONTINUED RELEVANCE OF OBJECTIVES

Project objectives remain relevant. The approach to evaluating some of the problems needs to be strengthened by expanding environmental control facilities available to test water and temperature stress problems. Objective B3 was made slightly broader to include all experiments dealing with cultural practice considerations. Objectives 10 and 11 have been added to the original contract list. Financial support for objective 11 has been essentially nothing from the current budget.

D. ACCOMPLISHMENTS TO DATE

1. Findings

OBJECTIVE 1. Incorporate yellow endosperm lines into a Nebraska-developed population.

W. M. Ross and K. D. Kofoid. Yellow endosperm lines incorporated into random mating populations have been cycled 2 times. About 2000 head selections were made in 1976 from both NP12B and NP13R. A portion will be used in a study of grain quality. All have been subjected to a rapid bleach test to determine presence or absence of a testa. Absence of testa generally infers improved digestibility. Lines will be selected from head rows for other studies relating to metabolic characteristics and possibly root function since the yellows seem to possess some stress tolerance.

OBJECTIVE 2. Develop suitable selection techniques and breeding methods for use with random mating populations destined for tropical environments.

W. M. Ross and K. D. Kofoid. Pertinent results of several studies are summarized:

a. NP3R and NP5R have yielded about 90% of RS 626 and RS 671 over a 4-year period. All populations yielded relatively better in the favorable years of 1972 and 1973 than in the stressed years of 1974 and 1975.

b. Mass selection for yield in NP3R over three cycles was ineffective. Propagation of NP3R under irrigation and under dryland for three years did not affect the yield of the population.

c. Recombined high yielding families from the first cycle of family testing with NP3R gave realized gains of 7.5% for S1's, 5.2% for full sibs, and 4.4% for half sibs. Predicted gains from second cycle testing in 1975

were about the same as from the first cycle and in most cases are approximately twice the realized gains.

d. Preliminary study was made of population crosses and of full-sib reciprocal crosses involving a B and an R population. Reciprocal recurrent selection in sorghum needs to be studied in comparison with other methods of family testing and population improvement.

e. Cytoplasmic male-sterile varieties planted in a random-mating population produced topcrosses that gave a good indication of general combining ability of the lines and of the heterotic potential of the population.

f. Isogenic twin-seeded and normal hybrids were grown at Manhattan, Kansas, and Mead, Nebraska. Four of six normal hybrids significantly outyielded their twinned counterparts, and no differences existed in the other two pairs. These data are pertinent to deciding how important the seed number component of yield is as a limiting factor from the standpoint of grain sink size available as opposed to assimilate supply available (rate of photosynthesis and duration of grain fill). Much remains to be learned on this point. The next item on selection on duration of grain fill relates to this broader question which will be a subject of research for some years to come.

J. D. Eastin and W. M. Ross. Approximately 800 NP13R (partial yellow population) heads were tagged at bloom for grain fill length determinations. Recombination to form short and long grain fill population was intended. Extreme heat about midway into grain fill forced an unusual compression of grain filling time making the distinction between long and short grain fill difficult. A decision has not been made yet on whether to recombine suspected

long and short fill genotypes from this selection or to just start over.

Heads selected from NP3R in 1970 for variable grain fill period have been carried to F_5 and F_6 generations, hybridized and checked for yield. Data on the regression of yield on GS_3 (grain fill period) and related factors are being tabulated currently in a Ph.D. dissertation by Mr. David Basiime, a student from Nigeria.

OBJECTIVE 3. Cultural investigations.

Eastin, Clegg, Maranville, and Sullivan. Tillage experiments. Data for a third year show the Orthman bedding system (a minimum till approach) to give yields equal to conventional tillage. Usually the bedding system requires less trips through the field and presumably a lower energy requirement.

Several comparative tillage systems in a separate experiment gave equal yields for a second year in a row.

Max D. Clegg. Sorghum-Soybean Cropping Systems. A sorghum-soybean cropping system was designed as a rotation to conserve water, fuel and nitrogen. Tillage was done only after sorghum was grown. Each tillage operation exposes moist soil which in turn dries resulting in a soil moisture loss. Also greatest fuel consumption occurs during heavy tillage. By minimizing the number of tillage operations, both moisture and fuel can be conserved. Nitrogen is fixed by legumes, so possibly less nitrogen is needed following soybeans.

The treatments in the experiment consisted of:

1.	Continuous sorghum,			kg/ha N,	conventional tillage.			
2.	"	"	, 57	"	"	"		.
3.	"	"	, 114	"	"	"		.
4.	"	"	, 170	"	"	"		.
5.	"	"	,	no N	conventional tillage.			
6.	SB - SB - Sorg		,	kg/ha N,	conventional tillage following sorghum.			
7.	"		, 57	"	"	"	"	" .
8.	"		, 114	"	"	"	"	" .
9.	"		, 170	"	"	"	"	" .
10.	SB - Sorg		,	kg/ha N,	conventional tillage following sorghum.			
11.	"		, 57	"	"	"	"	" .
12.	"		, 114	"	"	"	"	" .
13.	"		, 170	"	"	"	"	" .

With exception of treatment five, the crops were planted with a no-till planter following soybeans. Weeds in the no-till plots were controlled with herbicides.

Various combinations of nitrogen to sorghum vs. soybean-sorghum or continuous sorghum showed a trend for slightly higher yields of grain from sorghum following beans. At least, the grain yields were better than or as good as grain yield of sorghum grown in the conventional continuous sorghum system. The production cost should be less because of fewer heavy operations. Sorghum responded to nitrogen fertilization as indicated by higher grain yields.

