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Report No. 7

Prepared by:

R. C. Pickett, Project Leader, Department of Agronomy
Agricultural Experiment Station
Purdue University, Lafayette, Indiana

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I. PERSONNEL

Department of Agronomy	% Contract Funding
Dr. R. C. Pickett, Project Director	50
Dr. D. T. Cooper, Assistant Project Director (Postdoctorate)	100
Mr. Dallas Oswalt, (Graduate Research Assistant)	75
Mr. D. P. Mohan, (Graduate Research Assistant-India)	75
Mr. Robert Schaffert, (Graduate Student)**	
Mr. Rameshwar Singh, (Graduate Student-India)*	
Mr. Samwiri Mukuru, (Graduate Student-Uganda)*	
Mr. Bantayehu Gelaw, (Graduate Student-Ethiopia)*	
Mrs. Ardith Spies, (Administrative Assistant)	50
Mr. John Fisher, (Field Technician)	40
Mrs. C. Dian Tollinger, (Laboratory Technician)	100
Mr. John Wells, (Laboratory Technician)	100
Mrs. Louisa Lai, (Laboratory Technician)	50
Department of Biochemistry	
Dr. E. T. Mertz	5
Dr. R. Jambunathan, (Postdoctorate)	100
Department of Animal Science	
Mr. Joseph Olagoke Ilori, (Graduate Student)**	
Mr. Jose Brandao Fonseca, (Graduate Student)**	

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II. INTRODUCTION

This research report constitutes a summary of the accomplishments during the 1970 crop season which aided in the fulfillment of the original objectives as stated at the initiation of this project in 1966 and enlarged later.

The year's work was directed toward organizing, maintaining, evaluating and adequately sampling the collected lines and selected hybrids in common environments. The growout resulted in the identification of duplications and similarities in order to reduce the size of the collection to a more useful and workable representative germplasm pool. The segments not previously included in the working germplasm pool were identified for future collection and investigation. The seed produced established an essential working inventory for maintaining viable seed stocks. The quantity of seed produced made it possible for further biological evaluation and intensive inheritance investigation. This extensive growout resulted in the identification of germplasm with high yield potentiality, agronomic usefulness, diversity, adaptation and acceptability. The computerized data collected and inventory established this year will make it possible for more intensive quality and inheritance investigations entailing smaller numbers but maintaining a broad representative germplasm base. The number of protein and amino acid determinations was increased due to automation of the procedure and making available a larger number of samples.

The general objectives of this project are to find, produce and distribute sorghum lines with wide environmental adaptation and the best combination of high yield, improved protein quantity, quality (amino acid composition) and digestibility. For maximum potential around the world, a wide diversity of sources are retained with variations in height, seed color, taxonomic groupings and other characters of interest.

The more specific objectives as expanded for 1970 by mutual agreement between AID and Purdue are as follows:

A. To screen for high lysine and nitrogen levels in selected lines from the world collection and various breeding programs in the U.S., Africa and India. Crosses and inbreds from them would also be examined to determine the inheritance pattern.

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

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

D. To determine biological or nutritional value of high protein, high quality amino acid selections.

E. To study the chemical nature of proteins of sorghum endosperm and embryo. Sorghum selections with the greatest differences in amino acid composition would also be studied.

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

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

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

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

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

III. RESEARCH REPORT

The work completed and pending as the result of the 1970 crop season research efforts under this contract are summarized in this section. The ten project objectives are indicated by subtitles. Where appropriate, individual project staff members having major responsibility for specific segments of the work are indicated.

A. Screening Collections Obtained.

The available collection items (12,000 plus) were grown to replenish seed stocks and to make additional evaluations for day-length sensitivity, flowering date, height, lodging resistance, yield and other agronomic characters on lines not previously grown at Purdue. Items not yet included in the India Sorghum collection, but screened here this year included entries from Ethiopia (3929), South Africa (77), Nigeria (3), Ethiopia/Swartz (57), Botswana (10), Texas (3), and Cameroun (1887). The origins, yield, protein and amino acid data from experiments are to be organized and computerized for 1971 distribution.

Over 3,450 F_1's made with four cytoplasmic male sterile females and 100 hand emasculated crosses were grown with approximately 1,000 parent lines in replicated trials. Line evaluations based on hybrid yield, protein quality and quantity, height, restoration and agronomic values were made. F_2 grain and tissue samples were collected on selected families for laboratory and inheritance studies. Over 750 selected F_2's were grown in replicated yield trials for inheritance studies and selections.

Approximately 4,000 selected lines were crossed heavily with Martin and Redlan male steriles. Sufficient F_1 seed was obtained for future yield trials and for the detection of duplication and similarity among lines. Also an estimate of line and F_1 yield at different locations and disease and insect resistances can now be effectively accomplished by use of this seed supply.

Over 1,000 selected lines were placed into Indiana yield trials including the 400 lines distributed to overseas cooperators. From these yield trials eighty-seven lines yielding above the average commercial hybrid checks were selected for entry into the 1971 advanced yield trials and for further inheritance and quality studies. An additional 350 grassy-type lines and their F_1's, all having high protein content, were grown in replicated trials to evaluate heritability and yield response.

Over 7,600 individual plant selections made in 1969 were grown in single rows. About one-half of these selections were obtained from populations involving male sterile cytoplasm and the remainder were from populations with normal cytoplasm. Approximately 4,000 individual plants were selected based on the 1970 single row performance. These are to be further studied in the 1971 single row plantings.

The field screening program this year provided adequate seed supplies of lines and their hybrids to more adequately test for grain yield, protein amount and quality. Selected entries can then be made for advanced yield trials, for disease and insect resistance trials and for inheritance studies in 1971 and succeeding years. The large volume of items resulted in the establishment of an inventory and catalog storage procedure. This made the process of obtaining chemical and biological testing samples more complete and representative and has resulted in a selection of approximately 800 new lines from the collection for detailed study in 1971. This selection was also based

on phenotypic observations in Puerto Rico and at Purdue in 1970. The mechanics of this task has consumed considerable field space, required temporary drier facilities and a large labor force, but was required for the establishment of working seed supplies and for the identification of potentially useful sources of germplasm. This year's procedure has resulted in about 10 to 15 percent of the total collection being selected for additional and detailed study in Indiana, thus reducing the numbers being directly investigated.

B. Study of Amino Acid Content and Inheritance.

Over 6,250 samples were analyzed for nitrogen content by the micro-Kjeldahl method and of these 1,620 samples were analyzed on the converted Model 121 Beckman 120 C automatic injection amino acid analyzer. This number of analyses was possible for the first time this year as the new apparatus became functional. In addition, 2,700 samples were analyzed by contract with the Shuman Laboratory for protein and lysine content. Also, the University of Illinois analyzed 720 samples for oil content using the nuclear magnetic resonance procedure.

Data from the inheritance studies grown and sampled in 1970 was collected for later analysis and utilization. A computerized output containing all complete amino acid results to date will be available by mid-1971. Protein data processing is progressing for over 50 percent of the world collection items grown here and for the light sensitive portion from seed sources produced in Puerto Rico. This data has been organized and is planned for compilation in 1971.

