AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY

1. SUBJECT CLASSIFICATION

A. PRIMARY: Agriculture — AF00-0170-0000

B. SECONDARY: Plant production--Cereals--Sorghum

2. TITLE AND SUBTITLE

Purdue international sorghum program

3. AUTHOR(S)

Axtell,J.D.

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1972	48p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS

Purdue

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*

(Presented at AAAS Washington meeting,Dec.,1972)

9. ABSTRACT

10. CONTROL NUMBER

PN-RAA-443

11. PRICE OF DOCUMENT

12. DESCRIPTORS

Nutritive value
Plant genetics
Proteins
Sorghum
Research

13. PROJECT NUMBER

14. CONTRACT NUMBER

CSD-1175 Res.

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

csd-1175

PAPER, AAAS WASHINGTON MEETING, DECEMBER 26-31, 1972

SUBJECT: PURDUE INTERNATIONAL SORGHUM PROGRAM

AUTHOR: JOHN D. AXTELL, PH.D., DIRECTOR
PURDUE INTERNATIONAL SORGHUM PROGRAM

ADDRESS: DEPARTMENT OF AGRONOMY
PURDUE UNIVERSITY
WEST LAFAYETTE, INDIANA 47907

TIME: 9:00 A.M., DECEMBER 28, 1972

PLACE: WASHINGTON-HILTON HOTEL, GEORGETOWN EAST ROOM

PROGRAM: AAAS SYMPOSIUM, ORGANIZING FOR INTERNATIONAL RESEARCH

CONVENTION ADDRESS: ROGER SMITH HOTEL

NOT FOR PUBLICATION

PURDUE INTERNATIONAL SORGHUM PROGRAM*

by
John D. Axtell
Purdue University

INTRODUCTION

SORGHUM IS THE FOURTH MOST IMPORTANT CEREAL CROP IN THE WORLD, BEING SURPASSED ONLY BY WHEAT, RICE AND CORN IN WORLD-WIDE IMPORTANCE. IN AFRICA AND MUCH OF ASIA, GRAIN SORGHUM IS THE PRINCIPAL SOURCE OF ENERGY FOR MANY MILLIONS OF PEOPLE, AND PROVIDES A MAJOR SOURCE OF PROTEIN ~~IS~~ IN THE HUMAN DIET. SOME DATA ON THE SORGHUM AND MILLET CROPS, EXTRACTED FROM THE F.A.O. PRODUCTION BOOK FOR 1968, ARE SHOWN IN TABLE 1. THE DISCREPANCY BETWEEN THE SUM OF THE TWO SUBTOTALS AND THE WORLD TOTAL ARISES BECAUSE THE U.S.S.R. WITH 3,844,000 HA IS ADDED, AND THE REGIONS "NEAR EAST," "FAR EAST," AND "AFRICA" DO NOT EMBRACE ALL THE COUNTRIES GROWING THESE CROPS. FIGURES FOR THE FAR EAST EXCLUDE CHINA.

THE STRIKING FEATURES OF TABLE 1 ARE FOUND IN THE AREAS WHERE THESE CROPS ARE USED FOR HUMAN FOOD. THEY ARE (1) THE

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*Supported by the U.S. Agency for International Development under contract CSD-1175--"Inheritance and Improvement of Protein Quality and Content in *Sorghum bicolor* (Linn.) Moench." J.D. Axtell, Project Director.

RELATIVELY HIGH PROPORTION OF THE TOTAL CEREAL ACREAGE PLANTED TO SORGHUM AND MILLETS, ALMOST 25 PERCENT, AND (2) THE LOW YIELDS IN THESE AREAS, COMPARED WITH YIELDS IN THE DEVELOPED COUNTRIES USING SORGHUMS AND MILLETS FOR STOCK FEED. THE FAR EAST HAS THE GREATEST ACREAGE, 40 MILLION HA, WHILE AFRICA HAS THE GREATEST PROPORTION OF ITS TOTAL CEREALS AREA UNDER SORGHUM AND MILLETS, ALMOST 60 PERCENT. THERE IS A GREAT NEED FOR INCREASED SORGHUM YIELDS IN THESE AREAS OF THE WORLD AND IT IS GRATIFYING TO NOTE THAT THIS NEED HAS BEEN RECOGNIZED WITH THE ESTABLISHMENT OF I C R I S A T, AN INTERNATIONAL CENTER FOR RESEARCH IN THE SEMI-ARID TROPICS, DURING THIS PAST YEAR.

THERE IS ALSO AN URGENT NEED FOR IMPROVING THE NUTRITIONAL QUALITY OF THE GRAIN SORGHUMS WHICH ARE USED IN THE HUMAN DIET IN THESE AREAS OF THE WORLD. THIS NEED WAS RECOGNIZED IN 1966 BY THE U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT WITH THE ESTABLISHMENT OF OUR PROGRAM AT PURDUE UNIVERSITY; WITH THE PRIMARY PURPOSE OF DEVELOPING AND RELEASING SORGHUM GERMPLASM WITH HIGHER PROTEIN CONTENT, IMPROVED AMINO ACID BALANCE, AND BETTER TOTAL DIGESTIBILITY FOR UTILIZATION IN THE LESSER DEVELOPED COUNTRIES OF THE WORLD. OUR PROJECT HAS MAJOR OBJECTIVES IN THREE AREAS; RESEARCH, APPLICATION AND UTILIZATION OF THE RESEARCH FINDINGS, AND TRAINING. I WOULD LIKE TO DISCUSS EACH OF THESE AREAS TO ILLUSTRATE THE INTER-DEPENDENCE OF THESE FUNCTIONS IN MEETING THE OVERALL OBJECTIVES OF THE PROJECT. I SHOULD MENTION AT THE OUTSET

THAT THIS PROJECT AT PURDUE IS BOTH INTERDEPARTMENTAL AND INTERDISCIPLINARY, INVOLVING THE DEPARTMENTS OF BIOCHEMISTRY, ANIMAL SCIENCE AND AGRONOMY WITH PARTICIPANT SCIENTISTS IN THE AREA OF PROTEIN BIOCHEMISTRY, HUMAN AND ANIMAL NUTRITION, AS WELL AS GENETICISTS, PLANT BREEDERS, AND STATISTICIANS.

RESEARCH

WE HAVE FOUR MAJOR RESEARCH OBJECTIVES AS ILLUSTRATED IN TABLE 2. FIRST, TO IDENTIFY SORGHUM LINES WITH IMPROVED PROTEIN QUALITY AND QUANTITY UTILIZING BOTH CHEMICAL AND BIOLOGICAL METHODS. SECOND, TO IDENTIFY THE CHEMICAL NATURE AND COMPOSITION OF THE PROTEIN FRACTIONS OF SELECTED SORGHUM GENOTYPES AND CORRELATE THE GRAIN FRACTION COMPOSITION WITH NUTRITIONAL QUALITY. THIRD, TO ASCERTAIN THE ROLE OF VARIOUS CHEMICAL COMPONENTS OF SORGHUM GRAIN SUCH AS TANNINS, PROTEIN QUALITY AND CARBOHYDRATE AVAILABILITY IN MONOGASTRIC ANIMAL NUTRITION. FOURTH, TO DETERMINE THE MECHANISM OF INHERITANCE OF HIGH NUTRITIONAL QUALITY AND DEVELOP BREEDING METHODS AND MATERIALS INCLUDING POPULATIONS WITH IMPROVED BIOLOGICAL QUALITY FOR POTENTIAL UTILIZATION IN DEVELOPING COUNTRIES. I WOULD LIKE TO SPEND A FEW MINUTES DESCRIBING SOME OF THE RESULTS OF OUR RESEARCH ON NUTRITIONAL QUALITY IN SORGHUM BECAUSE I BELIEVE IT WILL GIVE YOU A BETTER IDEA OF THE ROLE OF RESEARCH IN WORLD-WIDE SORGHUM PROGRAMS AT THIS POINT IN TIME.

THE NUTRITIONAL PROBLEMS IN SORGHUM PARALLEL THOSE IN OTHER MAJOR CEREALS IN MANY RESPECTS, BUT ALSO DIFFER IN SOME IMPORTANT RESPECTS. THE MAJOR COMPONENTS OF NUTRITIONAL QUALITY IN SORGHUM ARE LISTED IN FIGURE 1. PROTEIN QUALITY IS LIMITED BY THE LOW LYSINE CONTENT OF SORGHUM GRAIN, WHICH REFLECTS THE HIGH PROLAMINE CONTENT OF THE ENDOSPERM, AND THE RELATIVELY SMALL EMBRYO SIZE AS A PROPORTION OF THE MATURE

GRAIN. PROTEIN AVAILABILITY IS APPARENTLY LIMITED IN SOME SORGHUM GENOTYPES BY THE PRESENCE OF UNIDENTIFIED POLYPHENOLIC COMPOUNDS LOCATED primarily IN THE TESTA LAYER OF THE GRAIN. THESE PIGMENTED COMPOUNDS HAVE NOT BEEN WELL CHARACTERIZED CHEMICALLY AND ARE REFERRED TO GENERICALLY AS "TANNINS." THE TESTA LAYER LIES BETWEEN THE ALEURONE CELLS WHICH COMPRISE THE OUTER LAYER OF THE ENDOSPERM AND THE PERICARP OR SEED COAT AS ILLUSTRATED ON THE NEXT SLIDE. WE DO NOT FULLY UNDERSTAND HOW THESE TANNIN COMPOUNDS INFLUENCE THE NUTRITIONAL QUALITY OF SORGHUM. OUR HYPOTHESIS AT PRESENT IS THAT THE SEED PROTEINS BECOME COMPLEXED OR BOUND WITH THE TANNIN COMPOUNDS OF THE WHOLE GRAIN, AND THAT THE COMPLEXED PROTEINS ARE SUBSTANTIALLY LESS AVAILABLE FOR UTILIZATION BY MONOGASTRIC ANIMALS.

AMINO ACID COMPOSITION. THE AVERAGE PROTEIN AND AMINO ACID COMPOSITION OF 522 LINES FROM THE WORLD SORGHUM COLLECTION IS PRESENTED IN TABLE 3. THE AVERAGE PROTEIN CONTENT OF THESE LINES IS 12.6 PERCENT AND THE AVERAGE LYSINE CONTENT (EXPRESSED AS A PERCENT OF PROTEIN) IS 2.1 PERCENT. A MORE MEANINGFUL ASSESSMENT OF AMINO ACID CONTENT FROM A NUTRITIONAL POINT OF VIEW IS A COMPARISON OF ESSENTIAL AMINO ACID CONTENT IN SORGHUM WITH THE RAT REQUIREMENT, AS SHOWN IN FIGURE 3. THIS ILLUSTRATES THE DEFICIENCY IN LYSINE, AND THE EXCESSIVE LEUCINE CONTENT PRESENT IN SORGHUM. THE METHIONONE CONTENT OF SORGHUM IS LOW, BUT IF ONE CONSIDERS THE CYSTINE

CONTENT OF 1.5 PERCENT THE OVERALL SULFUR AMINO ACID CONENT APPROACHES THAT REQUIRED BY THE RAT. THE TRYPTOPHAN CONTENT OF SORGHUM BASED ON OUR EVIDENCE AT THIS TIME SEEMS TO BE ADEQUATE WHICH IS IN CONTRAST TO THE LOW TRYPTOPHAN CONTENT IN NORMAL CORN.