Max D. Clegg, J. W. Maranville, J. D. Eastin and C. Y. Sullivan. Dryland Responses of Six Grain Sorghum Hybrids Grown at Three Plant Populations. Six sorghum hybrids (RS 626, DeKalb E-57, RS 671, Martin x SC33, CK60 x SC33 and Redlan x SC33) were planted in 0.76 meter rows at plant populations of 75,000, 225,000 and 375,000 plant per hectare. One objective was to see if erect leaved hybrids would perform better than non-erect leaved hybrids under dryland conditions

Yield data showed no advantage of erect leaved hybrids over non-erect hybrids. Yields were dramatically affected by plant population. The highest

yield (5997 kg/ha) was obtained with the plants at 75,000 plants/ha. As the plant population increased yields decreased to 5698 kg/ha with a plant population of 225,000 plants/ha and 5360 kg/ha with a plant population/375,000 plants/ha.

These results agree with the general recommendation that sorghum should be planted at relatively low plant populations. The amount of seed needed to plant each rate was 2.34 kg/ha (10.32 lbs/A), this is assuming an emergence rate of 80%. Thus, the greatest advantage of planting at low plant populations is that if moisture is good the crop will often tiller and compensate for the initial low plant population and maintain a good yield. If moisture is lacking, loss of yield due to excessive vegetative growth is prevented. However, one must be cautious since not all genotypes tiller and a poor tillering type will not have the ability to compensate.

Jerry W. Maranville and Max D. Clegg. Influence of Seed Size and Density on Germination, Seedling Emergence and Yield of Grain Sorghum. An experiment designed to determine the effects of seed size and density on general field performance of the plants produced from these seeds showed that only the denser kernels had a significant increase in percent germination over the control. The lighter seeds were also significantly lower in percent germinateability. Size did not influence this parameter which was in contrast to previous results where lighter seeds had higher percentage germination values. There was also no difference in seed size between the dense or heavy seed and the light seed.

In field performance, the only difference between any seed treatment was initial emergence of seedlings. There was no difference among large, small, heavy, light or control seed lots for final seedlings produced, final

harvested stand, or grain yield. There was a significant difference among the genotypes RS 671, 70 X and Esp. SC33 x Martin for all the parameters. There was also a significant difference between the two populations tested. It was concluded that although the denser or larger seed lots may have a higher germination percentage, that they will have a better field performanc over the small or lighter seeds if the desired number of viable seeds are planted. It was observed, however, that the denser or larger seeds produced an apparently more vigorous seedling. When conditions of stress are imposed such as soil crusting or low moisture, perhaps the benefit of a more vigorous seedling would be evident in final grain yield.

OBJECTIVE 4. Develop screening techniques applicable to random mating populations for stress tolerance and stress avoidance mechanisms.

Norma V. Norcio and C. Y. Sullivan. Effect of High Temperature on Photosynthesis Rate of Sorghum Genotypes. Continued use is being made of the heat disc test where comparative cell damage from heat is estimated by electrolyte leakage from heat treated leaf discs. Four sorghum genotypes were selected for heat tolerance on the basis of the disc test for metabolic studies. Redlan and RS 626 were heat sensitive compared to RS 691 and 9040.

This study included the effect of temperature on the photosynthesis rate of sorghum and corn genotypes. Four sorghum genotypes, RS 626, RS 691, 9040 and Redlan were included. Photosynthesis and respiration rates were measured at panicle initiation and flowering stages and at two temperature levels, 40 and 43 C using the oxygen evolution technique.

RS 691 and 9040 were found to have a high photosynthesis rate at 43 C compared to RS 626 and Redlan, which had an abrupt decrease as temperature

was increased from 40 C. In addition, a higher photosynthetic rate at panicle initiation stage was observed compared to flowering stage both at 40 and 43 C. The ability to maintain a higher photosynthesis rate at these two growth stages when exposed to high temperature stress is important in the growth and development of the plants. Sorghum lines which are able to photosynthesize at an appreciable rate when subjected to this stress will be advantageous in selecting for parent materials in breeding programs geared towards varietal improvement under environmental stress.

Jerry W. Maranville and C. Y. Sullivan. Studies of Nitrate Reductase Activity in Sorghum in Relation to Heat Stress. Experiments were conducted to determine the relationship of nitrate reductase (NR) to overall performance of sorghum genotypes to heat stress. RS 671 was used to establish a proper elevated assay temperature in order to evaluate the enzyme stability for the various treatments. It was found that 40 C was the point at which most of, but not all, the activity was lost for this genotype and tests were compared at this temperature against a 30 C control assay. Eight genotypes differing in their ability to function at high heat (drought) stress were tested. The preliminary results showed that the enzyme stability generally did not relate to the original ranking with respect to stress tolerance. The activity was more closely associated with the vigor of the plants at the time they were measured. The genotypes which had the least growth at high temperatures generally had the least activity. When the plants were hardened, the enzyme became much more stable to the elevated assay temperature. There also appeared to be some relationship between NR activity and resistance to tissue injury as measured by the conductivity test over all genotypes. Again, however, the

ranking did not follow the order overall heat (drought) resistance expressed by the genotypes, but rather to vigor of growth. It appears from the initial study that NR enzyme stability is not a feasible method of evaluating genotype response to environmental stress such as heat or drought. More studies will be conducted, however, to observe this more closely.

C. Y. Sullivan. Resistance to Water Loss. Significant genotype differences in quantities of cuticular covering which ratards water loss was noted after stomata closed. Sorghum generally had higher amounts than corn. Genotype differences in time of stomatal closure when exposed to field drought stress sometimes, but not always, correlated with visual leaf curl.