1. Screening of Available Methods for the Determination of Lysine and Tryptophan in Pigmented Sorghum Samples (E. T. Mertz and R. Jambunathan).

In our last report we reported a simple method for the determination of lysine and tryptophan in sorghum. It was also observed that the method was not reliable in case of pigmented sorghum samples. Further work was carried out along these lines including the use of detergent, sodium lauryl ether sulfate (sipon) alone or in conjunction with alcohol and alkali for the extraction of nitrogen from sorghum samples. The recovery of nitrogen using this method was not good.

Pigment was partially removed using the solvent methanol containing one percent hydrochloric acid on a soxhlet apparatus. Nitrogen was extracted using the mixture of copper sulfate and sodium sulfite. Lysine and tryptophan values determined on this extract were lower compared to previous values. Another reagent that was tried without success was the combination of hexane, acetone, absolute ethanol and toluene in the proportion of 10:7:6:7. (Journal of AOAC 53, 181 1970) This reagent has been claimed to remove the pigments of corn.

Selim (J. Agr. Food Chem. 13, 435 1965) has published a method for the micro-determination of lysine using the reagent 1-fluoro-2, 4-dinitro benzene. This method was tried using two different reagents, 2,4,6-trinitro-benzene sulfonic acid and 2-chloro, 3,5-dinitropyridine on acid hydrolyzed, acid hydrolyzed charcoal treated

and enzyme hydrolyzed samples of sorghum. Lysozyme and opaque-2 corn were used as standard to check the observed values. Also, true lysine values were obtained in the extracts using the amino acid analyzer. None of the above modifications gave a reasonable value for lysine in sorghum samples (Table 1).

Table 1. Determination of Lysine in Sorghum (Acid and Enzyme Hyrolysis) (gms lysine/100 gms protein).

Sample	Acid Hydrolysis Analyzer/TNBS*/Pyridine**			Acid Hydrolysis + Carbon Treated Analyzer/TNBS/Pyridine			Pronase Hydrolysis TNBS/Pyridine	
Lysozyme	4.86	5.75	6.86				7.39	6.37
Sorghum-1840	2.13	3.46	3.98	1.65	2.75	2.65	7.54	2.99
Sorghum-0923	2.06	3.83	3.71	1.51	2.84	2.43	7.35	2.78
Opaque-2 Corn	4.10	4.06	6.72	3.26	3.53	3.96	7.69	5.24

* 2,4,6-trinitrobenzene sulfonic acid
** 2 chloro-3,5-dinitropyridine

The biuret method was tried on the copper extracts of sorghum and compared with the value obtained using micro-Kjeldahl method on the same extracts. There was a good agreement between the values obtained by these two methods except in the case of highly pigmented samples (Table 2).

Table 2. Determination of Protein in Sorghum Extracts (Selected representation of samples run).

Sample no.	0026*	0305	0355	0786	0819*	1406*
Biuret method (mg/ml)	3.50	1.97	2.58	2.23	1.80	2.50
Micro-Kjeldahl method (mg/ml)	2.26	1.90	2.50	2.12	1.53	1.85

* pigmented samples

2. <u>The Transmission of Protein, Lysine, Oil and Certain Other Characteristics from Sudangrass Lines to Cultivated Grain Sorghum</u> (Sam Mukuru).

Eleven grain sorghum and thirty-five sudangrass lines were each crossed to Redlan cytoplasmic male sterile lines. Four of the grain sorghum lines and eight of the sudangrass lines were also crossed to Martin cytoplasmic male sterile lines. All the F_1 hybrids, pollinator lines, Redlan and Martin "B" lines and four checks were planted in 1970 at the Purdue Agronomy Farm. There were three replications in a randomized complete block design. Several agronomic characteristics were recorded in the field and laboratory on a plot basis.

This study will compare populations, percent protein and oil, yield, 100 seed weight, percent lysine and other characters of lines with their respective hybrids. The analysis of this study will be completed in 1971.

3. <u>Relationships of Certain Morphological Characteristics with Grain Yield and Quality of Phenotypically Diverse Lines and Hybrids</u> (Bantayehu Gelaw).

Twenty-four phenotypically diverse lines of sorghum which included all height and maturity groups and general morphological traits were used as male parents in this study. These lines were selected partly from the world sorghum collection and partly from those entries that had survived considerable screening in previous thesis studies.

Three cytoplasmic male sterile lines, namely CK60, Martin and Redlan were used as female parents. The three female parents were selected on the basis of their widespread adaptation and use for commercial hybrid seed production.

Each of the 24 male parent lines were crossed with the three female parents in 1969. In 1970, the 72 F_1's and the 24 male parents along with the three male fertile versions of the male steriles ("B" lines), and three commercial check varieties, namely RS610, BR64 and NK300 were planted in a randomized complete block design with a split plot feature, replicated four times. Each plot was 15 feet (457.5 cm) long and 30 inches (76 cm) apart with a 3.5 foot (106.75 cm) alley and a population of approximately 120,000 plants per acre (300,000 plants per hectare) or about 7 plants per foot (30.5 cm) of row.

Either directly by measurement or indirectly by calculation, the following characters were studied: early vigor, days to 50 percent flowering, leaf number, flag leaf length, flag leaf width, flag leaf area, length of third leaf from the top, width of third leaf, area of third leaf, plant height, stem diameter, head exertion, panicle length, tillering, lodging, number of heads per plot, threshing percent, grain yield, percent protein (non-defatted), percent protein (fat-free), percent lysine and percent oil.

Grain yield for the 72 F_1 hybrids ranged from 4282 to 8639 kg/ha while the range for their parents was from 4418 to 7536 kg/ha. The range for percent protein was from 7.75 to 12.60 percent for hybrids

and 10.30 to 14.85 percent for their parents. Values for lysine ranged from 1.61 to 2.67 percent for the hybrids and from 1.54 to 2.55 percent for their parents. Percent oil ranged from 2.95 to 4.05 percent for hybrids and 2.77 to 4.50 percent for their parents. The analysis for other values and their inheritance studies will be completed in 1971.

C. Genetic Recombination and Genotype by Environment Interactions.

The three locations used in Indiana gave significant genotype by location interactions and facilitated the identification of the more stable lines and hybrids. Selections made in Indiana correspond closely with overseas data related to yield ratings which were returned by cooperators. This data supports our theory that lines and recombinations can be tested in three locations in Indiana thus giving a reasonable assurance of their potential performance in a wider range of climates.

1. 1970 Studies on High Protein-High Lysine Sorghum Lines (D.P. Mohan).

Many select lines in the world collection have been analyzed for protein and a somewhat smaller number have been analyzed for lysine. Only a single sample has been analyzed from most of these lines and the samples have come from a number of different environments. Therefore, retesting in a uniform environment was needed to confirm previous quality data and to make this material available for further breeding and genetic work.