FRACTIONATION OF WHOLE GRAIN AND ENDOSPERM PROTEINS. DR. JAMBUNATHAN AND DR. MERTZ AT PURDUE HAVE RECENTLY COMPLETED THE FRACTIONATION OF SORGHUM PROTEINS USING THE PROCEDURE OF LANDRY AND MOREAUX (1970). THIS PROCEDURE SOLUBILIZES MOST OF THE NITROGEN OF SORGHUM AND YIELDS FIVE DIFFERENT SOLUBILITY FRACTIONS. RESULTS OF THE FRACTIONATION OF WHOLE GRAIN FROM TWO LOW TANNIN AND TWO HIGH TANNIN SORGHUM LINES ARE SHOWN IN TABLE 4. THE AVERAGE PERCENT NITROGEN IN EACH FRACTION FOR THE LOW AND HIGH TANNIN LINES IS SHOWN IN EACH COLUMN, WITH THE AVERAGE LYSINE CONTENT EXPRESSED AS PERCENT OF PROTEIN FOR EACH FRACTION IN PARENTHESES. A NUMBER OF OBSERVATIONS COULD BE MADE BUT I WOULD LIKE TO CALL YOUR ATTENTION TO TWO. FIRST, THE DISTRIBUTION OF PROTEIN IN VARIOUS FRACTIONS IS DISTINCTLY DIFFERENT BETWEEN THE HIGH TANNIN AND LOW TANNIN LINES. THIS SUGGESTS THAT THE PRESENCE OF TANNINS HAS ALTERED THE SOLUBILITY OF SORGHUM PROTEINS, PERHAPS BY BINDING OR FORMING COMPLEXES WITH THE PROTEIN. THIS IDEA IS SUPPORTED BY THE OBSERVATION THAT THE FIRST FRACTION IN THE HIGH TANNIN SAMPLES IS VERY LOW IN

PROTEIN CONTENT, ALTHOUGH ONE WOULD EXPECT IT TO BE REASONABLY HIGH SINCE FRACTION I REPRESENTS THE ALBUMINS AND GLOBULINS WHICH ARE INDISPENSABLE FOR THE GERMINATION AND SUSTENANCE OF THE PLANT. SECOND, WITHIN THE LOW TANNIN SORGHUM, THE PROTEIN CONTENT OF FRACTIONS II AND III IS HIGH, BUT THE LYSINE CONTENT OF THESE PROTEINS IS VERY LOW. A SUMMARY ILLUSTRATION OF DR. JAMBUNATHAN'S FRACTIONATION STUDIES OF PROTEINS FROM LOW TANNIN SORGHUMS IS PRESENTED IN FIGURE 4. THE BAR ON THE RIGHT OF EACH PAIR REPRESENTS PROTEIN AND LYSINE CONTENT OF THE ENDOSPERM FRACTIONS, WITH THE BAR ON THE LEFT REPRESENTING WHOLE GRAIN FRACTIONATIONS. THIS ILLUSTRATES THE PREPONDERANCE OF PROTEIN IN FRACTION II AND FRACTION III IN ENDOSPERM AND WHOLE GRAIN FRACTIONATIONS AND ALSO THE LOW LYSINE CONTENT OF PROTEINS IN THESE FRACTIONS.

GROWTH RESPONSE OF RATS RELATIVE TO LYSINE AND TANNIN CONTENT. SINCE LYSINE IS THE FIRST LIMITING AMINO ACID IN SORGHUM AN EXPERIMENT WAS DESIGNED TO VERIFY THE GROWTH RESPONSE OF RATS WHEN FED SORGHUM RATIONS SUPPLEMENTED WITH ADEQUATE LYSINE HYDROCHLORIDE TO FULFILL THE RAT REQUIREMENT FOR LYSINE PLUS A 25 PERCENT EXCESS. THE RESULTS OF THIS EXPERIMENT ARE SHOWN IN FIGURE 5. ~~THREE~~ Two LOW TANNIN LINES (IS2319, [redacted], AND IS0129) AND ONE HIGH TANNIN LINE (IS6992) WERE INCLUDED IN THIS TRIAL. AS YOU CAN SEE THE RAT GROWTH ON LOW TANNIN SORGHUM RATIONS SUPPLEMENTED

WITH LYSINE, VITAMINS, AND MINERALS WAS SUBSTANTIALLY GREATER THAN GROWTH ON THE RATION SUPPLEMENTED ONLY WITH VITAMINS AND MINERALS. IN CONTRAST, RATS FED THE HIGH TANNIN SORGHUM (IS6992) LOST WEIGHT ON THE UNSUPPLEMENTED RATION AND GAINED ONLY SLIGHTLY ON THE RATION SUPPLEMENTED WITH LYSINE. THIS OBSERVATION WAS FIRST NOTED BY DR. MERTZ AND JAMBUNATHAN ABOUT A YEAR AGO USING OTHER HIGH TANNIN SORGHUMS, AND HAS SINCE BEEN REPEATED WITH SEVERAL HIGH TANNIN LINES. THESE RESULTS SUGGEST THAT LYSINE IS THE FIRST LIMITING AMINO ACID IN LOW TANNIN SORGHUM LINES BUT THAT OTHER FACTORS ARE FIRST LIMITING IN HIGH TANNIN LINES.

THE RESULTS OBTAINED FROM LYSINE SUPPLEMENTATION EXPERIMENTS ARE SUBSTANTIATED BY DATA FROM RAT GROWTH TRIALS CONDUCTED BY DALLAS OSWALT AT PURDUE. IN THIS EXPERIMENT WE USED 17 LOW TANNIN SORGHUM LINES AND 10 HIGH TANNIN LINES WHICH REPRESENTED THE RANGE IN VARIATION FOR PROTEIN AND LYSINE CONTENT OF SORGHUM LINES AVAILABLE FROM OUR SCREENING PROGRAM OF THE WORLD SORGHUM COLLECTION. THE RESULTS OF THIS EXPERIMENT, ILLUSTRATED IN FIGURE 6, DEMONSTRATE THAT RAT WEIGHT GAIN IS DEPENDENT ON LYSINE CONTENT IN THE LOW TANNIN SORGHUM GROUP, BUT NOT IN THE HIGH TANNIN SORGHUM GROUP. THE REGRESSION OF RAT WEIGHT GAIN ON LYSINE CONTENT FOR THE HIGH TANNIN GROUP IS NEARLY ZERO WHEREAS THE REGRESSION COEFFICIENT FOR THE LOW TANNIN GROUP IS ABOUT 65. (COMMENT. I WISH I HAD TIME TO COMMENT FROM THE HISTORICAL POINT OF VIEW ON THE DIFFICULTIES CAUSED BY THIS DIFFERENCE IN RESPONSE TO LYSINE

CONTENT BETWEEN HIGH AND LOW TANNIN SORGHUM LINES BEFORE WE WERE ABLE TO DISTINGUISH DIFFERENCES BETWEEN THESE TWO GROUPS. PERHAPS YOU CAN IMAGINE THE PROBLEMS WHICH WOULD BE INVOLVED IN INTERPRETING THIS DATA IF ALL THE POINTS ON THIS GRAPH WERE INDISTINGUISHABLE. ONE WOULD CERTAINLY BE TEMPTED TO CONCLUDE THAT CHEMICAL ANALYSIS FOR LYSINE CONTENT WAS UNRELATED TO THE BIOLOGICAL VALUE OF THE GRAIN.) WE NOW HAVE A SIMPLE, RAPID CHEMICAL ASSAY FOR TANNIN CONTENT WHICH SO FAR HAS BEEN THOROUGHLY RELIABLE FOR SEPARATING SORGHUM LINES INTO HIGH AND LOW TANNIN GROUPS. THE ACIDIFIED VANILLIN METHOD OF TANNIN ANALYSIS DESCRIBED BY BURNS (1970) ESTIMATES TANNIN CONTENT AS CATECHIN EQUIVALENTS. I SHOULD EMPHASIZE THAT THE VALUES OBTAINED FROM THIS TEST ARE BASED ON CATECHIN EQUIVALENTS, NOT ACTUAL TANNIN CONTENT. ROONEY ET AL. (1972) AT TEXAS A & M HAVE REPORTED RECENTLY THAT CATECHIN EQUIVALENT VALUES FOR GRAIN SORGHUM ARE CORRELATED WITH TANNIN VALUES OBTAINED WITH OTHER METHODS. IN OUR EXPERIENCE THE RANGE OF CATECHIN EQUIVALENTS FOR SORGHUM IS FROM 0 TO 10. WE HAVE CLASSIFIED SORGHUM LINES AS LOW TANNIN IF THE CATECHIN EQUIVALENT VALUE IS BELOW 1.00.

FREQUENCY OF HIGH TANNIN SORGHUM GENEOTYPES IN THE WORLD COLLECTION. WE HAVE ONLY LIMITED EVIDENCE AT THIS TIME ON THE FREQUENCY OF HIGH TANNIN SORGHUM GENOTYPES IN THE WORLD COLLECTION. AMONG 472 LINES WHICH WE HAVE ANALYZED FOR AMINO ACID CONTENT, SHOWN

IN TABLE 5, 300 WERE CLASSIFIED AS LOW TANNIN AND 172 WERE HIGH TANNIN LINES. THE AVERAGE CATECHIN EQUIVALENT VALUES FOR THE LOW AND HIGH TANNIN LINES WERE 0.38 AND 3.40, RESPECTIVELY. THERE WERE NO SIGNIFICANT DIFFERENCES IN PROTEIN OR ESSENTIAL AMINO ACID CONTENT BETWEEN THE TWO GROUPS. WE HAVE JUST COMPLETED EVALUATING 288 LINES COLLECTED RECENTLY IN CAMEROON, AFRICA. THE DATA ON TANNIN AND PROTEIN CONTENT OF THESE LINES IS REPORTED IN TABLE 6. ROUGHLY 80 PERCENT OF THESE LINES WERE CLASSIFIED AS HIGH TANNIN GENOTYPES WITH AN AVERAGE CATECHIN EQUIVALENT VALUE OF 4.07. THERE WAS NO DIFFERENCE IN PROTEIN CONTENT BETWEEN HIGH AND LOW TANNIN GROUPS, ALTHOUGH BOTH WERE LOWER THAN THE OVERALL AVERAGE OF 12.6 PERCENT REPORTED IN TABLE 2. THIS CAN PROBABLY BE ACCOUNTED FOR BY THE OBSERVATION THAT THE CAMEROON LINES REPRESENT AN UNUSUALLY LARGE SEEDED COLLECTION. I DO NOT MEAN TO IMPLY THAT THESE HIGH TANNIN SORGHUMS ARE CONSUMED BY HUMANS. IN FACT, WE KNOW THAT THERE IS AN ALMOST UNIVERSAL PREFERENCE FOR COLORLESS, LOW TANNIN SORGHUM GRAIN FOR HUMAN CONSUMPTION WHEN THESE ARE AVAILABLE. WE DO NOT KNOW HOW FREQUENTLY HIGH TANNIN TYPES ARE USED. NOR DO I MEAN TO IMPLY THAT SOME METHOD OF FOOD PREPARATION MIGHT NOT ELIMINATE THE TANNIN BEFORE THE GRAIN IS CONSUMED. AGAIN, WE DO NOT KNOW AT THIS TIME. IN GENERAL, HOWEVER, IT CAN BE CONCLUDED THAT HIGH TANNIN SORGHUM GENOTYPES MAY COMPRISE A SIGNIFICANT PROPORTION OF THE SORGHUM GERMPLASM IN SOME AREAS OF THE WORLD.