Jeffrey C. Larson and Jerry W. Maranville. The Effects of Lodging on Yield, Protein, and Test Weight of Grain Sorghum. Lodging is one of the main deleterious effects of moisture and/or heat stress. This experiment was designed mainly to quantitate lodging effects on yield. Data collected confirmed previous results that lodging decreased yield, test weight and total protein production in grain sorghum. Protein concentration generally tended to increase which was most likely due to the lower grain yield in lodged treatments. Yields were lower with earlier lodging and increased severity. The lowest yield was found with the stalk break at heading time which had a 31.3% reduction from the control. The percent protein values for the low yielding treatments tended to be higher than the control, but the differences were not significant as in 1973. Test weights were reduced by lodging treatments and may be the primary reason for grain yield reductions. Apparently, photosynthesis and/or translocation are severely impaired due to lodging. Total protein production was generally a reflection of grain yield

rather than protein concentration of the grain.

Todd Dickinson and J. D. Eastin. Seed Development in Sorghum Panicles and Susceptibility to Heat Stress. The grain filling curve in sorghum panicles is pretty much a straight line beginning 3 or 4 days after bloom. The dry matter accumulation curve in individual kernels may differ from the whole panicle curve since a wide range of maturities exists within the panicle. Maturities differ because bloom occurs 4 or more days earlier in the tip and physiologic maturity occurs 1 to 2 weeks later at the panicle base than in the tip.

Progressive head sampling at 5-day intervals and subsequent sectioning of heads into quarters provided information on rate of kernel development by head section. Kernel development among head sections followed the total panicle development pattern suggesting that individual kernel development is similar to total panicle development. Dry matter accumulation curves are relatively straight lines as expected for all sections but the accumulation rate in the base section was slightly slower.

Clear plastic bags were applied to sorghum heads to test heat tolerance in a companion experiment. Temperature elevations up to 10 C occurred inside the bags. Bags were applied every 3 days following bloom and removed after different lengths of time (up to 16 days). Longer treatment intervals usually reduced seed number and seed size whenever applied within 2 weeks after bloom. Shorter treatments (2 to 4 days) were quite effective in reducing seed number and size when applied 7-10 days after completion of bloom. This appears to be a time period when developing grain is sensitive to stress. The possible utility of testing for stress reaction using this crude field test will be further evaluated in 1976 in a random mating population.

C. Y. Sullivan: Root Investigations. Initial evaluation of a hydroponic system utilizing 4-inch PVC pipe to study root system differences appears promising. Root function under temperature and water stress conditions is obviously critical. A more complete evaluation will be reported on in a year.

OBJECTIVE 5. Investigate plant reaction survival mechanisms operative in environmentally stressed plants in the more marginal crop production areas of the tropics. An attempt shall be made to develop additional screening methods based on new knowledge gained on operation of survival mechanisms.

Norma V. Norcio and C. Y. Sullivan. Stomatal and Non-stomatal Inhibition of Photosynthesis at High Temperatures in Sorghum. Two systems were designed to differentiate the biophysical from the biochemical effects of high temperature on the photosynthetic mechanism of preheat treated sorghum leaves. One system involved measurement of oxygen evolution in leaf sections submerged in a surrounding of high CO_2 concentration thereby initiating stomatal closure The other system measured net carbon exchange of intact leaves by employing an infrared analyzer which included stomatal control of CO_2 diffusion. The responses of two sorghum hybrids and their parental lines were investigated.

The results show that temperature affects both the stomatal and photochemical apparatus of sorghum leaves and that the two may interact. Plants that were preheat treated showed thermal stability at the chloroplast level in the high temperature range that was used in the measurements. Some of the entries, however, were affected by the heat treatment at the stomatal level as shown by the lower leaf conductance thus exhibiting lower photosynthesis rate as measured by the gas exchange technique.

Both hybrids exhibited hybrid vigor in photosynthesis rate and followed the response of one of the parent lines.

J. D. Eastin. Influence of High Temperature on Growth Processes. Preliminary experiments indicate differences exist between corn and sorghum in capacity for dark seedling growth in the 35-40 C range. More extensive investigation is underway. The evaluation test is fairly simple. While it is not particularly fast, it holds some promise as a breeder screening tool for tropical germ plasm where temperatures are frequently quite high.

OBJECTIVE 6. Develop Screening Methods for Early Season Cool Tolerance Growth Capability. Both the tropics and temperate zones have semiarid high elevation areas where temperatures, especially at night, are frequently quite cool. These relatively dry areas are ideally suited to sorghum culture except for the cool temperature. Hence research in cool temperature development is needed. Part of the work underway is summarized in the following:

L. Mendoza-Onofre, J. D. Eastin, C. Y. Sullivan, W. M. Ross. Relationship Between Laboratory and Field Observations of Sorghum Seedlings Grown Under Cold Temperatures. Six hundred ninety-three S_1 progenies developed from sorghum populations NPB8R and NP10BR were planted under cold temperatures in field and laboratory conditions.

Field planting was done on April 22, 1975. Each S_1 progeny was planted in single rows. Two checks were planted each 20 rows. Maximum and minimum daily soil temperatures at two inches deep, as an average over the first 19 days, were 23 C and 10 C respectively. Nineteen days after planting,

visual grades (FG-1) (F for field) were given to each S_1 according to the relative seedling growth and number of seedlings emerged from each S_1 row in relation to those of the checks immediately preceding them. A second evaluation of the same material on the same replication was done 5 days later (FG-2).

Laboratory observations were obtained from the same 693 S_1 by growing them under similar temperatures and the same planting arrangement as occurred in the field planting. Two replications were planted and visual grades (GCH-1 and G-CH_2) (G-CH for growth chamber) were given to each S_1 following the procedure already mentioned.

Correlation analysis was performed with the four sets of data and the results are given in Table 1.

Table 1. Correlation coefficients between field and laboratory observations.

Grade	FG-2	GCH-1	GCH-2
FG-1	0.83**	0.62**	0.55**
FG-2		0.62**	0.54**
GCH-1			0.67**

** significant at the 1% probability level.

The laboratory technique used in this study permits us to screen large numbers of genotypes for cold tolerance in the germination and seedling growth stages. It showed significant correlation with field observations and can be considered a useful tool in the selection procedures of breeding programs. The modest r^2 values suggest that looking at large numbers are necessary to reasonably evaluate the range of temperature reaction available in a population. The technique suggested is workable from a

practical point of view.