Three hundred fifty high protein lines (14.0 to 20.2 percent) and 150 high lysine lines (2.3 to 3.7 percent) were chosen to be re-evaluated in 1970. Most of these were grown in two-row plots, two replications per location and at two locations. A number of these lines were also crossed onto Redlan and Martin male steriles to study the inheritance of protein and lysine. Two replications at one location and one replication at the other location were analyzed for protein and lysine. All replications were rated for yield. The protein range was from 9.4 to 15.9 percent and lysine 1.83 to 2.53 percent of the protein. The grand mean of three replications was 12.3 percent for protein. There were 61 lines which were above this mean at both locations. Similarly the grand mean for lysine for three replications was 2.2 percent of protein and there were 61 lines which were above this.

Eight lines with lysine above 2.2 percent and 12 lines with protein above 13 percent and their Redlan hybrids were selected for replicated yield trials at two locations in 1971. All lines selected had a high rating for yield. These twenty lines together represented a range of protein from 10.0 to 14.8 percent and lysine 1.62 to 2.58 percent of protein. The low level of protein was associated with high level of lysine and vice versa.

Of the original 500 lines, seed of 119 which did not flower or were late in flowering were sent to Puerto Rico for planting in the winter of 1970-71 and to obtain chemical samples.

A total of 216 lines out of 500 were selected for planting in 1971 in two locations to obtain reliable estimates of yield and protein over years and locations.

2. Genotype by Environment Interaction (Robert Schaffert).

A genotype by environment investigation was initiated in 1970 to study the effects of environments on yield, protein content and lysine content in addition to other agronomic factors. This study consisted of 10 diverse lines from the world collection, the hybrid of each line by Redlan, the hybrid of each line by Martin, Redlan and Martin B lines and three checks. These 35 entries have been planted at four locations in Indiana, Lubbock. Texas and Mead, Nebraska. This study will be conducted for two years and the results will be available in 1971 and 1972.

3. Recurrent Selection (Robert Schaffert).

Twelve sets of four by four partial diallel crosses were made using hot water emasculation. The lines selected for the crosses were from the world collection and were high in protein and/or lysine. The F_1's were sent to be selfed in the winter nursery in Puerto Rico. The F_2 families will be grown in Lafayette in 1971 and selected for a combination of yield, protein and lysine. The next cycle will involve pyramiding the selected families in the next round of crossing.

4. Evaluation of High Protein and High Lysine Lines in a Top Cross (Robert Schaffert).

Three hundred lines selected from the world collection and other sources for high protein and/or high lysine were crossed onto two male sterile lines. The lines and hybrids will be evaluated for yield and chemical composition in three locations in 1971.

5. Tiller Control and Contribution to Yield (Dallas Oswalt).

The contribution of tillers to yield has been noted as a variable determined by population, genotype, soil and water conditions and temperature. Four populations were selected using eight selected lines and hybrids. The responses reported occurred during 1970 under moderate mid-season moisture stress. The study is to be continued looking at possible ways to control the basal tiller initiation and to determine the contribution of tillers to yield under various conditions. The results are as follows:

	Thousands/A			
Theoretical population	44	87	174	261
Main plants (48 days)	49	98	160	221
Side tillers (48 days)	87	118	94	64
Potential heads (48 days)	135	216	254	286
Heads harvested	67	95	132	175
Yield (bu/A)	111	117	117	115

6. Root Separation and Tiller Initiation (Dallas Oswalt).

Three sorghum lines and five hybrids were planted in the field with vertical separations of plant roots by plastic sheets to a six inch depth. Plant populations of 174,240 and 261,360 plants per acre were used. The number of basal tillers initiated was counted 40 days after planting. When the plant roots were separated there was an average of 23.3 and 12.9 basal tillers initiated per 20 plants compared to the checks where 6.4 and 6.1 were counted at the two respective populations. The separated plants thus had a striking increase in number of basal tillers initiated. The study is to be continued to attempt to identify the mechanisms influencing the initiation of tillers.

7. Temperature and Light Relationships to Floral Bud Initiation (Dallas Oswalt).

Eighty lines were selected for subjection to a minimum temperature of 90°F in the greenhouse and for observation in the field on identical planting dates at one location. Of the lines investigated 23 failed to produce a head in all replications, 25 lines failed to produce a head in one or more replications and the remaining 32 lines produced at least one head in each replication. All lines produced heads on all plants in the field. The study is to be continued with those that did not head and those that did produce heads and their hybrids to attempt to identify further the response of these selected entries to light and temperature in regard to floral bud initiation.

8. Results of Hot Water Emasculation (Robert Schaffert).

In 1969 several hundred sorghum inflorescences were emasculated with hot water and crossed with other lines in the nursery in order to obtain sufficient hybrid seed to plant at least two 15-foot rows. The percentage of selfed seed on the emasculated panicle was determined by comparing the progeny of the cross and the parent lines in a 20-foot row in Puerto Rico in 1969 and where seed supply permitted in the Purdue nursery in 1970.

A panicle that was estimated to begin anthesis within one to three days was selected for the hot water emasculation. An open-ended plastic tube was placed around the panicle and secured at the base of the inflorescence with an elastic band. Hot water was then placed in the tube and left for varying periods of time. No attempt was made to maintain the initial temperature, however, with the volume of water used the temperature normally dropped only two or three degrees during the duration of the time period. Early observations indicated that an initial temperature of 48°C for a period of ten minutes was the most effective for the diverse material in our nursery. Temperatures above 48°C frequently resulted in much female sterility. Temperatures below 47°C frequently resulted in a higher percentage of selfed seed on the lower panicle branches and the greatest degree of female sterility occurred on the upper panicle branches. The length of time was not as critical as the temperature of the water because the water cooled one or two degrees within a few minutes after being added to the water jacket.

When a panicle was selected that was too immature a greater amount of selfed seed was obtained. A determination of the amount of selfed seed to be expected was made by placing a small glassine bag over the lowest panicle branch before pollinating. Pollinations were made three or four days after the emasculation and repeated two days later. A few lines failed to set seed when emasculated with water at 48°C and others had over 50 percent selfed seed. The average percent of selfed seed that was produced from 30 lines emasculated with water at 48°C for 10 minutes and tested in the winter of 1969 in Puerto Rico and at Purdue during the summer of 1970 was 10.1 percent. Genotypic differences in response were apparent. The percentage of selfed seed was increased when the initial temperature was lowered to 46°C and the percentage of selfed seed was greatly increased when the initial temperature was lowered to 44°C.

9. Study on Response of Different Sorghum Hybrids to Dates of Planting, Varying Levels of Nitrogen, Plant Population and Row Spacing (Rameshwar Singh).

Six commercial hybrids (RS610, BR64, NK300, FS1A, FS24 and FS4) representing diverse height classes were planted during the summer of 1970 at Lafayette to study their responses to two planting dates (May 9 and June 9), two levels of nitrogen (150 and 300 kg available N/Ha), three row spacings (18.75, 37.50 and 75 cm) and three plant population levels (300,000, 600,000 and 900,000 plants/Ha).