ALKALI DEHULLING OF HIGH AND LOW TANNIN SORGHUM GRAIN. SINCE THE TANNIN IN SORGHUM GRAIN IS CONTAINED PRIMARILY IN THE TESTA LAYER BENEATH THE PERICARP, WE HAVE TRIED WITH SOME SUCCESS TO REMOVE THE TANNIN WITH AN ALKALI DEHULLING TECHNIQUE DESCRIBED BY DR. BLESSING (1971) AT THE USDA LABORATORY IN PEORIA, ILLINOIS. THIS METHOD INVOLVES HOT SODIUM HYDROXIDE TREATMENT OF THE WHOLE GRAIN FOR 6-8 MINUTES FOLLOWED BY REPEATED WASHING WITH DISTILLED WATER. THE DATA IN TABLE 7 SHOWS THE EFFECT OF DEHULLING ON TANNIN CONTENT, PROTEIN CONTENT, RAT GAIN AND FEED CONSUMPTION FOR ONE LOW TANNIN TEXAS HYBRID (RS610) AND TWO HIGH TANNIN LINES (IS6992) AND (IS8260) FROM THE WORLD COLLECTION. CATECHIN EQUIVALENT VALUES WERE REDUCED WITHOUT SUBSTANTIAL CHANGE IN PROTEIN CONTENT IN ALL CASES. RAT WEIGHT GAIN WAS NOT SIGNIFICANTLY IMPROVED BY DEHULLING THE LOW TANNIN RS610 HYBRID, BUT WAS SUBSTANTIALLY INCREASED BY DEHULLING OF BOTH HIGH TANNIN LINES. THERE WAS NO LARGE DIFFERENCE IN THE AMOUNT OF FEED CONSUMED BETWEEN HULLED AND DEHULLED SAMPLES WHICH INDICATES THAT THE POOR WEIGHT GAIN FOR WHOLE GRAIN SAMPLES OF IS6992 OR IS8260 WAS NOT CAUSED BY REDUCED INTAKE.

ALL OF OUR PREVIOUS TESTS ON THE DIFFERENCE IN RESPONSE OF LYSINE SUPPLEMENTATION BETWEEN HIGH AND LOW TANNIN SORGHUM LINES HAVE BEEN MADE BY COMPARING LINES FROM THE WORLD COLLECTION WHICH DIFFER IN TANNIN CONTENT BUT ARE NOT ISOGENIC FOR OTHER CHARACTERISTICS. A MORE DIRECT TEST CAN BE MADE BY

UTILIZING THE ALKALI DEHULLING TECHNIQUE TO OBTAIN "LOW TANNIN" CONTROL LINES WHICH CAN THEN BE COMPARED WITH WHOLE GRAIN WITH THE SAME GENETIC BACKGROUND BUT WITH A HIGH TANNIN CONTENT. THE RESULTS OF AN EXPERIMENT COMPARING THE BIOLOGICAL VALUE OF WHOLE GRAIN SAMPLES FROM TWO HIGH TANNIN LINES, AND DEHULLED COUNTERPARTS OF EACH LINE, WITH AND WITHOUT LYSINE SUPPLEMENTATION ARE SHOWN IN FIGURE 7. IN BOTH CASES THE RATS GAINED LITTLE OR NO WEIGHT ON THE WHOLE GRAIN (HIGH TANNIN) RATIONS SUPPLEMENTED WITH LYSINE, BUT RESPONDED TO LYSINE SUPPLEMENTATION OF THE DEHULLED (LOW TANNIN) COUNTERPART RATIONS. THE EVIDENCE FROM THIS AND OTHER STUDIES DISCUSSED DEMONSTRATES THAT LYSINE CONTENT IS THE MAJOR FACTOR LIMITING THE BIOLOGICAL VALUE OF LOW TANNIN SORGHUM GRAIN, BUT IS NOT FIRST LIMITING FOR HIGH TANNIN SORGHUM.

SUPPLEMENTATION WITH SOYBEAN MEAL. ONE POSSIBLE EXPLANATION FOR LACK OF RAT GROWTH RESPONSE IN LYSINE SUPPLEMENTED HIGH TANNIN SORGHUM RATIONS IS THAT THE TANNIN COMPOUNDS MAY PRODUCE A TOXIC EFFECT WHICH COUNTERACTS THE EXPECTED GROWTH RESPONSE FROM LYSINE SUPPLEMENTATION. THE DATA IN FIGURE 8 SUGGEST THAT THIS IS NOT THE CASE SINCE THE ADDITION OF ONLY FIVE PERCENT SOYBEAN OIL MEAL TO HIGH TANNIN RATIONS PRODUCED A VERY SIGNIFICANT INCREASE IN RAT GROWTH. IN THIS EXPERIMENT, CONDUCTED BY SCHAFFERT (1972) AT PURDUE, RATIONS CONTAINING TWO LOW TANNIN AND TWO HIGH TANNIN LINES

WERE SUPPLEMENTED WITH 0, 5, 10, OR 15 PERCENT SOYBEAN OIL MEAL, AND RAT GROWTH RESPONSE MEASURED IN A 13-DAY TRIAL. IT SEEMS UNLIKELY THAT THE ADDITION OF SMALL QUANTITIES OF SOYBEAN MEAL WOULD DILUTE ANY TOXIC EFFECT TO THE EXTENT REQUIRED TO ACCOUNT FOR THE SUBSTANTIAL RAT GAIN ILLUSTRATED IN FIGURE 8. WE WOULD EXPECT THE LOW TANNIN LINES TO RESPOND TO SOYBEAN SUPPLEMENTATION BECAUSE OF THE RELATIVELY HIGH LYSINE CONTENT SUPPLIED. IT IS QUITE APPARENT THAT SOMETHING IS ADDED WITH THE SOYBEAN OIL MEAL WHICH CAN CORRECT A NUTRITIONAL DEFICIENCY OR IMBALANCE IN THE HIGH TANNIN RATIONS. THE EFFECT OF SOYBEAN MEAL SUPPLEMENTATION ON FEED EFFICIENCY RATIOS IS ILLUSTRATED IN FIGURE 9. THIS AGAIN SHOWS THE STRIKING reduction [redacted]NT IN AMOUNT OF FEED CONSUMED PER GRAM OF GAIN WHEN HIGH TANNIN RATIONS ARE SUPPLEMENTED WITH 5 PERCENT OR MORE SOYBEAN MEAL. THE MOST VIABLE POSSIBILITY AT THIS TIME IS THAT THE SOYBEAN MEAL SUPPLIES AVAILABLE PROTEIN WHICH IS DEFICIENT IN HIGH TANNIN LINES BECAUSE THE SORGHUM PROTEIN IS COMPLEXED OR BY SOME OTHER MECHANISM MADE UNAVAILABLE FOR MONOGASTRIC ANIMALS. THE EVIDENCE OBTAINED BY JAMBUNATHAN AND MERTZ ON PROTEIN FRACTIONATION SUPPORTS THIS EXPLANATION, SINCE THE PRESENCE OF TANNIN COMPOUNDS APPARENTLY ALTERS THE SOLUBILITY OF MAJOR PROTEIN COMPONENTS IN HIGH TANNIN SORGHUM LINES. DR. JAMBUNATHAN IS CURRENTLY DETERMINING THE MOLECULAR WEIGHT AND OTHER CHARACTERISTICS OF THE PROTEINS IN EACH HIGH TANNIN SORGHUM FRACTION, WHICH SHOULD PROVIDE DIRECT BIOCHEMICAL EVIDENCE ON WHETHER THESE PROTEINS

ARE COMPLEXED WITH TANNINS OR NOT. THERE ARE OTHER POSSIBLE EXPLANATIONS WHICH NEED TO BE TESTED, INCLUDING THE FOLLOWING:

A) SOYBEAN MEAL MAY PROVIDE SOME OTHER ESSENTIAL AMINO ACID WHICH IS SELECTIVELY UNAVILABLE IN HIGH TANNIN RATIONS.

B) THERE MAY BE A DEFICIENCY OF AVAILABLE INORGANIC NITROGEN, NEEDED FOR BIOSYNTHESIS OF NON-ESSENTIAL AMINO ACIDS AND/OR OTHER NITROGENOUS COMPOUNDS VITAL FOR NORMAL GROWTH AND DEVELOPMENT, IN HIGH TANNIN SORGHUM RATIONS, PERHAPS BECAUSE OF THE UNAVAILABILITY OF THE NITROGEN FROM THE SORGHUM PROTEIN.

C) THERE MAY BE COMPOUNDS IN SOYBEAN MEAL WHICH CAN BIND MORE COMPETITIVELY WITH TANNINS, AND THEREBY REPLACE THE PROTEIN BOUND TO TANNIN MAKING IT MORE AVAILABLE.

EACH OF THESE POSSIBILITIES IS CURRENTLY UNDER TEST.

IN SUMMARY, THE PROTEIN QUALITY IN MOST GRAIN SORGHUM IS MARGINAL WITH REGARD TO LYSINE CONTENT, AND IT WOULD APPEAR THAT AMONG THE HIGH TANNIN LINES ONLY A PART OF THIS PROTEIN IS AVAILABLE FOR UTILIZATION BY MONOGRASTRIC ANIMALS.

WHAT IS THE STATUS OF OUR EFFORTS IN IMPROVING THE NUTRITIONAL QUALITY IN SORGHUM? I HAVE ALREADY TALKED ABOUT THE TANNIN PROBLEM. IF WE ARE CORRECT IN OUR ASSUMPTION THAT TANNINS COMPLEX WITH SEED PROTEINS, AND THAT THESE PROTEINS

ARE THEN LESS AVAILABLE IN MONOGASTRIC THERE ARE SEVERAL ALTERNATIVES:

1) USE ONLY LOW TANNIN SORGHUMS FOR CONSUMPTION BY HUMAN AND OTHER MONOGASTRIC ANIMALS AND FIND OTHER METHODS FOR CONTROLLING BIRDS, WHICH IS ONE MAJOR REASON FOR USING HIGH TANNIN SORGHUM GERMPLASM. SINCE TANNIN CONTENT IS SIMPLY INHERITED AND CONTROLLED BY ONLY ONE OR TWO MAJOR GENES THIS IS AN EASY TASK FOR THE BREEDER.