J. D. Eastin, L. Mendoza, M. Clegg, C. Y. Sullivan. Temperature Influence on Grain Yield. Yield results were reported in the last Annual Report (No. 8) when different genotypes were subjected to different day/night temperature combinations. Yield results are repeated in Table 1.

Table 1: Temperature Influence on Sorghum Grain Yield (G/Head

Genotype	Grain yield in g/head (% Reduction from Maximum Yield)		
	: day/night temperature in C		
	: 29/17	29/22	29/27
RS 610 1/ (CK60 x 7078	36.8 (14)	42.6 --	31.8 (25)
CK60 x 606 2/	32.8 (4)	34.0 --	21.7 (36)
33 3/ x 606	62.3 --	42.1 (32)	28.3 (55)
606	18.8 --	18.0 (4)	8.9 (53)
SJ7 2/ x 156 2/	50.7 --	38.3 (25)	26.8 (47)

1/ temperate hybrid
2/ cool tolerant genotype
3/ intermediate temperature genotype

Note first that when a hybrid genotype is placed at a night temperature 5 C above its approximate temperature optimum, yield reductions in the range of 25 to 33% result. The second point to note is that the temperature optima for genotypes differ considerably. The temperate type (RS 610) peaked near 22 C night while the more cool tolerant types peaked nearer the 17 C night temperature. Field observations prior to these growth

chamber studies suggested that differences would likely appear in the genotypes chosen. Therefore, some whole plant respiration measurements were made to check for metabolic rate differences at selected temperatures.

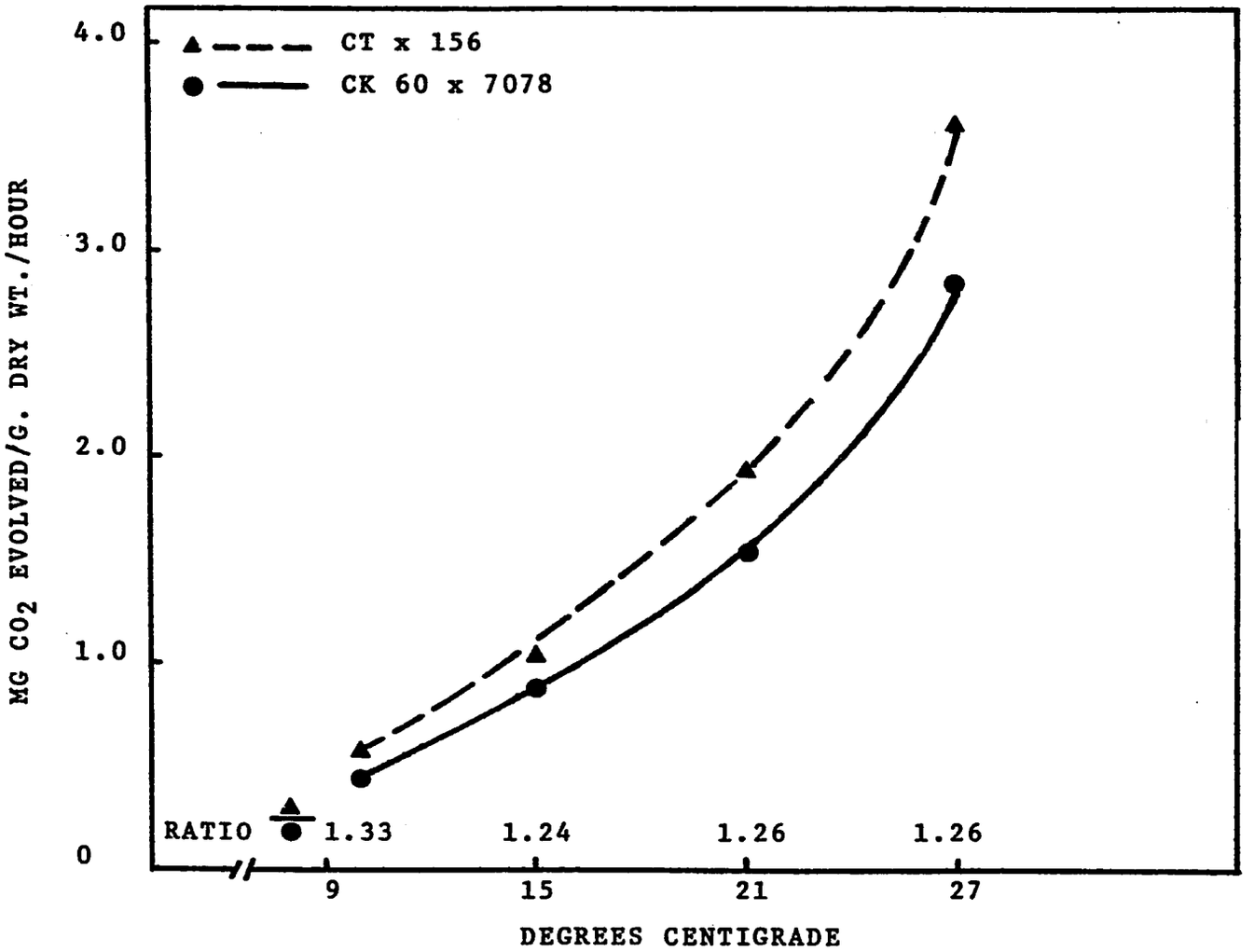
Results showed that respiration rates of cool tolerant sorghum were about 25% faster than rates of temperate sorghums over a range from 10 to 27 C (see Fig. 1). Metabolic lesions are not likely until temperatures in the 35-40 C range are encountered. Therefore, the 25% faster respiration rates likely remain coupled to dependent synthetic activities (protein, CNO syntheses, etc.) and it can be assumed with reasonable assurance that metabolic activity in general is about 25% faster in the cool types. Since metabolic pace dictates metabolic efficiency (growth per unit of energy input) the different metabolic paces appear to explain in part (1) the fact that cool types peaked in grain yield near 17 C at night while the temperate type peaked at 22 C and (2) that the relatively similar yield losses observed occur at different night temperatures for different genotypes (contrast RS 61(and SJ7 x 156 for example) when they are subjected to nights 5 C warmer than their optima.