A split-split plot design, with combination of dates of plantings, nitrogen and variety as main plot treatment, row spacings as sub-plot treatment and plant population as sub-sub plot treatment was used with three replications. Three hybrids, FS1A, FS24 and FS4 were discarded finally on the basis of their susceptibility to lodging. Mean yield for various treatments is given below:

Treatment		Mean yield (kg/ha)
Dates of planting	- May 9, 1970	7349.71
	- June 9, 1970	6900.83
Nitrogen levels	- 150 kg N/ha	6846.56
	- 300 kg N/ha	7403.98
Hybrids	- RS610	7455.56
	- BR64	6433.56
	- NK300	7486.69
Spacings	- 18.75 cm	6849.19
	- 37.50 cm	7287.81
	- 75.00 cm	7238.81
Plant popl./ha	- 300,000	7367.31
	- 600,000	6997.04
	- 900,000	7011.46

The early planting was superior to the late planting. The addition of 150 kg N/ha increased the grain yield by 557 kg. Of the three hybrids studied, NK300 gave the maximum yield of 7487 kg/ha. Very narrow row spacing reduced the yield significantly, but there was no marked difference when the row spacing was 37.50 or 75 cm. Three hundred thousand plants/ha, which is considered the optimum plant population, out-yielded both higher population levels in 1970 when there was mid-season moisture stress. Trials

for 1971 to measure a given hybrid's response to a high population and high soil fertility levels were to be designed on the basis of the information from this trial.

10. Seed Set Related to Time of Pollination.

Martin male steriles were bagged when approximately one-half exerted and on succeeding days pollen was collected from RS610 each day for three weeks. The amount of seed set indicates the receptivity of the stigma and viability of the pollen each day. From ten to twenty male sterile heads were pollinated each day.

Days after bagging	Average weight of seed set per head (g)
1-3	0.9
4-6	4.3
7-14	6.1
15-21	0.6

The appearance of the heads and the amount of seed set would support the hypothesis that the male sterile studied would be most receptive and make maximum seed set from about the sixth to the fourteenth day after bagging, if bagged when approximately one-half exerted. For set of lesser seed amounts the upper section was receptive after the fourth day and the lower head section remained receptive to the sixteenth day and beyond.

D. Biological and Nutritional Value Studies.

Selected lines and hybrids were provided for chick and rat feeding trials in the animal science department. Significant differences in animal performance existed when levels of protein and amino acids were

similar. The use of an in vitro dry matter disappearance measurement (IVDMD) was initiated to facilitate the selection of entries for future rat and small animal studies. Selected lines showed a strong correlation of IVDMD and polyphenol content with animal response. Seed supplies of selected types, origins and protein levels for future studies of quality performance and inheritance resulted with this crop season.

1. Short Term Feeding Experkments for the Biological Evaluation of Sorghum Samples (E. T. Mertz and R. Jambunathan).

In most rat feeding experiments for biological evaluation of a given sample, the sample is fed to six rats for a period of four weeks. Since this method needs more sample, is time consuming and expensive, we wanted to see whether we could reduce the time, sample and the number of rats used in the experiment and still obtain a meaningful nutritional evaluation of the tested samples. Twenty-one day-old weanling male rats were chosen for this study. They were fed opaque-2 cereal diet (95% opaque-2 corn, 4% salt mixture and 1% vitamin fortification mix) for a period of one week to get them accustomed to the cereal diet. The rats were then divided into groups of three having the same total weight gain and were fed the experimental sorghum diets (95% sorghum, 4% salt mixture and 1% vitamin fortification mix) for one week, and the weight gain on this diet was noted.

Table 3. Experiment I

	025-042-1	025-035	025-149	025-187	025-074	025-075	025-154
Average weight gain (1 week, 3 rats)	6	5.3	4.3	2	-4.7	-5.3	-9.0
IVDMD percent	91	71	90	59	56	40	48
Tannin percent (catechin equiv.)	0.47	0.39	0.77	5.39	9.72	11.54	12.74
Protein percent	8.51	11.57	10.82	8.44	7.50	9.07	9.16
Lysine percent	2.94	1.94	2.74	2.57	3.78	2.26	2.75

As shown in Table 3 there is a great variation in rat response within a period of one week. It was also possible to show a significant difference between the poor and the good quality of sorghum samples. When the weight gains were compared with the results obtained with IVDMD tests and the tannin content (catechin equivalent) of samples, a good similarity was observed between the weight gain and the IVDMD and the tannin content of that particular sample. The results of feeding sorghum samples to three rats for a period of two weeks are shown in Table 4 which follows. Again there is a significant difference between the good and the poor quality of sorghum samples.

Table 4. Experiment II

	0819	025-089	025-006-1	025-070	025-015	025-162	025-010-1	025-166
Average weight gain (3 rats, 2 weeks)	8.3	6.7	4.7	4.0	1.0	0.7	0.7	-4.0
IVDMD percent	90	76	72	80	61	55	72	43

2. High Protein Sorghum in Chick Diets (Jose Brandao Fonseca as part of a Ph.D. thesis in the Animal Science Department entitled "Evaluation of the Protein Quality of Selected Varieties of Corn and Sorghum for Poultry").

In experiment I the high protein sorghum 0819 was compared with regular sorghum RS610 on an iso-sorghum nitrogen basis. The results in Table 5 indicate slightly better growth and feed conversion. Methionine supplementation of either sorghum diet failed to improve growth or feed conversion.

When the two sorghums were compared on a pound for pound basis, significantly better growth resulted from the feeding of high protein sorghum 0819. The improved feed conversion of chicks fed the sorghum 0819 was not significantly different from that of chicks fed the RS610 sorghum diet.

Chicks fed a normal corn control diet presented significantly better growth and feed conversion, as compared with the sorghum diets fed at equal dietary protein levels.

Table 5. Body Weight and Feed Conversion of Chicks at Three Weeks of Age.*

Diet no.	Treatments	Dietary protein %	Chick weight[1]	Feed gain[1]
1	Sorghum RS610	16.0	268.0[c]	1.90[b]
2	Sorghum RS610 + methionine	16.0	272.6[bc]	1.92[b]
3	Sorghum 0819 + cerelose	16.0	297.6[bc]	1.82[b]
4	Sorghum 0819 + cerelose + methionine	16.0	285.4[bc]	1.83[b]
5	Sorghum 0819, same amount as sorghum in diet 1, no cerelose	17.4	318.7[b]	1.79[b]
6	Normal corn + methionine	16.0	424.0[a]	1.58[a]

[1] Means in same vertical column bearing the same superscripts are not significantly different (P> .05).

* Included glucose monohydrate and basal diet of limestone, Dicalcium phosphate, "vitamin premix" soybean oil, NaCl (iodized) and soybean meal (50% protein).

In experiment 2, except for sorghum A872 (Table 6) there were no significant differences in growth and feed conversions of chicks fed any of the high protein sorghum diets as compared with that of chicks fed the control RS610 diet. With sorghum A872, there was a significant difference in growth, but not feed conversion, when compared with RS610 on an equal sorghum protein basis, but not when compared on an equal percentage sorghum basis.

Chicks fed the 15% protein normal corn diet exhibited significantly better growth than chicks on the sorghum diets. However,

the normal corn diet containing an amount of corn and soybean meal equal to the amount of sorghum and soybean meal in the sorghum diets produced growth and feed conversion similar to those of the sorghum diets, probably because of the lower protein content (14.24%).