2) USE HIGH TANNIN SORGHUM LINES FOR THEIR DESIRABLE AGRONOMIC CHARACTERISTICS, AND PLAN TO SUPPLEMENT WITH ADDITIONAL PROTEIN TO MEET THE NUTRITIONAL REQUIREMENT. IF THIS APPROACH IS ADOPTED ONE SHOULD BEAR IN MIND THE POSSIBILITY THAT YOU ARE ESSENTIALLY WASTING SOME OF THE PROTEIN IN THE SORGHUM GRAIN. I DO NOT BELIEVE THAT THIS IS ECONOMICALLY FEASIBLE IN MOST AREAS OF THE WORLD WHERE SORGHUM IS A MAJOR COMPONENT OF THE HUMAN DIET.

3) THERE MAY BE DEHULLING PROCEDURES OR METHODS OF DRY MILLING THAT COULD BE USED TO REMOVE THE PERICARP AND TESTA CELLS WHICH CONTAIN THE TANNIN COMPOUNDS.

4) THERE MAY BE ADDITIVES THAT WILL PREFERENTIALLY BIND WITH THE TANNINS AND ALLOW THE PROTEIN TO BE UTILIZED.

WITH REGARD TO IMPROVEMENT OF LYSINE CONTENT THERE ARE EXCELLENT OPPORTUNITIES FOR INCREASING GERM SIZE. GRAIN SORGHUM GERM SIZE RANGES FROM 7.8 TO 12 PERCENT OF THE WHOLE GRAIN. THIS IS SMALLER THAN THE GERM SIZE IN CORN. IN MY ESTIMATION THIS DIFFERENCE EXPLAINS PART OF THE DIFFERENCE IN LYSINE CONTENT BETWEEN NORMAL CORN AND SORGHUM. NORMAL CORN CONTAINS APPROXIMATELY 2.5 TO 2.8 PERCENT LYSINE (EXPRESSED AS PERCENT OF PROTEIN) WHEREAS NORMAL SORGHUM CONTAINS APPROXIMATELY 1.9 TO 2.2 PERCENT LYSINE. THE DIFFERENCE IN AVERAGE OIL CONTENT BETWEEN CORN (4 TO 5 PERCENT) AND SORGHUM (2 TO 3 PERCENT) ALSO SUGGESTS DIFFERENCE IN GERM SIZES BETWEEN THESE SPECIES SINCE MOST OF THE OIL IS CONTAINED IN THE GERM. WE HAVE IDENTIFIED SEVERAL SORGHUM LINES WITH 2.5 TO 2.6 PERCENT LYSINE WHICH HAVE A RELATIVELY LARGE GERM SIZE. ONE SUCH LINE IS SHOWN IN THE NEXT SLIDE. WE SHOULD BE ABLE TO MAKE QUITE RAPID PROGRESS IN SELECTIONS FROM RANDOM MATING POPULATIONS DERIVED FROM SELECTED LARGE GERM LINES WITHOUT REDUCTION IN YIELD POTENTIAL. THIS SHOULD LEAD TO IMPROVED NUTRITIONAL QUALITY.

ANOTHER POSSIBILITY FOR IMPROVING LYSINE CONTENT IS THROUGH THE USE OF ENDOSPERM "MUTANTS" WHICH EFFECT CARBOHYDRATE SYNTHESIS. MISHRA ET AL. (1972) HAVE REPORTED RECENTLY THAT THESE MUTANTS IN CORN ALSO EFFECT LYSINE CONTENT IN THE ENDOSPERM. MR. RAMESHWAR SINGH WORKING IN OUR LABORATORY HAS IDENTIFIED FIVE SUCH "MUTANT" LINES IN THE WORLD SORGHUM COLLECTION THIS PAST YEAR. THE PHENOTYPES OF TWO OF THESE LINES ARE SHOWN IN THE NEXT TWO SLIDES. THE PROTEIN AND LYSINE

CONTENT OF ALL FIVE LINES ARE SHOWN IN TABLE 8. THESE ARE PRELIMINARY RESULTS, AND ARE VERY INTERESTING FROM A THEORETICAL POINT OF VIEW, BUT IT IS TOO EARLY TO SPECULATE ON THE PRACTICAL VALUE OF THESE CARBOHYDRATE MUTANTS FOR IMPROVING THE NUTRITIONAL QUALITY OF SORGHUM.

THE PROLAMINE CONTENT OF SORGHUM ENDOSPERM IS HIGH, AS WE HAVE SEEN, AND THE LYSINE CONTENT OF THE PROLAMINE FRACTION IS VERY LOW IN SORGHUM AS IT IS IN CORN. THE SITUATION IN SORGHUM PARALLELS THAT IN NORMAL CORN IN MANY RESPECTS. THERE IS EVERY REASON TO BELIEVE THAT MUTANTS WHICH REDUCE OR BLOCK PROLAMINE SYNTHESIS ALSO OCCUR IN SORGHUM. WE HAVE NOW COMPLETED EXAMINING SECTIONED KERNELS OF MOST LINES IN THE WORLD COLLECTION AND IDENTIFIED POSSIBLE OPAQUE KERNEL PHENOTYPES. SOME HAVE BEEN GROWN IN LAFAYETTE IN 1972 AND OTHERS (LIGHT-SENSITIVE LINES) ARE BEING GROWN IN PUERTO RICO THIS WINTER. PROTEIN AND LYSINE ANALYSIS OF THESE PUTATIVE OPAQUE LINES WILL REVEAL WHETHER ANY LOW PROLAMINE LINES HAVE BEEN IDENTIFIED. PRELIMINARY RESULTS OF TWO LINES FROM ETHIOPIA IDENTIFIED BY MR. RAMESHWAR SINGH ARE ENCOURAGING. THE PROTEIN CONTENT OF THESE LINES IS 12 AND 15 PERCENT, WITH LYSINE CONTENTS OF 3.0 AND 2.9 PERCENT (EXPRESSED AS PERCENT OF PROTEIN), RESPECTIVELY. DR. JAMBUNATHAN HAS JUST COMPLETED FRACTIONATION OF THE ENDOSPERN PROTEINS OF THESE TWO LINES AND THE RESULTS ARE PRESENTED IN TABLE 9. NOTE THE REDUCTION IN PERCENT PROTEIN IN THE PROLAMINE FRACTIONS (II AND III) AND THE INCREASE IN PERCENT PROTEIN IN

FRACTION I, WHICH IS THE LYSINE RICH FRACTION IN SORGHUM. DATA FROM A PRELIMINARY RAT FEEDING TRIAL OF ONE OF THESE LINES COMPARED WITH OUR BEST CHECK LINE (IS2319) IS PRESENTED IN TABLE 10. THIS VERIFIES THAT THE BIOLOGICAL VALUE OF ETHIOPIA 204-2 IS INDEED SUPERIOR TO OUR BEST CHECK LINE. WE DO NOT BELIEVE, AT THIS TIME, THAT THESE LINES FROM ETHIOPIA REPRESENT THE EQUIVALENT IN SORGHUM OF THE OPAQUE-2 HIGH LYSINE MUTANTS IN CORN. MUCH MORE INFORMATION IS NEEDED, BUT IT IS FAIR TO CONCLUDE THAT THEY REPRESENT A STEP IN THE RIGHT DIRECTION, I.E., TOWARD BETTER NUTRITIONAL QUALITY IN GRAIN SORGHUM.

IN SUMMARY, IT WILL BE NECESSARY TO CONSIDER EACH OF THESE PARAMETERS IN THE IMPROVEMENT OF NUTRITIONAL QUALITY IN SORGHUM. IT IS UNLIKELY THAT ANY LINE IN THE WORLD COLLECTION WILL HAVE ALL THREE NECESSARY CHARACTERISTICS. IN MY ESTIMATION WE WILL HAVE TO IDENTIFY LINES WITH EACH COMPONENT OF NUTRITIONAL QUALITY AND THEN RECOMBINE THEM TO OBTAIN GENOTYPES WITH THE DESIRED COMBINATION OF CHARACTERISTICS.

Application and Utilization

During the past six years numerous requests for sorghum germplasm have been received from breeders in 53 countries in all parts of the world. In response to these requests sets of potential breeding materials (including up to 500 lines) selected at Purdue for protein yield potential, diversity and potential adaptation were distributed to overseas cooperators. In addition these 500 lines were entered simultaneously in protein yield trials at two or three Indiana locations for two or more years. The Indiana tests contained 10 to 15 commercial hybrid checks representing the various height and maturity groups. Production of lines was then compared to the average commercial check production and removed if the line results were significantly lower than the hybrid check average. The data returned by overseas cooperators were utilized to evaluate yield potential and line adaptation (including disease and insect resistance) to further identify the lines showing a wide range of adaptation with the highest protein yield potential. Each of these lines has been analyzed for protein and lysine content at Purdue and fed to weanling rats for determination of nutritional quality.

Based on this data twenty lines have been selected as relatively stable in a wide range of environments for protein yield as compared to the 16 commercial hybrids used as checks. They are entered with four checks into protein yield

TRIALS DURING 1972 AT ONE OR MORE NITROGEN LEVELS WITH OVER 15 COOPERATORS WHO HAVE ACCEPTED THE RESPONSIBILITY FOR SUCH TESTS. THE COOPERATORS ARE LOCATED IN BRASIL, PERU, COLOMBIA, ARGENTINA, PUERTO RICO, INDIA, ETHIOPIA, NIGERIA, UGANDA, INDONESIA, KOREA, THAILAND, PHILIPPINES AND WEST PAKISTAN. THE LOCATION OF THESE TRIALS IS SHOWN IN FIGURE 10. IN ADDITION THESE SAME LINES HAVE BEEN SCREENED FOR DISEASE AND INSECT RESISTANCE IN COOPERATION WITH DR. FREDERICKSON AT TEXAS A & M UNIVERSITY.

EACH OF THESE COOPERATORS HAS AGREED IN ADVANCE TO RECORD AND RETURN DATA ON ADAPTABILITY INCLUDING PLANT HEIGHT, MATURITY AND LODGING RESISTANCE, AS WELL AS GRAIN YIELD, DISEASE REACTION, AND INSECT REACTION. EACH WILL RETURN A SAMPLE OF SEED PRODUCED IN THEIR TRIAL FOR CHEMICAL ANALYSIS IN OUR LABORATORY AT PURDUE.