The basic differences in yield at different night temperatures along with different metabolic rates are being used to attempt devising a screening technique for both cool and high temperature screening for more than just early spring growth.

OBJECTIVE 7. Conduct analyses of energy requirements of sorghums for the main developmental stages including the periods from planting to panicle initiation (GS_1), panicle initiation to bloom (GS_2) and bloom to physiological maturity (GS_3).

FIGURE 1. TEMPERATURE INFLUENCE ON RESPIRATION IN SORGHUM

(15 PLANT AVERAGE, 1973)



J. D. Eastin, R. M. Castleberry, M. D. Clegg, C. Y. Sullivan and J. W. Maranville. Energy Requirements for Respective Growth Stages.

We have arbitrarily divided sorghum development into the vegetative (GS_1), panicle development (GS_2) and grain filling stages (GS_3). GS_2 is a critical period during which the seed number potential is set. Seed number correlates positively with yield. Grain filling is also obviously critical. Unless environmental stresses are fairly severe, the regression of yield on GS_3 is positive and the coefficients of determination often run between .5 and .7. Stated differently from about 25 to 50% of the variation noted in yield relates to variation in duration of grain fill. Therefore, we are analyzing radiation receipt and related parameters during the respective growth stages and will check to see if any of the parameters correlate closely with yield.

A knowledge of the energy requirements to achieve certain developmental stages should be useful in (1) evaluating the suitability of a given area for sorghum culture and (2) should also permit fitting selected maturity classes to a given environment. To partially evaluate these possibilities 20 hybrids were grown two years under dryland and irrigation and checked for duration in GS_1, GS_2 and GS_3. Energy and energy associated expressions calculated for the days spent in each growth stage follow. Values are means of all 20 hybrids for two years.

			GS_1	GS_2	GS_3
Stage duration in days			39.2	35.6	45.5
Langleys (cal/cm^2)			22,418	18,639	19,235
GDU1/	@ base	12 C	363	394	415
		15 C	252	287	291
		18 C	151	183	182
Solar - GDU Units		12 C	204,992	207,286	189,087
		15 C	141,650	151,54	135,697
		18 C	84,658	96,56	88,283

1/ Growing degree units
2/ A combination solar energy - GDU expression

More detailed analyses of these data will appear in later technical reports illustrating which energy expressions at which growth stage(s) correlate most positively with yield. Generally the regression of yield on total energy in Langleys during GS_3 days is positive and significant.

PUBLICATION OF RESULTS

OBJECTIVE 8

Bashford, L. L., J. W. Maranville, S. A. Weeks, and R. Campbell. 1975. Mechanical properties affecting lodging in grain sorghum. ASAE paper 74-3507. Proc. Winter Meetings Am Soc Ag. Eng. Chicago.

Clegg, M. D. 1975. Climatic factors related to crop yield. Proc. International Sorghum Workshop. pp 175-185. Published by the University of Puerto Rico, College of Agricultural Sciences, Mayaguez, Puerto Rico. 00708. Sponsored by US AID Grant G-1184.

Clegg, M. D., H. M. Nadar and J. W. Maranville. 1975. Cytokinin like activity of organic sulfur compounds as measured by sorghum callus growth. Plant Physiology Abst. 1975. paper 150.

Eastin, J. D., I. Brooking, and A. O. Taylor. 1975. Temperature influence on sorghum development and yield components. Sorghum Newsletter. 18:84.

Eastin, J. D., J. T. Hultquist and C. Y. Sullivan. 1976. University of Nebraska Farm, Ranch and Home Quarterly. Winter. Vol 22, No. 4. pp 16-17

Maranville, J. W. 1975. Sorghum in high production cropping systems. Proc. International Sorghum Workshop. pp 110-132. Published by the University of Puerto Rico, College of Agricultural Sciences, Mayaguez, Puerto Rico. 00708. Sponsored by US AID Grant G-1184.

Maranville, Jerry W. 1975. What's new in sorghum physiology? Proceedings of the Twenty-ninth Annual Corn and Sorghum Research Conference

Nadar, H. M. 1975. Utilization of tissue culture techniques in sorghum. Ph. D. Dissertation. University of Nebraska.

Nadar, Hassan M., Max D. Clegg, and Jerry W. Maranville. 1975. Promotion of sorghum callus growth by the s-triazine herbicides. Plant Physiol. (1975) 56, 747-751.

Ogunlela, V. B. 1975. Selecting for heat and drought tolerance in grain sorghum (Sorghum bicolor L. Moench) Sorghum Newsletter 18:83.

Rojas, Emiro A. 1975. Agronomic aspects of double cropping in East Central Nebraska. Ph.D. Dissertation, University of Nebraska.

Wall, J. S. and W. M. Ross. 1975. Produccion y Usos del Sorgo. Editorial Hemisferio Sur. Buenos Aires, Argentina. 399 p.

Several manuscripts are in preparation.

OBJECTIVE 9. Meet once a year with other AID financed institutions involved in sorghum improvement to review results, exchange information, etc.