The results of experiment 2 agree with those of experiment 1 where a high protein sorghum failed to produce results better than

Table 6. Body Weight and Feed Conversion of Chicks at Two Weeks of Age.**

Diet No.	Treatment	Diet Protein %	Chick Weight (g)	Feed/Gain[1]
1	Sorghum RS610	15.0	154.7[c]	1.96[b]
2	Sorghum A872, equal pounds as diet 1	15.6	154.7[c]	2.26[b]
3*	Sorghum A872, isosorghum protein with diet 1	15.0	140.8[d]	2.21[b]
4	Sorghum A913, equal pounds as diet 1	17.4	156.5[c]	1.94[b]
5*	Sorghum A913, isosorghum protein with diet 1	15.0	156.9[c]	1.95[b]
6	Sorghum A881, equal pounds as diet 1	16.8	158.8[c]	1.72[b]
7*	Sorghum A881, isosorghum protein with diet 1	15.0	153.1[c]	1.95[b]
8	Normal corn, equal pounds of corn as sorghum in diet 1 and equal soybeans	14.2	162.6[c]	1.84[b]
9	Normal corn, calculated to have 15% protein	15.0	188.8[b]	1.72[b]
10	Normal corn diet + methionine up to that of diet 1	20.0	286.4[a]	1.32[a]

[1] Means in a vertical column bearing the same superscripts are not significantly different (P > .05).

* Included glucose monohydrate and basal diet of limestone, Dicalcium phosphate, "vitamin premix", soybean oil, NaCl (iodized) and soybean meal (50% protein).

** All diets included basal diet of "vitamin premix", Dicalcium phosphate, limestone, NaCl (iodized) and soybean oil.

those of regular sorghum on an iso-sorghum protein basis, and was inferior to an isonitrogenous normal corn-soybean meal diet for the growing chick when fed at suboptimal protein levels with the addition of methionine.

It should be noted that the isonitrogenous corn-soybean meal diet had more soybean protein than did the sorghum-soybean meal diets. This difference may account for the improved growth of chicks fed the isonitrogenous corn-soybean meal diets.

According to Sanford et al. (1967) methionine was the first limiting amino acid in a sorguum-soybean meal diet, with lysine being second. The results of experiment 1 do not suggest that methionine is the first limiting amino acid in these sorghum-soybean meal diets. Better growth and feed conversion of chicks fed normal corn diets as compared with chicks on sorghum diets have been reported by Kemmer and Heywang (1965) and Sanford et al. (1968), and similar results were found in these experiments. Vavich et al. (1959) showed that the nutritional value of a high protein sorghum was inferior to that of a low protein sorghum for the chick, when compared on an isonitrogenous basis. The results of this experiment suggest that the nutritive value of these three high protein sorghums is similar to that of the control sorghum RS610 when compared to an isonitrogenous basis.

In summary, the two experiments were conducted to study the nutritional value of four high protein sorghums in soybean meal type diets when fed to chicks at suboptimal protein level (15 to 16%).

In one experiment, high protein sorghum resulted in better growth as compared with regular sorghum on a pound for pound comparison basis, however, in the second experiment high protein sorghums produced similar results to those of regular sorghum when compared on the same basis. When the sorghums were compared on an isonitrogenous basis, in both experiments, similar growth and feed conversion resulted, with the exception of one high protein sorghum which produced growth significantly poorer. In both experiments, a normal corn diet isonitrogenous with the sorghum diets produced growth which was significantly better.

3. Nutritional Evaluation of Selected Sorghum Lines for Rats (Joseph Olagoke Ilori as part of a Ph.D. thesis in the Animal Science Department entitled "Nutritional Evaluation of Amino Acid Supplemented Corn Diets for Pigs and Selected Sorghum Lines for Rats").

The dietary high protein levels used, which more closely meet the rat requirement, and the overshadowing of the amino acid content of the sorghums by soybean meal which was used to raise the dietary protein level of the sorghum diets, make definite conclusions regarding the nutritive value of the three sorghums tested less apparent. However, the data from this experiment suggest that the amino acid balance of the ingested protein, rather than the absolute amount of protein ingested, is more critical in relating performance to quality. Thus, on an isonitrogenous basis, the low protein RS610 sorghum, with a slightly higher lysine level than the high protein 5147 sorghum, had a higher nutritive value. When the lysine level of all sorghum diets was to a higher but equal level for the three

sorghums, the higher protein sorghums 0819 and 5147 supported a slightly superior rat performance than the lower protein RS610 sorghum. (See Table 7)

Table 7. Effect of Sorghum Diets on Food Consumption, Weight Gain, Feed Efficiency and Serum Protein Levels of Rats in Experiment 1.

	Treatments					
	1*	2*	3*	4**	5**	6**
Sorghums	0819	5147	RS610	0819	5147	RS610
Protein %	16.0	16.0	16.0	17.1	19.0	18.1
Lysine	0.61	0.57	0.59	0.68	0.68	0.68
Daily intakes, g	15.7	15.7	17.2	16.2	17.0	17.3
Daily weight gain, g	5.8^{bc}	5.5^{c}	6.2^{ab}	6.3^{ab}	6.6^{a}	6.5^{a}
Gain/Feed	0.36^{bc}	0.33^{c}	0.35^{bc}	0.39^{a}	0.39^{a}	0.38^{ab}
Serum perotein (g/100 ml serum)	6.8^{bc}	6.5^{c}	7.2^{ab}	7.1^{ab}	7.6^{a}	7.5^{a}

abc Means within rows with different superscripts differ significantly ($P < .05$).

* 50% soybean meal as 14% of diet plus Dicalcium phosphate, limestone salt (trace mineralized), vitamin (antiobiotic premix) and cerelose.

** 50% soybean meal as 17% of diet plus above additives.

The second experiment indicated that sorghums 0819 and 2478 were nutritionally superior to all the high protein sorghums 2190, 2197, 2481, 2486 and the commercial RS610, on the basis of rat performance. (See Table 8) Sorghum 2197 was slightly nutritionally superior to all the other sorghums tested except 0819 and 2478 despite its poor

Table 8. Effect of Sorghums on Weight Gain, Feed Consumption and Feed Efficiency in Experiment 2.*

	Treatment						
	1	2	3	4	5	6	7
Sorghum no.	0819	2190	2197	2478	2481	2486	RS610
protein %	9.5	9.5	9.5	9.5	9.5	9.5	9.5
lysine %	0.25	0.20	0.28	0.25	0.23	0.20	0.19
meth.+ cystine %	0.16	0.12	0.14	0.16	0.12	0.11	0.14
threonine %	0.33	0.29	0.33	0.33	0.31	0.30	0.28
Daily gains, g	1.1^{a}	0.6^{b}	0.7^{b}	1.1^{a}	0.6^{b}	0.6^{b}	0.5^{b}
Daily feed intake, g	10.4^{ab}	10.7^{a}	8.5^{cd}	11.3^{a}	9.4^{bcd}	9.8^{bc}	8.3^{d}
Gain/feed	0.106^{a}	0.056^{c}	0.032^{b}	0.097^{a}	0.064^{c}	0.061^{c}	0.06^{c}

abcd Means within rows with different superscripts are significantly different ($P < .05$).