WE ARE NOW RECEIVING THE RESULTS OF THIS FIRST INTERNATIONAL TRIAL BUT IT WILL BE SEVERAL WEEKS BEFORE AN EVALUATION CAN BE MADE. WE DO HAVE INFORMATION FROM ONE COOPERATOR, DR. M. A. FARIS IN NORTHEASTERN BRAZIL, WHICH WILL PERHAPS ILLUSTRATE WHAT CAN BE ACHIEVED UNDER SOMEWHAT OPTIMAL CONDITIONS. DR. FARIS' PROGRAM IN FORTALEZA, BRAZIL IS SPONSORED BY THE FORD FOUNDATION AND HAS BEEN IN OPERATION FOR ONLY ONE YEAR. DURING 1972 DR. FARIS EVALUATED SORGHUM LINES FROM PURDUE AND FROM SEVERAL OTHER UNITED STATES BREEDING PROGRAMS ALONG WITH AS MUCH GERMPLASM FROM OTHE PROGRAMS AROUND THE WORLD AS HE COULD OBTAIN. FROM THIS EVALUATION HE

SELECTED 25 LINES WHICH ARE BEING ENTERED IN TRIALS AT 25-30 LOCATIONS THROUGHOUT BRAZIL. NINE OF THE 15 LINES HE SELECTED WERE OBTAINED FROM THE 20 LINES IN THE PURDUE/USAID INTERNATIONAL PROTEIN TRIAL. SOME OF THESE LINES PRODUCED FIRST HARVEST YIELDS OF 4000 LBS. OF GRAIN PER ACRE UNDER IRRIGATED CONDITIONS, AND PRODUCED A SECOND RATOON CROP OF AN ADDITIONAL 5000 LBS. OF GRAIN IN A TOTAL OF LESS THAN 180 DAYS FOR THE TWO CROPS. A THIRD CROP WAS ON THE WAY WHEN DALLAS OSWALT FROM PURDUE VISITED DR. FARIS IN BRAZIL LAST AUGUST. THIS KIND OF PRODUCTION IS PROBABLY NOT AS MUCH A REFLECTION OF SUPERIOR GERMPLASM, ALTHOUGH WE HOPE THIS PLAYED A PART, AS IT IS AN ILLUSTRATION OF THE YIELD POTENTIAL OF GRAIN SORGHUM IN SOME AREAS OF THE WORLD.

I DO NOT MEAN TO BE OVERLY OPTIMISTIC ABOUT THIS PART OF OUR PROGRAM BECAUSE THERE ARE MANY DIFFICULTIES INVOLVED. THE COOPERATIVE PROGRAM IN NORTHEASTERN BRAZIL REPRESENTS ONE WITH WELL TRAINED PERSONNEL AND WITH ADEQUATE FUNDING TO DO THE JOB. NOT ALL OF OUR COOPERATORS HAVE THESE ADVANTAGES. WE NOW HAVE A PH.D. DEGREE STUDENT FROM FORTALEZA, SPONSORED BY USAID AND THE FORD FOUNDATION, WHO WE HOPE WILL PROVIDE THE CONTINUITY NEEDED FOR A SUSTAINED SORGHUM IMPROVEMENT EFFORT WHEN HE RETURNS TO BRAZIL. IT IS ALSO ENCOURAGING TO NOTE THAT THE BANK OF THE NORTHEAST IN BRAZIL HAS PROVIDED UNSOLICITED SUPPORT IN THE AMOUNT OF $10,000 PER YEAR TO DR. FARIS FOR HIS SORGHUM PROGRAM.

WE HOPE THAT THE PURDUE/USAID PROTEIN YIELD TRIAL WILL PROVIDE A BEGINNING FOR THE DEVELOPMENT OF AN INTERNATIONAL

SORGHUM IMPROVEMENT NETWORK. THIS NETWORK SHOULD INCLUDE THE UNITED STATES BASED PROGRAMS AT PURDUE; FOR NUTRITIONAL QUALITY RESEARCH; AT NEBRASKA, FOR RESEARCH ON THE PHYSIOLOGY OF YIELD; AT TEXAS A & M FOR RESEARCH ON DISEASE AND INSECT PROBLEMS, AND FOR THE COOPERATIVE U.S.D.A. CONVERSION PROGRAM; AT PUERTO RICO, FOR TROPICAL ADAPTATION RESEARCH; ALL WORKING COOPERATIVELY WITH I C R I S A T AND THE SATELLITE STATIONS ESTABLISHED BY THE HYDERBAD CENTER. IT WILL REQUIRE THE COORDINATED EFFORTS OF ALL THESE RESEARCH GROUPS TO DEVELOP THE GREAT POTENTIAL OF GRAIN SORGHUM IN SUPPLYING THE CALORIE AND PROTEIN NEEDS OF THE WORLD.

TRAINING

THE THIRD AND PERHAPS MOST IMPORTANT AREA OF EMPHASIS IN OUR PROGRAM IS TRAINING. THE MOST DELIGHTFUL ASPECT OF TEACHING, IN WHATEVER FORM IT TAKES, IN THAT IT NEVER FAILS TO BE MUTUALLY BENEFICIAL -- WE LEARN AS MUCH AS WE TEACH. THIS EFFORT IS NEVER ENDING AND INCLUDES A WIDE VARIETY OF ENDEAVORS. I WOULD LIKE TO MENTION A FEW OF THE KINDS OF EDUCATIONAL PROGRAMS WHICH WE AND OTHER PROGRAMS SUCH AS OURS ARE INVOLVED IN.

1) TRAINING INCLUDES THE GRADUATE STUDENT FROM ANOTHER CULTURE, WHO BATTLES THE LANGUAGE BARRIER, COURSE REQUIREMENTS, AND THESIS RESEARCH PROBLEM TO EMERGE WITH AN M.S. OR PH.D. DEGREE; AND AMPLE ENTHUSIASM TO SPUR US ALL ON TO MEET THE CHALLENGES OF THE WORLD AS SEEN THROUGH HIS EYES.
2) TRAINING INCLUDES THE MAN IN PERU WITH AN M.S. DEGREE FROM A U.S. UNIVERSITY WHO HAS BEEN STRUGGLING BY CORRESPONDENCE WITH US THIS PAST YEAR TO UNDERSTAND HOW TO USE THE CYTOPLASMIC MALE STERILITY SYSTEM HE HEARD ABOUT IN CLASS, IN HIS OWN SORGHUM BREEDING PROGRAM.
3) TRAINING INCLUDES THE SORGHUM WORKSHOP IN BRAZILIAN WHICH WE SPONSORED JOINTLY WITH THE MINISTRY OF AGRICULTURE AND THE BRAZILIAN USAID OFFICE THIS PAST SUMMER.

4) TRAINING INCLUDES THE UNDERGRADUATE AGRONOMY STUDENT WORKING AS EXTRA LABOR ON OUR PROJECT TO SUSTAIN HIMSELF, AND AT THE SAME TIME TRYING TO DECIDE IF GENETICS AND PLANT BREEDING IS "HIS CUP OF TEA."

5) TRAINING INCLUDES THE MANY FOREIGN VISITORS WHO SPEND A DAY OR TWO AT PURDUE TRYING TO ABSORB SOME INFORMATION HE CAN USE IN HIS OWN PROGRAM, [redacted]

6) TRAINING INCLUDES THE VISITING POST-DOCTORATE WHO HOPES TO EXTRACT THE PRACTICAL INTERDISCIPLINARY INFORMATION HE WILL NEED WHEN HE GETS HOME, AND AT THE SAME TIME COMPLETE A PUBLISHABLE RESEARCH STUDY WHICH HE NEEDS FOR HIS OWN CAREER ADVANCEMENT, ALL DURING ONLY ONE YEAR OF STUDY.

ULTIMATELY THE LONG TERM SUCCESS OR FAILURE OF OUR INTERNATIONAL PROGRAM WILL, IN MY OPINION, DEPEND ON OUR ABILITY TO TRAIN PEOPLE FROM THE LESSER DEVELOPED COUNTRIES TO RUN THEIR OWN CROP IMPROVEMENT PROGRAMS. THIS WILL REQUIRE TRAINED PEOPLE AT ALL LEVELS, FROM THE SKILLED TECHNICIAN WHO HAS SPENT 6 MONTHS AT AN INTERNATIONAL CENTER, TO THE PH.D. RESEARCH SCIENTIST WHO HAS BEEN TRAINED AT A MAJOR UNIVERSITY.

I WOULD LIKE TO CLOSE BY EMPHASIZING THE COOPERATIVE EFFORTS REQUIRED FOR THE TRAINING OF SCIENTISTS WHO CAN MEET THE CHALLENGE FACING INTERNATIONAL AGRICULTURE IN THE FUTURE.

TO ILLUSTRATE THIS POINT I WOULD LIKE TO CITE THE CASE HISTORY OF A RECENT PH.D. GRADUATE FROM THE AGRONOMY DEPARTMENT AT PURDUE UNIVERSITY. THIS YOUNG MAN RECEVIED HIS UNDERGRADUATE TRAINING AT WESTERN MARYLAND COLLEGE; A SMALL LIBERAL ARTS COLLEGE IN WESTMINISTER, MARYLAND. HE WAS AN OUTSTANDING SENIOR MAJORING IN BIOLOGY WHEN DR. WAYNE KEIM FROM PURDUE SPENT TWO DAYS ON THE WESTERN MARYLAND CAMPUS AS AN AMERICAN SOCIETY OF AGRONOMY VISITING SCIENTIST IN GENETICS, A PROGRAM SPONSORED BY THE NATIONAL SCIENCE FOUNDATION. DR. KEIM STIMULATED HIS INTEREST IN GENETICS AND HE ENTERED GRADUATE SCHOOL AT PURDUE THE FOLLOWING FALL WITH AN NSF PREDOCTORAL FELLOWSHIP. DURING HIS THREE YEARS AT PURDUE HIS INTERESTS EVOLVED FROM A STRONG INTEREST IN FUNDAMENTAL GENETICS TO A STRONG INTEREST IN APPLIED PLANT BREEDING AND INTERNATIONAL AGRICULTURE, MOTIVATED LARGELY BY A HUMANITARIAN INTEREST IN THE WELFARE OF MANKIND. HE SPENT THE LAST TWO YEARS OF HIS GRADUATE STUDENT CAREER ON A FOREIGN AREA FELLOWSHIP IN CALI, COLOMBIA SPONSORED BY THE FORD FOUNDATION. HIS PH.D. THESIS RESEARCH WAS CONDUCTED IN COLOMBIA UNDER THE GUIDANCE OF DR. CAMACHO AT THE UNIVERSITY AND DRS. GRANT AND MANER AT CIAT. ~~THE~~ HIS THESIS PROBLEM INVOLVED DEVELOPMENT OF AN ASSAY FOR TOTAL SULFUR IN GRAIN LEGUMES AND CORRELATING THE SULFUR ANALYSIS WITH AMINO ACID ANALYSIS FOR CYSTINE AND METHIONINE CONTENT, AND WITH BIOLOGICAL VALUE OF THE GRAIN LEGUME IN RAT FEEDING TRIALS. THE TECHNIQUE WAS SUCCESSFUL AND IS NOW BEING USED BY DR. MANER AT CIAT, AS WELL AS BY

OTHERS, TO SCREEN GRAIN LEGUME SPECIES FOR NUTRITIONAL QUALITY. HE IS CURRENTLY EMPLOYED BY THE ROCKEFELLER FOUNDATION AT THE INTERNATIONAL TROPICAL RESEARCH CENTER IN IBADEN, NIGERIA IN A GRAIN LEGUME BREEDING AND IMPROVEMENT PROGRAM. THIS ILLUSTRATES, IN MY OPINION, THE EXCELLENT KIND OF EDUCATIONAL EXPERIENCE WHICH IS AVAILABLE TO STUDENTS INTERESTED IN INTERNATIONAL AGRICULTURE TODAY. BOTH THE UNITED STATES UNIVERSITIES AND THE INTERNATIONAL CENTERS WILL BENEFIT FROM THIS KIND OF A COOPERATIVE EFFORT IN GRADUATE TRAINING PROGRAMS IN THE FUTURE.