Nebraska hosted a US AID cooperators meeting at Lincoln and the Mead Field Laboratory in September, 1975. Dr. Earl Leng and several other US AID representatives attended the review of past work and work in progress. Dr. Hugh Doggett represented ICRISAT and IDRC. Dr. L. R. House represented ALAD and the Rockefeller Foundation. Member Universities of the North American Sorghum Improvement Conference, The University of Puerto Rico, The University of Saskatchewan. The North Central Region of ARS, USDA had representatives participating in the review and discussing research needs. Three special industry representatives attended the review and formally evaluated the project. They were Dr. R. F. Holland, Vice President for Agronomic Research, DeKalb AgResearch; Dr. Gene Dalton, Sorghum Research Director, Pioneer Hi-Bred Company; Mr. Jack King, Research Director of the Grain Sorghum Producers Association.

Dr. Hugh Doggett prepared an analyses of the work being done. His comments are in the last portion of section D^2, accomplishments to date, under the title Interpretation of Data and Supporting Evidence section.

A US AID sponsored library networking group met simultaneously at Nebraska to continue evaluating efficient means of providing working information to crop production and breeding researchers in LDC's. Mr. Wayne Collings of the University of Nebraska library hosted the meeting.

OBJECTIVE 10. Provide control of environmental variables to facilitate research.

A statement appears desirable relating to research design and integration of selected components of research in objectives 2, 4, 5, 6 and 7. Research components mentioned therein bear on plant reactions to various environmental variables. Added emphasis must be placed on environmental control in both field and growth chambers experiments for whole plant work in addition to the supporting plant organ and molecular level effort now underway and partially covered in 2, 4, 5, 6 and 7 above. There is no substitute for subjecting plants to various levels of controlle temperature and water stress and quantitating the effect on grain yield and its seed size and seed number components.

As implied above, effective integration of several lines of effort depends on ability to control environment in both laboratory and field circumstances.

Considerable errort has gone into researching controlled environment facility construction. Almost enough technical data on growth rooms has been collected to permit decisions on using local workers to fabricate facilities or to use commercial companies. Commercial company estimates have been surprisingly favorable.

OBJECTIVE 11. Ralph Clark and J. W. Maranville. Mineral Nutrition Investigations.

Preliminary studies were intitiated to screen sorghum lines for differential P and Fe uptake and utilization efficiencies. In this study, twenty-three sorghum lines were grown on low P (Valentine), low Fe (Bridgett), and nondeficient (Sharpsburg) soils. Sorghum hybrids RS 610 and RS 626 and corn inbreds known to show differential P and Fe responses were also grown on

these soils for comparative purposes. Wide differences in growth (dry-matter yield). mineral element deficiency symptoms. P and Fe contents were noted for the lines. Iron and P concentrations were not significantly different among lines showing differential responses to P and Fe nutrition and do not appear to be good parameters to screen sorghum lines for differential P and Fe nutrition.

When grown on the low P soil, the sorghum lines that grew best, showed the least P deficiency symptoms, and highest P contents were KS35, Martin, EH-KS19, and KS5. The lines that grew poorest, showed the worst P deficiency symptoms, and had the lowest P contents were CK60-Korgi, SC177-155, CK60-Shallu, SC119-9-2-2-2, and a North Platte line. When grown on a low Fe soil, the lines that grew best, had least Fe deficiency symptoms, and highest Fe contents were Ck-60, Redbine-60, SC29-6-1, and SC118, and lines that grew poorest, had the most severe Fe deficiency symptoms, and lowest Fe contents were KS35, TAM 618, and TAM BLK25. The identification of superior lines for P appears feasible using Valentine soil, even though certain physical properties were undesirable. Differences among lines for Fe were not as great as desired.

Other soils or methods for inducing Fe stress will be used in future experiments.

2. Interpretation of Data and Supporting Evidence.

Many of the summary-type comments in Section D 1. describing research results are interpretive in nature. A more detailed analysis of most project objectives is given in a technical report which has been prepared for users in LDC's. The technical report is attached. A skeleton

summary of accomplishments follows:

Broad based random mated populations are being synthesized by both Nebraska and Texas for use in LDC's. The gains to be realized by using these populations depends on how effectively selection pressure can be applied in the respective LDC's to meet production requirements of the local LDC soil, water and atmospheric environments. Further, the utility of any genetic selection depends heavily on available production resources and cultural practices which permit the most efficient use of those production resources. Objectives relate to developing efficient selection pressure techniques and optimizing cultural practices to make full use of production resources.

a) Yellow endosperm lines having good potential quality and stress tolerance have been incorporated into RMP's and quality tests have been started on selections.

b) Population yield checks reach up to 90% of standard hybrids.

c) Population breeding techniques successfully used in corn are being tested on sorghum. Mass selection appeared ineffective after 3 cycles in one population. Recombining in family selection techniques are being evaluated. Defining which standard breeding techniques are the most effective for use in LDC's is important. Developing selection pressure techniques for superior physiologic traits follows.

d) The heat stress disc test is showing promise in evaluating lines and population selections which have superior photosynthesis under stress.

e) The drought stress disc test is useful as is the heat test but is slower.

f) The first evaluation stage of a field heat test for developing grain has been completed. Utility of this test remains unknown at this point and is being further tested.

g) A quick, accurate technique has been developed for measuring physiologic maturity so that grain fill length can be determined in the field in LDC's. Up to 50% of the variability in yield appears associated with variability in length of the grain filling period. Grain fill period length is variable within a population and can be selected for. A grain fill time consistent with temperature conditions and water supply should be selected for. Research evaluating root function under optimal and stress conditions using hydroponics is underway. Further studies in the next 2 to 3 years will determine whether or not a hydroponic root screening technique can be developed.

i) Definite difference in photosynthetic capacities at high temperatures have been shown. Genotypes can be selected for high temperature

j) Differences in resistance to water loss have been shown.

k) Lodging effects associated with yield can easily account for a 1/3 yield reduction.

l) Minimum tillage operations which minimize power input and water loss give yields at least as good as conventional tillage.

m) Sorghum-soybean rotations are in their second year and will require at least 2 more years to evaluate possible benefits of a grain legume to the nitrogen economy of sorghum. The rotations also are set up to see if water loss can be minimized by lighter tillage.

n) Initial screening for genotypic differences in efficiency of nutrient uptake and utilization appear promising. These investigations should be expanded.