* All treatments are supplemented with Dicalcium phosphate, limestone, salt (trace mineralized) vitamin (antibiotic premix) and cerelose.

consumption by rats. However, under the conditions of this experiment the nutritional superiority of sorghums 0819 and 2478 over all the others tested, appeared to be primarily due to their superior amino acid balance, which was reflected in the superior feed efficiency data of rats fed these two sorghum diets. Higher protein sorghums 2190, 2481 and 2486 were not nutritionally superior to the commercial RS610 sorghum.

In general, on the basis of amino acid composition and rat performance, lysine, threonine and the total sulfur amino acids were limiting in all of the sorghum grains investigated in this experiment.

Sorghum 2190 had a poor amino acid balance but was readily consumed and 2197 had a good amino acid balance but its consumption by rats was poor. These observations tend to illustrate the importance of amino acid balance, relative to the animal's amino acid requirement and the acceptability of the ingested grain. Both factors hence need to be considered together when evaluating the nutritive value of sorghum grains.

On the basis of metabolism trials in experiment 3 it appears that the nutritional superiority of sorghums 0819 and 2478 over all others tested, was not due to differences in the digestibility of either dry matter or crude protein. (See Table 9) There was no significant difference in dry matter or crude protein digestibility in the sorghums tested. Rats fed sorghums 0819 and 2478 retained significantly ($P < .01$) more nitrogen than those fed sorghums 2486 and RS610, and significantly ($P < .05$) more than sorghums 2190, 2197 and 2481. On the basis of percent of nitrogen intake retained, the rats fed sorghums 0819 and 2478 retained a highly significant ($P < .01$) greater percentage of the N consumed than did rats fed sorghums 2190, 2481, 2486 and RS610. The percentage retention of dietary N was significantly ($P < .05$) greater in rats fed 0819 and 2478 sorghums than for 2197. Percent retention of N from 2197 was significantly ($P < .05$) greater than for 2486 and RS610. The greater amount and percent of N retained by rats fed 0819 and 2478 appeared to be due to their superior essential amino acid balance.

Table 9. The Digestibility and Nitrogen Retention of Sorghums in Experiment 3.*

	Treatment						
	1	2	3	4	5	6	7
Sorghum no.	0819	2190	2197	2478	2481	2486	RS610
protein %	9.5	9.5	9.5	9.5	9.5	9.5	9.5
lysine %	0.25	0.20	0.28	0.25	0.23	0.20	0.19
methione + cystine %	0.16	0.12	0.14	0.16	0.12	0.11	0.14
threonine %	0.33	0.29	0.33	0.33	0.31	0.30	0.28
IVDMD %[1]	83.2	85.2	85.6	84.8	85.1	84.5	85.3
Crude protein digestibility %[2]	71.3	72.6	73.7	71.5	73.7	74.5	70.7
Nitrogen retained, g	0.54^{a}	0.39^{b}	0.40^{b}	0.52^{a}	0.41^{b}	0.34^{b}	0.33^{b}
Nitrogen intake retained %	10.3^{a}	9.1^{bc}	9.3^{b}	10.9^{a}	9.0^{bc}	8.1^{c}	7.9^{c}

[1] Coefficient of apparent digestibility (ferric oxide method - at 1% level) = $\frac{\text{Feed intake-Feces}}{\text{Feed intake}} \times 100$

[2] Coefficient of apparent digestibility = $\frac{\text{N intake} - \text{Fecal N}}{\text{Nitrogen (N) intake}} \times 100$

[abc] Means within rows with different superscripts are significantly different ($P<.05$).

* Same diet as experiment II.

4. <u>In Vitro Dry Matter Disappearance Procedure Uses</u>

The system developed by Tilley and Terry (1963) was tested on grain sorghum selections and two-fold differences in amounts of dry matter lost were found. These differences correlated with brown seed coat, levels of polyphenols in the grain and animal performance. The procedure was used to make original selections for rat feeding tests. Further work is to be done to compare costs of non-biological

procedures that will give the same screen for non-ruminant feeding performance of the large number of samples available.

E. Embryo and Endosperm Composition Studies.

Previous studies indicate the embryo size and the composition of the grain sections were important for inheritance studies. Hand separations were undertaken and the sections analyzed as a follow-up to earlier work. The range and means with the correlations among these variables are presented for a selected variable oil and a high oil series of samples.

These results indicate the need for continuation of this study. Complete amino acid determinations will be made on the embryo and endosperm parts of the seed in 1971.

Variable measured	Range	Average
% protein in whole seed	9.67 to 15.45	11.57
% protein in embryo	15.49 to 21.58	18.89
% protein in non-embryo	8.42 to 14.07	10.64
weight of 100 seeds	1.506 to 3.363	2.387
% of embryo of whole seed	5.42 to 11.65	8.10
% oil of whole seed	1.92 to 5.22	3.88

Variable oil series correlations:

	% protein whole seed	% protein embryo	% protein non-embryo	Oil in whole seed	% embryo	Lys. as % protein of whole seed	Meth. in whole seed
% protein whole seed		.9540	.1639	.6671	.2552	.0749	.2967
% protein embryo			.2475	.5610	.1265	.0624	.2579
% protein non-embryo				-.0416	-.3061	.0354	.2430
Oil in whole					.7101	.3176	.3932
% embryo						.3772	-.0583
Lys. as % protein of whole seed							.0244
Meth. in whole seed							

High oil series composition:

Variable measured	Range	Average
% protein in whole seed	8.75 to 17.24	12.97
% protein non-embryo	8.16 to 16.30	12.05
% protein embryo	16.77 to 25.78	20.84
% embryo of whole seed	6.72 to 10.03	2.32
% oil of whole seed	4.48 to 5.64	4.91

High oil series correlations:

	% protein whole seed	% protein embryo	% protein non-embryo	% Oil in whole seed	Lys. as % protein of whole seed	Meth. as % of whole seed	% embryo
% protein whole seed		.5675	.9292	-.2625	.1469	-.2048	.1505
% protein embryo			.7368	-.3293	.2728	-.0679	.6647
% protein non-embryo				-.2834	.0042	-.0904	.2939
% oil in whole seed					.2010	-.0920	-.2233
Lys. as % P of whole seed						-.32[illegible]	-.2938
Meth. as % of whole seed							.1655
% embryo							

F. Dissemination of Research Results.

The Summary of the Project to January 1970 was completed and distributed to cooperators to help explain the purpose and scope of this project. This summary also gave an indication of the types of information to be made available from this project.

Computerization of data received and developed by the project was continued with much progress made toward the completion of a workable and uniform data handling system.