IN SUMMARY, IT IS IMPORTANT FOR THE SUCCESS OF OUR INTERNATIONAL PROGRAMS TO HAVE BOTH PRODUCERS OF SCIENTIFIC INFORMATION AND CONSUMERS OF THIS INFORMATION. IT IS IMPORTANT TO HAVE BOTH PRODUCERS OF WELL-TRAINED AGRICULTURAL SCIENTISTS AND agencies who can effectively utilize their talents [redacted]. THE DIVERSE TALENTS OF UNITED STATES SCIENTIFIC PERSONNEL CAN BE, AND IN PART ARE NOW BEING COORDINATED WITH BOTH TRAINING PROGRAMS AND RESEARCH PROGRAM AT THE INTERNATIONAL CENTERS. IT WILL REQUIRE A CONTINUATION AND EXPANSION OF THESE COOPERATIVE EFFORTS IF WE ARE TO SUCCEED IN SOLVING THE FORMIDABLE CHALLENGES FACING WORLD AGRICULTURE TODAY.

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TABLE 1. Production Statistics on Sorghum and Millet Crops. (1967).

Region	Area Planted		Sorghum and Millets (% All Cereals)	Mean Yield Metric ton/ha)
	Sorghum and Millet (000 ha)	All Cereals (000 ha)		
1. Europe	142	189,898	0.07	2.10
2. North America	6,070	235,844	2.57	3.16
3. Latin America	3,311	64,690	3.57	1.50
4. Oceania	194	10,351	1.87	1.53
Subtotal	8,717	500,783	1.74	
5. Near East	2,934	41,543	7.06	1.38
6. Far East	40,683	217,891	18.67	0.50
7. Africa	29,881	51,636	57.87	0.68
Subtotal Mainly human food	73,498	311,070	23.63	
World Total	115,059	1,137,390	10.12	0.79

TABLE 2
RESEARCH OBJECTIVES FOR 1972-1977

OBJECTIVE 1

IDENTIFY SORGHUM LINES WITH IMPROVED PROTEIN QUALITY AND QUANTITY UTILIZING BOTH CHEMICAL AND BIOLOGICAL METHODS.

OBJECTIVE 2

IDENTIFY THE CHEMICAL NATURE AND COMPOSITION OF THE PROTEIN FRACTIONS OF SELECTED SORGHUM GENOTYPES AND CORRELATE THE GRAIN FRACTION COMPOSITION WITH NUTRITIONAL QUALITY.

OBJECTIVE 3

ASCERTAIN THE ROLE OF VARIOUS CHEMICAL COMPONENTS OF SORGHUM GRAIN SUCH AS POLYPHENOLS (TANNINS), PROTEIN QUALITY AND CARBOHYDRATE AVAILABILITY IN MONOGASTRIC ANIMAL NUTRITION.

OBJECTIVE 4

DETERMINE THE MECHANISM OF INHERITANCE OF HIGH NUTRITIONAL QUALITY AND DEVELOP BREEDING METHODS AND MATERIALS INCLUDING POPULATIONS WITH IMPROVED BIOLOGICAL QUALITY FOR POTENTIAL UTILIZATION IN DEVELOPING COUNTRIES.

For: Contract AID/csd-1175 - "Inheritance and Improvement of Protein Quality and Content in Sorghum bicolor (Linn.) Moench."
J. D. Axtell, Project Director.

TABLE 3

PROTEIN AND AMINO ACID COMPOSITION OF SORGHUM GRAIN*

Composition	Mean	Standard Deviation
Protein	12.61	1.89
Lysine	2.14	0.35
Histidine	2.01	0.20
Arginine	3.59	0.44
Aspartic Acid	7.83	0.77
Threonine	3.26	0.21
Serine	4.52	0.32
Glutamic Acid	23.22	1.99
Proline	8.16	0.89
Glycine	3.07	0.27
Alanine	9.89	0.71
Cystine**	1.50	
Valine	5.35	0.31
Methionine**	1.80	
Isoleucine	4.08	0.25
Leucine	14.27	1.21
Tyrosine	4.50	0.32
Phenylalanine	5.19	0.37
Tryptophan***	1.31	0.14

* Weighted average for 522 lines.
** Weighted average for 3 lines.
*** Weighted average for 9 lines.

Table 4. Nitrogen Distribution in Whole Kernels* (Lysine as Percent of Protein in Parentheses.

Fraction	Low Tannin	High Tannin
I (Saline)	16.1 (5.8)	4.9 (3.1)
II (Isopropanol)	14.5 (0.3)	4.2 (0.4)
II (Isopropanol + 2-Mercaptoethanol)	18.6 (0.1)	17.7 (0.2)
IV (Borate buffer + 2-Mercaptoethanol)	6.3 (2.3)	16.2 (2.9)
V (Borate buffer + 2-Mercaptoethanol Sodium Dodecyl Sulfate)	32.1 (2.8)	52.6 (1.3)
Total Nitrogen Extracted	87.5	89.9

*Percent of Soluble Nitrogen

Table 5. Protein and Amino Acid Composition of High and Low Tannin Grain Sorghum. (Amino Acid Content Expressed as Percent of Protein)

Essential Amino Acids	300 Low Tannin S.D.+	172 High Tannin S.D.++
Catechin Equivalents	0.38 ± 0.24	3.40 ± 2.35
Protein	12.71 ± 1.86	12.42 ± 1.95
Lysine	2.11 ± 0.33	2.15 ± 0.35
Histidine	2.02 ± 0.19	1.99 ± 0.21
Arginine	3.56 ± 0.42	3.60 ± 0.43
Threonine	3.26 ± 0.20	3.24 ± 0.18
Cystine*	0.94 ± 0.22	0.89 ± 0.22
Valine	5.33 ± 0.29	5.37 ± 0.31
Methionine*	1.02 ± 0.53	1.01 ± 0.36
Isoleucine	4.08 ± 0.25	4.07 ± 0.22
Leucine	14.33 ± 1.20	14.17 ± 1.10
Phenylalanine	5.21 ± 0.36	5.12 ± 0.34

Table 6. Frequency of High and Low Tannin Sorghum Genotypes Among 288 Lines Collected in Cameroon, Africa.

	High Tannin	Low Tannin
Number of Lines	229	59
Average Catechin Equivalent Value	4.07	0.49
Average Percent Crude Protein	10.61	10.93

Table 7

Alkali Dehulling of High and Low Tannin Grain Sorghum.

Entry	Catechin Equiv.	Percent Protein	14-Day Rat Weight Gain (g)	Feed Consumed (g)
RS 610	.48	9.90	5.26	112
RS 610 (Dehulled)	.10	9.95	6.72	132
IS 6992	1.74	9.4	5.73	99
IS 6992 (Dehulled)	.07	9.8	10.20	101
IS 8260	3.71	8.1	-4.12	95
IS 8260 (Dehulled)	.10	8.4	7.98	97

Table 8. "Sugary" or "Brittle" Endosperm Lines.

IS Number	% Protein	Lysine % of Protein	Lysine % of Sample
Sorghum Average	12.61	2.14	.269
5376	16.3	2.27	.370
5614	14.8	2.65	.392
5623	15.1	2.73	.412
4526	16.2	2.71	.439
4668	14.9	2.18	.325

Table 9. Nitrogen Distribution in Sorghum Endosperm.

Fraction	Sorghum Average	Ethiopia 204-1	Ethiopia 204-2
I	7.3	20.97	15.71
II	16.8	13.70	12.19
III	32.4	21.49	25.45
IV	7.8	8.43	5.98
V	25.3	24.23	31.84
Total Nitrogen Extracted	89.5	88.8	91.17

Table 10. Results of 7-Day Rat Feeding Trial.

Entry	Rat Weight Gain (Gms)
Ethiopia 204-2	10.2*
IS 2319 (Check)	4.3**

*Average of four rats

**Average of 3 rats

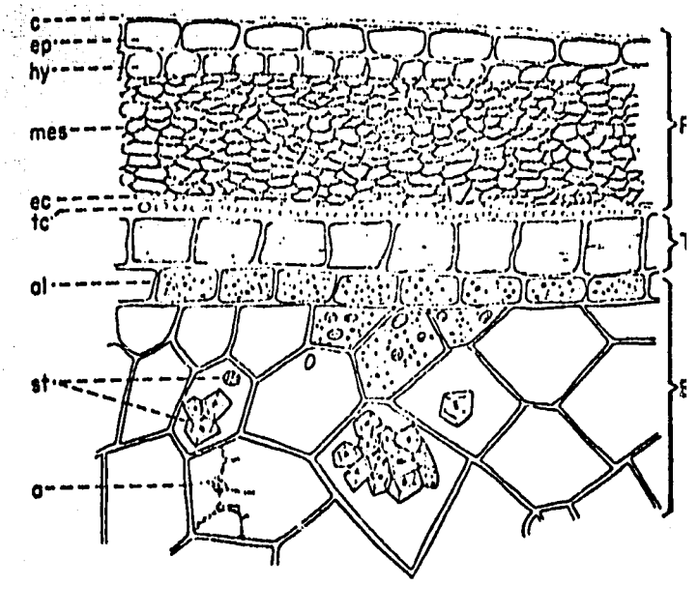
COMPONENTS OF NUTRITIONAL QUALITY IN GRAIN SORGHUM