3. Research Design.

The design approach to the research objectives remains pertinent. One of the biggest limitations remaining is the environmental control problem already discussed. Reasonable progress is being made on that. A fuller evaluation will be in order a year hence.

E. DISSEMINATION AND UTILIZATION OF RESEARCH RESULTS

1. A technical annual report has been prepared to complement this annual report. Approximately 150 copies are sent overseas, mostly to LDC's. Copies go to libraries in ICRISAT, CIMMYT, ALAD, IDRC, IRRI, IITA and CIAT. Many request are filled from individuals in Africa, Asia and Latin America.

   Nebraska has been especially active in hosting cooperator meetings including representatives from ICRISAT and ALAD.

2. Germplasm has been supplied by Dr. W. M. Ross as follows:

Country	No. samples*
Argentina	174
Australia	2
Brazil	177
Cameroon	7
France	76
Israel	15
Japan	7

Germplasm supplied (con't)

Country	No. samples*
Lebanon	2
Mexico	10
Pakistan	10
Thailand	45
Total	525

* Combined totals when more than one request received from a country. In addition, physiologists have sent seed of water or temperature stress tolerant lines to Canada, Israel, and India (ICRISAT). Approximately 160 genotypes with variable grain fill length were supplied ICRISAT scientists.

3. The method for using current research results seems reasonable. Cooperator meetings are effective in getting new research and application ideas out for trial. Remarks to follow in item 4 are pertinent.

4. Discuss the extent and nature of considerations to involve LDC personnel and/or institutions as an appropriate activity of the project. Liason with ICRISAT has been good. At ICRISAT request (Dr. H. Doggett) project personnel reviewed their physiology research program in April, 1975, and consulted on appropriate approaches for LDC research. Since then, seed and information exchange has taken place. Currently, discussions are in progress on co-investigation in the panicle heat tolerance testing work and grain

fill period evaluation. They are also working with heat tolerant lines from Nebraska.

Technical training of an IDRC scientist is helping them in a Senegal research program.

Native students have been and are being trained for work in Nigeria, Mexico, India, Uganda, The Phillipines and the U.S.

F. STATEMENT OF EXPENDITURES AND OBLIGATIONS AND CONTRACTOR RESOURCES

	Expended March '75 thru February 1976		Balance
laries	$14,766.54		
Hourly Pay	3,999.19		
Benefits	1,468.70		
Travel	1,392.84		
Supplies and Maintenance	7,053.70		
Equipment	3,963.42		
Overhead	9,758.35		
General	6,320.86*		
	48,723.60		
	49,720.12	Exp. Feb. '74-Febr'75	
Budget $160,000	98,443.72		$61,556.28

* $5,441.66 winter nursery
879.20 annual report
6,320.86

Note: Approximately $670.43 is encumbered but not included above.

The relatively large balance consists of money set aside for controlled environment room construction. We are analyzing commercial bids for portable chambers in relation to local construction. In about one month the contract office will be consulted about options available. Construction of these chambers constitutes the only major shift in fund use from original plans. This shift has been discussed thoroughly with AID personnel.

G. WORK PLAN AND BUDGET FORECAST

1. Anticipated Accomplishments.

Original objective statements are listed below and followed by a work pursuit statement for each objective.

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

Work pursuit.

1) S1 yellow endosperm population progeny have been selected and are being evaluated for nutritional quality. Special attention will be given B line populations.

2) Greenbug resistance is being incorporated into several populations.

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

Work pursuit

1) One more year of tests will be done on the initial grain fill period selections made from NP3R in 1970. Hybrids of selected F6 lines will be used.

2) Additional head selections from a yellow R population were made in 1975 for

length of grain fill. Short and long fill heads will be recombined separately to generate both early and late random mating populations of yellow endosperm material. This relates closely with work in Objective 1.

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

Work pursuit.

1) A minimum till soil bedding experiment compared with conventional tillage in sorghum will be continued one or two years more. A similar soil bedding - conventional tillage experiment was initiated this year with corn and will be continued.
2) A larger sorghum experiment initiated after (1) above is in progress using additional minimum tillage approaches to minimize energy usage.
3) A crop rotation experiment was established in 1974 involving sorghum, soybeans, no-tillage and various rates of nitrogen. The objectives are to: (a) reduce fuel usage by direct planting after soybeans, through reducing heavy tillage every other year with soybeans-sorghum or every two years with soybean-soybean-sorghum; (b) conserve moisture by not disturbing the soil and controlling weeds with herbicides and (c) evaluate possible nitrogen fertilizer savings by determining the contribution of nitrogen from the soybean crop.

4) Complete experiments on stand geometry (row spacing and population) and plant morphology (leaf type) as they influence light interception and yield.

Objective 4. Develop screening techniques applicable for stress tolerance and stress avoidance mechanism.

Work pursuit.

1) Use a heat test to evaluate germplasm from wide genetic diversity for heat and drought tolerance.
2) Grow genotypes under mineral stress conditions to evaluate germplasm for mineral uptake efficiencies and tolerances to excesses.
   (a) Expand methodology to screen large numbers of plants in relatively short time periods in both soils and nutrient solutions under mineral stress conditions.
   (b) Determine what plant properties and/or responses are responsible for high efficiency of mineral uptake and tolerance to mineral excesses.
   (c) Mineral elements of particular interest include phosphorus, iron and zinc
3) Continue work on root screening techniques.
4) Continue work on temperature adaptation screening.