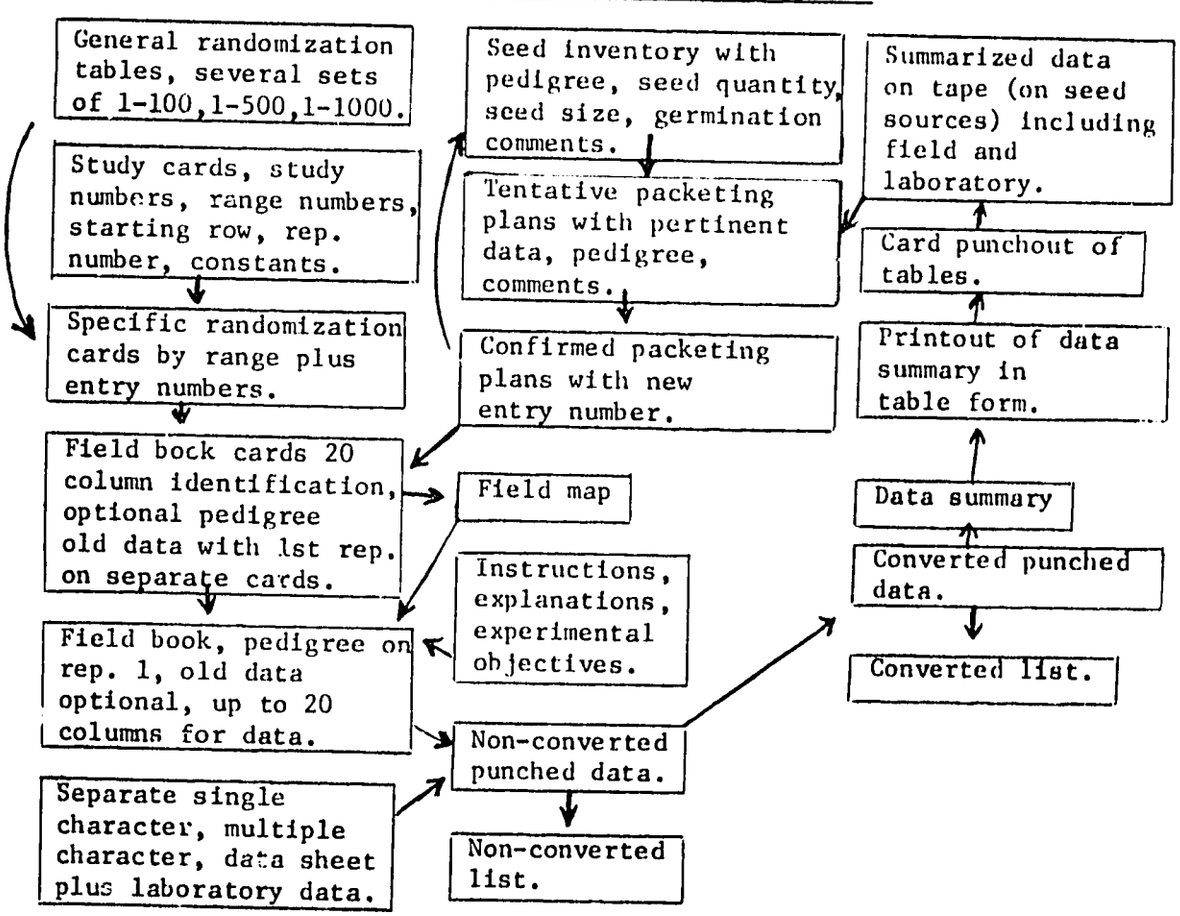
1. Purdue Sorghum Data Handling System.

In 1970 the integration of the complete data handling system came about after almost a year of planning by Dr. D. T. Cooper with the cooperation of the rest of the project staff. The field books were all print-out sheets from the computer for the first time and formats were set for getting data from all sources of field and laboratory experiments to the computer for listing, analysis and for distribution.

For many years the final data from most experiments was submitted to the computer for statistical analysis. The new dimensions this year included the computerization of randomization procedures, printing field maps and books and the printing of previous data in field books for the entries to be currently studied. These procedures made the current data from the field more easily analyzed as accumulated. A seed inventory plan was developed to facilitate packeting and sampling procedures and to handle all of these on a large scale at a greatly reduced cost. Perhaps the greatest value is in the increased accessibility to all data and the ability to rank and collate it to aid in its study and inspection.

Following is a flow chart that represents the first model of the data handling system. The rest of the system and its use is to be developed further in 1971. As one result the 1970 data were much more useful for planning and packeting the 1971 nursery.

Purdue Sorghum Data Handling System



G. Distribution of Selected Lines and Introductions.

To provide cooperators with breeding material or sources for selections of sorghum with improved yield and nutritional quality, to evaluate the lines and selections made in Indiana and to provide cooperators with a diverse array of phenotypes, sets of 300, 200 and 100 lines were distributed to 58, 43 and 12 cooperators, respectively, representing 56 countries. Instructions for management and a request for data to be returned were sent with each set of seed. Requests for seed samples to be returned for a technique study on composition and phenotypic data were sent to the 12 major cooperators. This number of sets distributed indicates the interest in and request for sets for use by cooperators. Almost all requests for seed sets were filled during the year.

The cooperators sent from their collections some 5,000 new selections for our evaluation in the 1970 nursery at Purdue. These were forwarded to India for inclusion in the world collection and Fort Collins for storage. One set was also grown in Puerto Rico for increasing seed on those that did not flower in Indiana.

A new variety "ICA-Marupaanste" was released in Colombia from seed sent to them by this project and numerous other selections have been maintained by other cooperators. The data received to date indicate that the Indiana selections from the non-sensitive light segment of the collection were usually adaptable to the over-

seas requirements and thus Indiana is an effective location for yield and quality evaluations.

These sets were selected on the basis of yield potential, protein, lysine and oil content and diversity of phenotypes. Data requested from the cooperator included flowering, height, climatic information, disease, insects and yield rating notes.

H. Encouragement of Sorghum Improvement Programs.

Personal visits by the project director were made to fifteen countries in South America, Africa and Asia to encourage personnel there and interested sponsoring agencies to make additional investments in sorghum improvement programs. Research planning for sorghum improvement, including the relatively new dimension of nutritional improvement, was conducted with concerned researchers. Correspondence has continued as the planning discussions have been followed and initiated with researchers in numerous countries not visited.

The first international meeting for sorghum investigators from all Latin American countries was held in conjunction with the VIII Reunion LatinoAmericana de Fitotecnia in Bogota, Colombia in November 1970. The project director was one of three persons who led in a roundtable discussion with over 100 workers in attendance at this meeting. The present stage of development and the availability of material for sorghum improvement in nutritional qualities dominated more than an hour of the discussion. The interest shown resulted in a suggested continuation of such meetings at least every two years.

Such meetings further indicate the need for workshops and training sessions to encourage and coordinate sorghum improvement programs.

I. Dissemination of Significant Results Obtained by Others.

Research reports which included work affected by maize research workers went to cooperators in all locations. Much correspondence and consultation was concerned with the general problems of management and environmental effects on crop nutritional quality. Consultation continued regularly with researchers in rice, wheat, maize and those concerned about possible new work with roots, tubers and edible legumes.

J. Cooperative Work Development.

The concept and actuality of a network of key sorghum research stations was further developed in 1970. The primary set of 100 lines selected for yield potential, protein level and agronomic usefulness was sent to 12 selected stations to study location interactions. These stations were in Ethiopia, Nigeria, Uganda, India (U.P. and A.P.), Korea, W. Pakistan, Thailand, Brazil (Recife, Fortaleza and São Paulo) and Peru. The response from these stations in this cooperative effort has been very good. Efforts will be made to continue to develop the effectiveness of this effort.