I. PROTEIN QUALITY
   A. LYSINE CONTENT
      1. PROLAMINE CONTENT
      2. EMBRYO SIZE

II. PROTEIN AVAILABILITY
   A. TANNIN CONTENT

FIGURE 1

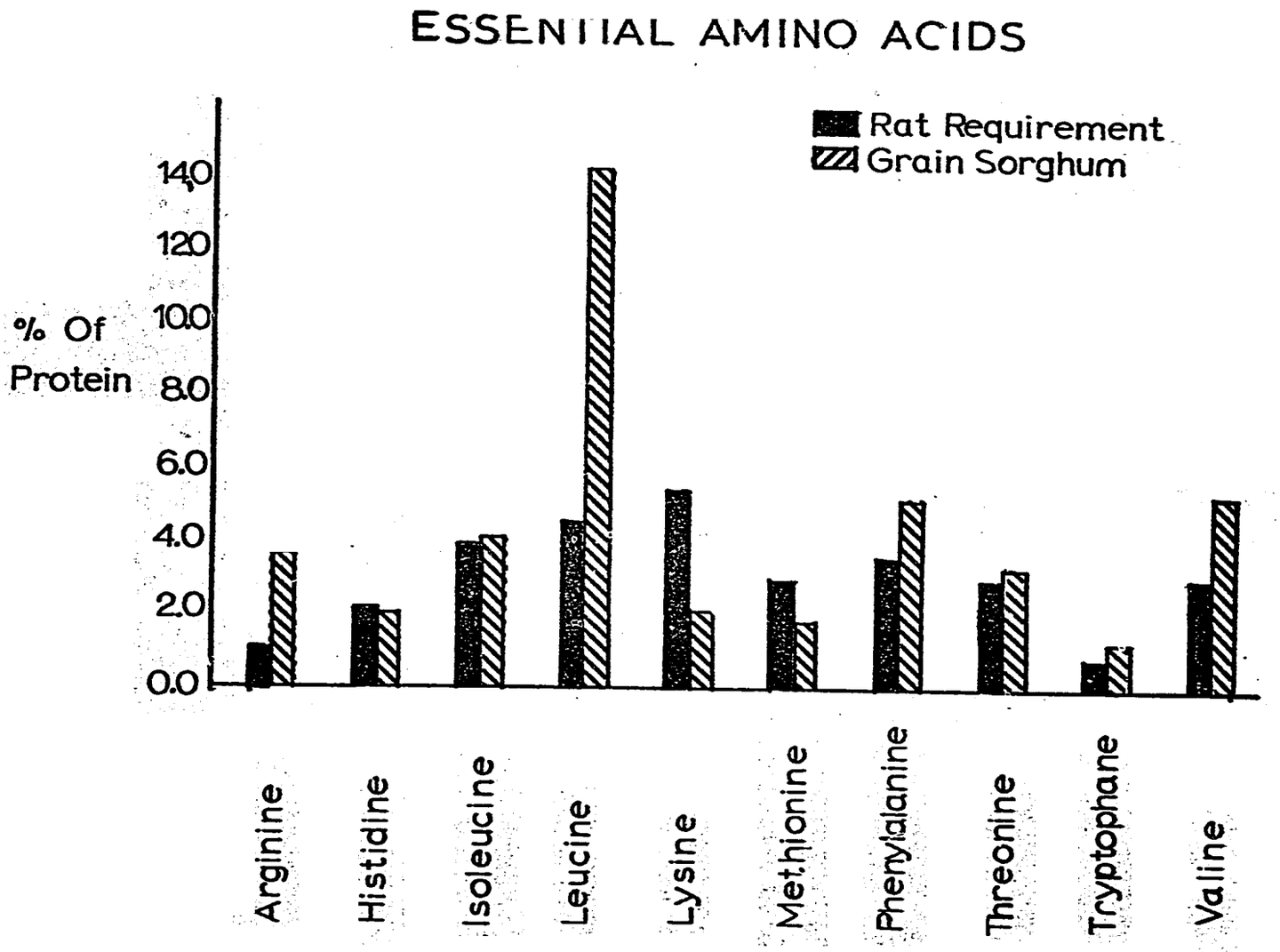
The Structure of the Mature Seed



A schematic transverse section of a portion of a feterita seed. P, pericarp, consisting of the cuticle *c*, the epidermis *ep*, the hypoderm *hy*, the starch-containing mesocarp *mes*, the cross cells *ec*, and the tube cells *tc*. T, testa or integument consisting of thick-walled, pigment-containing cells. E, endosperm, consisting of aleurone *al*, the starch cells containing granules *st*, and protein bodies *a* (Swanson, 192[illegible]

FIGURE 2

(Doggett, H. Sorghum. 1970)


ESSENTIAL AMINO ACIDS
Rat Requirement
Grain Sorghum
% Of Protein
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Arginine
Histidine
Isoleucine
Leucine
Lysine
Methionine
Phenylalanine
Threonine
Tryptophane
Valine

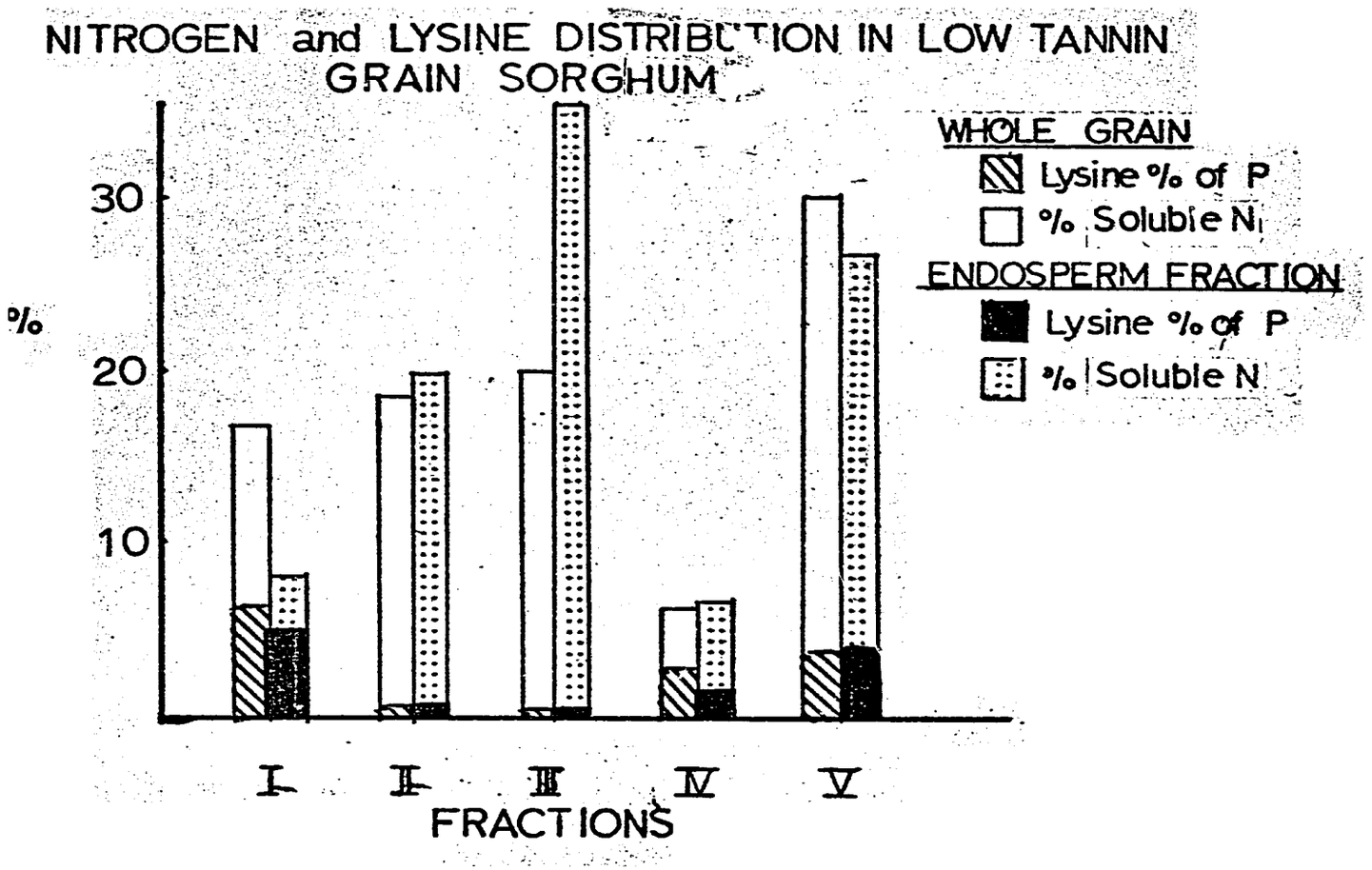

NITROGEN and LYSINE DISTRIBUTION IN LOW TANNIN GRAIN SORGHUM
%
30
20
10
WHOLE GRAIN
Lysine % of P
% Soluble N
ENDOSPERM FRACTION
Lysine % of P
% Soluble N
I
II
III
IV
V
FRACTIONS