Objective 5. Investigate survival mechanisms operative in environmentally stressed plants in the more marginal crop production areas of the tropics (both low and high altitudes). An attempt shall be made to develop additional screening methods.

Work pursuit.

1) Continue work on desiccation injury and associated leaf firing. The role of cuticular waxes and "bloom" needs further investigation.
2) Interactions between drought and high leaf temperature effects are being studied with particular emphasis on integrity of the photosynthetic apparatus as predicted from heat and drought screening tests.

3) A temperature-typing screening test is being evaluated in an effort to classify sorghums in terms of cool, temperate or tropical adaptation. For example, stress effects on the seed number component of yield are serious at the floret differentiation stage. Deleterious effects are compounded if cool adapted germplasm (high elevation tropical or temperate region) is placed in a temperate climate or if temperate material goes to a tropical low elevation climate. More quantitation on these effects is needed.

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

Work pursuit.

1) The temperature-typing technique mentioned in Objective 4, item 4 and Objective 5, item 3 needs much additional evaluation as to its suitability for a broad screening technique across a broad temperature range.
2) Work during the summer of 1975 on correlating field emergence under cool temperatures and a new growth chamber cool germination screening technique is being tested further on a population basis. NP8BR and NP10BR selections have been selected, tested and are now in Puerto Rico for increase prior to additional testing here in 1976.
3) Field climatic evaluation of genotypes in relation to cool tolerance in continuing to see if both bloom date and length of grain fill under contrasting climates can be used as a temperature-typing screening technique.

Objective 7. Conduct analysis of energy requirements of sorghums for the developmental stages including the periods from planting to panicle initiation. panicle initiation to bl

Work pursuit

The initial phase of this will be concluded and results published. Subsequent work will relate to Objective 6, item 3.

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

Objective 9. Meet at Beeville, Texas in July with other cooperators.

Objective 10. This objective was not included in the original work plan as such and is more or less a supporting activity to Objective 4, items 1, 2 and 4; Object: 5, items 1, 2 and 3 and Objective 6, items 1 and 3. Specifically, work initiated will include (1) building large controlled climate rooms indoors. Two prototype rooms will be completed in 1976 and tested. Two additional rooms would be planned for the 1976-77 work year if funds permit. (2) Building outdoor rain shelters will be continued. (3) Work on designing night temperature control facilities outdoors under rain shelters will be initiated in order to study water x temperature stress interactions.

Objective 11. Initiate investigations on genotype differences on nutrient uptake and utilization efficiency.

2. Procedures to be used are not changed too much. Activities place more emphasis on environmental control as outlined.

3. Significant factors relating to accomplishments. No serious problems are anticipated. Some consultation with Australian and New Zealand Scientists on comparative environmental control facilities would be very useful in the next 3 years.

4. Dissemination of results will follow established approaches. Additional emphasis will be on cooperation with ICRISAT scientists. The exchanges in progress is already appreciable through

a) Direct consultation of the request of ICRISAT.

b) Review by our staff of IDRC of their drought research project designed to better characterize drought induced problems in LDC's.

c) Exchange of seed supplies with LDC's.

d) Utilization of cooperative experiments with LDC scientists.

e) Close correlation with Texas A & M scientists on disease and insect problems in LDC's.

f) Follow up on any AID contacts called to our attention.

g) Training students from LDC's.

5. Proposed budget statement.

Salaries	44,000
Benefits	3,520
Travel	3,440
Supplies and Maintenance	14,605
Equipment	37,500
Overhead	27,935
Winter nursery	4,000
Carryover 1/ (mostly for environmental control)	61,000

1/ Estimate

H. APPENDICES

1) A technical report on items summarized in D2 will arrive under separate cover.

2) Abstracts from E1 are included in the technical report.

3) Use of research findings.

a) Results are being used to plan experiments at ICRISAT on field testing for heat stress during grain fill. Utility of the test is yet unknown.

b) The heat disc test is being used on vegetable crops in Taiwan, rice at IRRI and corn to a limited extent in the U.S.

c) The dark layer test for physiologic maturity determinations (and grain fill length) is being used at ICRISAT and the U.S.

d) Excerpts from a report by Dr. H. Doggett from the September.

1975, AID cooperators meeting hosted by Nebraska,

"During the Tuesday morning session, representatives of US AID lined some of the activities in which they had been involved, Dr. Harold Kugler giving an account of the project 26 co-operative activities in W. Africa, and the USAID/ARS projects in E. Africa in relation to sorghum and millets at Serere, and grain processing in Nairobi. The question was raised as to whether the kind of work being conducted at the universities under US AID contracts, which had been outlined to us on the previous day, was of any use to the small farmer in the developing world, and whether it was making any impact upon him. This question appeared to short-circuit a fairly complex chain of research and development which is required to produce the improvements which need to be carried to the small farmers. Dr. Leland House got up and outlined the big impact which sorghum work conducted in the United States had already made upon the developing world: he drew attention to material from Dr. Karper's nursery, which had formed the basis for the original CSH1 hybrid in India, and noted how much of this material is still proving valuable in many parts of the developing world. He emphasized strongly that without the research and development work going on in the USA, there was little to give the farmer in the developing world, at least with regard to the sorghum crop and semi-arid agriculture.

Dr. Doggett then reiterated the dependence of the ICRISAT programme upon the research work being conducted in the USA. He drew attention to the existing problems of seed movement, and expressed the hope that ideas put forward of obtaining an island, possibly one of the Virgin Islands, which could serve as a quarantine area for importing sorghums and millets to the USA, might be realized in the not too distant future. Dr. Doggett would like to see the world collection grown and maintained in Puerto Rico, or some other suitable place, with screening for genetic diversity in the characters being identified from the various programmes to which we had listened on the previous day."