V. SUMMARY

1. The complete collection was grown:

   a) to obtain workable amounts of seed and establish seed supplies for items not previously grown at Purdue,

   b) to further identify insensitive day-length phenotypes potentially available for study, and

   c) to select items not already investigated for quality and inheritance. About 800 lines were selected from approximately 15,000 planted for testing in three-row plots in 1971.

2. Obtained from the total collection grown in Puerto Rico seed samples for analysis to further screen the day-length sensitive types for protein quality.

3. Over 2,300 new introduction items were grown for increasing seed, making selected crosses, obtaining selected chemical samples and making phenotypic observations.

4. Selected 85 lines from the 500 plus entries in the yield trials which produced an average yield at three locations equal to or greater than the average commercial check yields for 1971 advanced yield studies.

5. Utilized Puerto Rico winter nursery to multiply and evaluate light-sensitive lines, advanced generations and make recombinations.

6. Approximately 7,600 individual plant selections were made from segregating sources to serve as an additional source of variability for 1971 head to row planting.

7. Over 1,600 selected samples from inheritance studies, location studies and key line selections based on protein and lysine data were analyzed for complete amino acid content.
8. Studies were carried out to evaluate protein inheritance and environment interactions with special studies by Schaffert, Mohan, Singh, Oswalt and Mukuru.
9. Grew over 1,000 lines with their F_1's on two or more male steriles for yield, sterility, height, and protein response. Protein and yield data indicate both are improvable and line selections were made for inheritance studies.
10. Significant line x location interactions were found and lines which hold up well over locations and years were identified and prepared for retesting.
11. Over 4,000 lines were crossed heavily with cytoplasmic male steriles and over 200 lines were emasculated with hot water for establishment of F_1 seed supplies to enable evaluation of these selected lines and field testing for yield followed by laboratory testing of quality and feeding performance.
12. Seed was furnished for chick and rat feeding and digestibility trials in the Animal Science Department.
13. Rat and chick feeding indicate significant differences among sorghum lines in rates of feed intake and gain. The weight gains were influenced by composition, digestibility and feed intake.

14. *In vitro* dry matter disapparance tests were begun to identify differences in feeding performances of lines and hybrids. The tests showed a range of 40 to 80 percent in IVDMD rates across and seemingly independent of protein and lysine levels.

15. Over 250 lines were increased for biological testing and distribution purposes.

16. Selected samples were fractionated and separate fractions investigated for their correlation with feeding trial results and protein relationships.

17. One hundred lines not previously distributed, plus the earlier sets of 400 lines were sent to those requesting them, making a total of 148 locations receiving from 100 to 500 lines during the past two years. Response in the form of information and samples returned, varieties selected by them for their use and additional requests are good and remain constantly arriving. Twelve key locations were established for specific location interaction and composition studies.

18. Research planning and consultation was continued with a return visit to stations located in 15 countries. New programs have been established by various agencies following the visits and consultation. Increasing efforts toward nutritional quality improvement have been initiated. The director counseled with research workers in various capacities and participated in the roundtable discussion on sorghum production at a meeting of sorghum and millet research workers of Latin America at Bogota, Colombia.

VI. PUBLICATIONS

1. Progress Reports

No. 1 July 1, 1966 to December 31, 1966

No. 2 January 1, 1967 to June 30, 1967

No. 3 July 1, 1967 to December 31, 1967

No. 4 January 1, 1968 to December 31, 1968

No. 5 January 1, 1969 to June 30, 1969

No. 6 July 1, 1969 to December 31, 1969

Progress Report - July 1966 to January 1970

No. 7 January 1, 1970 to December 31, 1970

2. Thesis Studies Completed

Abifarin, Ayotunku. 1969 Ph.D. "Combining Ability and Heterosis for Yield, Protein, Lysine and Certain Plant Characters in 18 Diverse Inbreds and 56 Hybrids in *Sorghum bicolor* (L.) Moench."

Campbell, A.R. 1967 M.S. "Effect of Nitrogen Fertilization on Protein Quality and Quantity and Certain Other Characteristics of 19 Strains of *Sorghum bicolor* (L.) Moench."

Collins, Fred. 1969 Ph.D. "Genetic and Environmental Control of Protein Quantity and Quality and Their Relationships with Certain Agronomic Characters in *Sorghum bicolor* (L.) Moench."

Rodriguez, Fernando. 1969 M.S. "The Influence of Population Density on the Embryo, Seed Size, Yield and other Agronomic Characters in *Sorghum bicolor* (L.) Moench."

3. Published Papers

Nawar, Isis; Helen E. Clark; R. C. Pickett and D. M. Hegsted. "Protein Quality of Selected Lines of Sorghum vulgare for the Growing Rat" Nutritional Reports International. January 1970. Vol. 1. No. 1. pp 75-81.

Campbell, A. R. and R. C. Pickett. "Effect of Nitrogen Fertilization on Protein Quality and Quantity and Certain Other Characteristics of 19 Strains of Sorghum bicolor (L.) Moench." Crop Science. 1969. Vol. 8. pp. 545-546.

Pickett, R. C. "Sorghum Protein Quantity and Quality." Proceeding of the Twenty-Third Annual Corn and Sorghum Research Conference. Chicago, Illinois. 1968. pp. 138-140.

4. Manuscripts

Collins, F. C. and R. C. Pickett. "Combining Ability for Yield, Protein and Lysine in an Incomplete Diallel of Sorghum." In Press. Crop Science.

Collins, F. C. and R. C. Pickett. "Combining Ability for Grain yield, Protein and Lysine in a Nine Parent Diallel of Sorghum bicolor (L.) Moench." In Press. Crop Science.

Abifarian, Ayotunku and R. C. Pickett. "Combining Ability and Heterosis for Yield, Protein, Lysine and Certain Plant Characters in 18 Diverse Inbreds and 56 Hybrids in Sorghum bicolor (L.) Moench." In review for press. Crop Science.

5. Papers or Seminars Presented

Pickett, R. C. "Sorghum Protein Quantity and Quality." Grain Sorghum Research and Utilization Conference. 1969. Amarillo, Texas.

Pickett, R. C. "Protein and Yield Research in Sorghum." International Cereal Conference. 1969. Zaria, Nigeria.

Pickett, R. C. "Sorghum Breeding for Improved Protein Content, Amino Acid Composition, Yield and Digestibility." 1970. Annapolis, Maryland. AID-sponsored Workshop on Improving the Nutritional Quality of Cereals Through Breeding and Fortification.

6. Other Contributions

Pickett, R. C. Contribution on subject of "Sorghum" for the latest edition of Encyclopedia of Science and Technology. 1969.

7. Thesis Studies Completed by Cooperators in Animal Science Department.

Ilori, J. C. 1970 Ph.D. "Nutritional Evaluation of Amino Acid Supplemental Corn Diets for Pigs and Selected Sorghum Lines for Rats." Major Professor, J. H. Conrad.

Fonseca, Jose Brandao. 1970 Ph.D. "Evaluation of Protein Quality of Selected Varieties of Corn and Sorghum for Poultry." Major Professor, W. R. Featherston.

VII. LITERATURE CITED

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