FIGURE 4

RAT WEIGHT GAINS ON ISO-NITROGENOUS SAMPLES OF SUPPLEMENTED GRAIN SORGHUM LINES

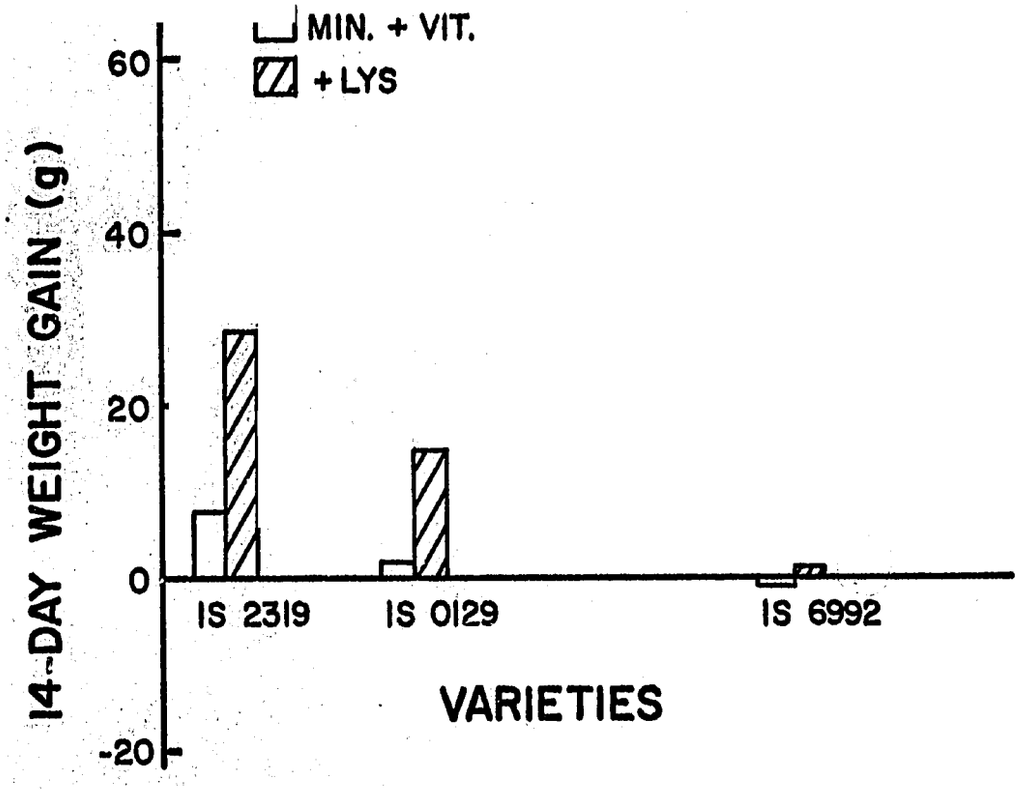


FIGURE 5

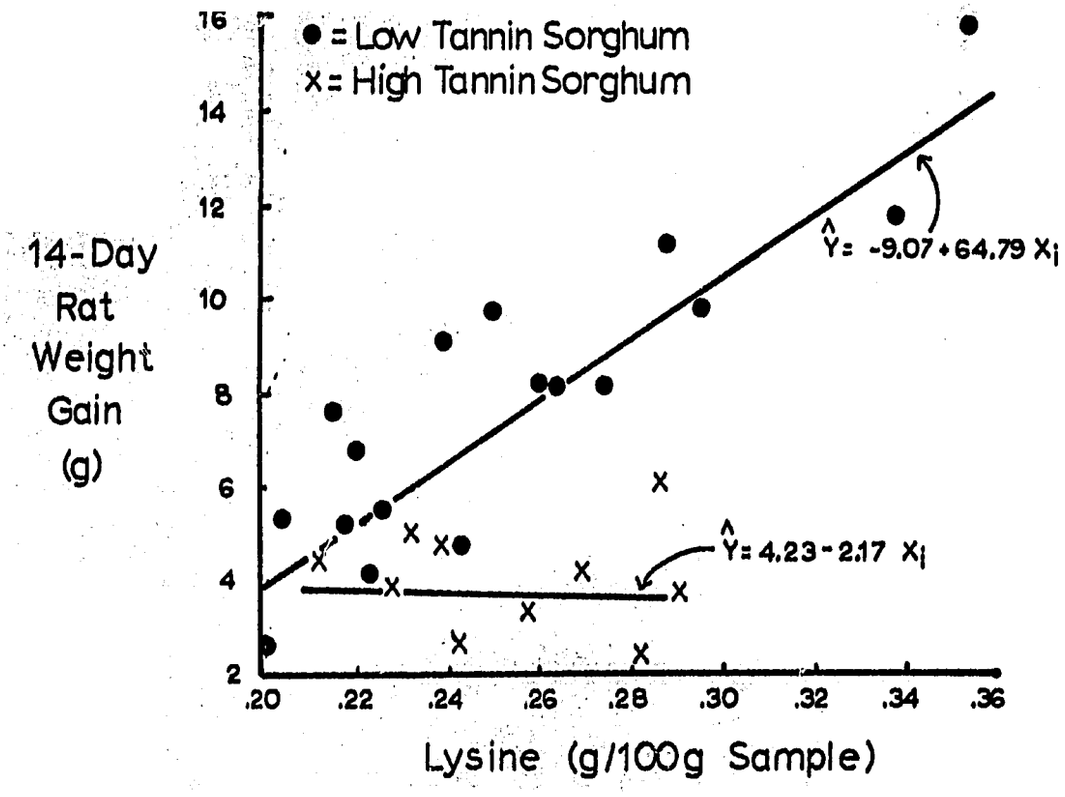

● = Low Tannin Sorghum
x = High Tannin Sorghum
14-Day Rat Weight Gain (g)
16
14
12
10
8
6
4
2
.20
.22
.24
.26
.28
.30
.32
.34
.36
Lysine (g/100g Sample)
Ŷ= -9.07 + 64.79 Xi
Ŷ= 4.23 - 2.17 Xi

FIGURE 6

Lysine Supplementation Of Whole Grain And Dehulled High Tannin Sorghum Lines.

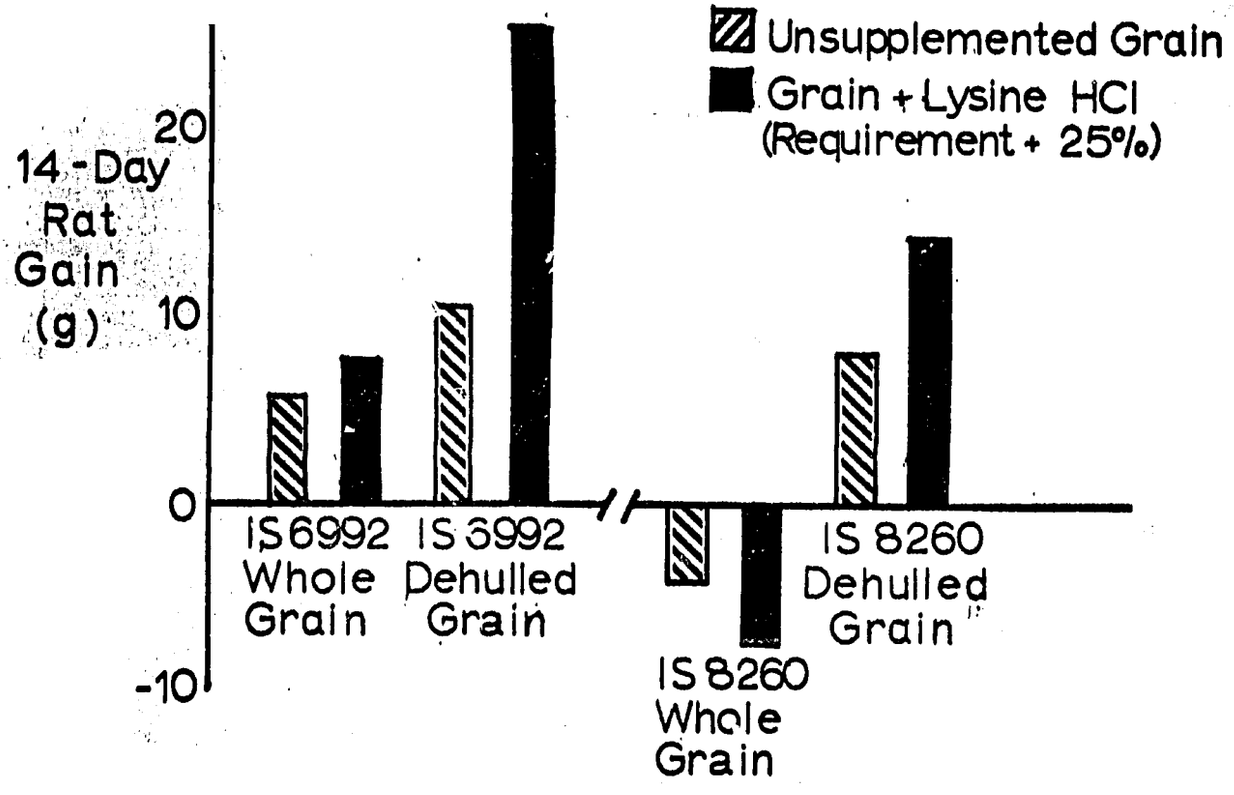


FIGURE 7

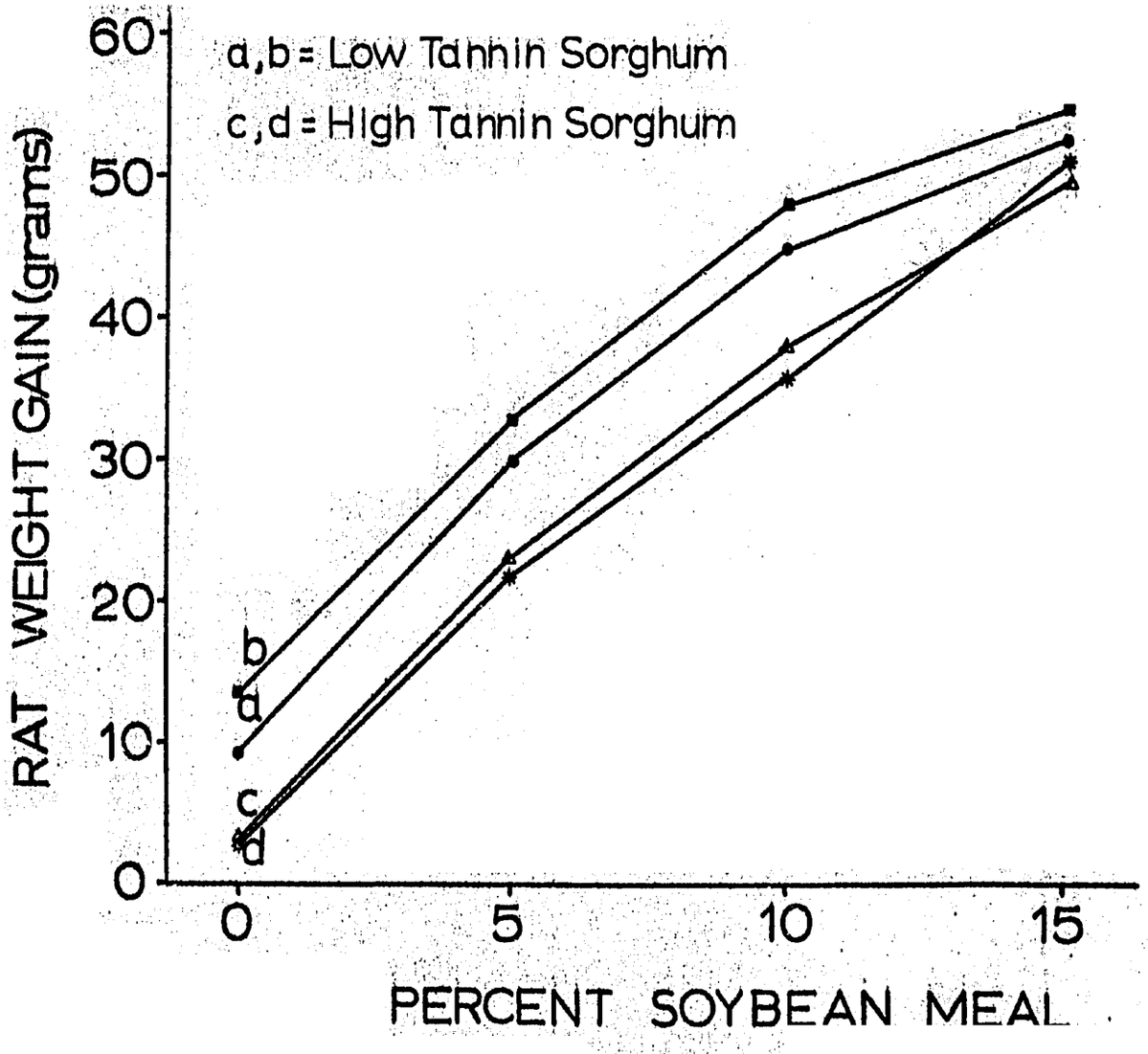

a,b = Low Tannin Sorghum
c,d = High Tannin Sorghum
RAT WEIGHT GAIN (grams)
60
50
40
30
20
10
0
b
a
c
d
0
5
10
15
PERCENT SOYBEAN MEAL

FIGURE 8

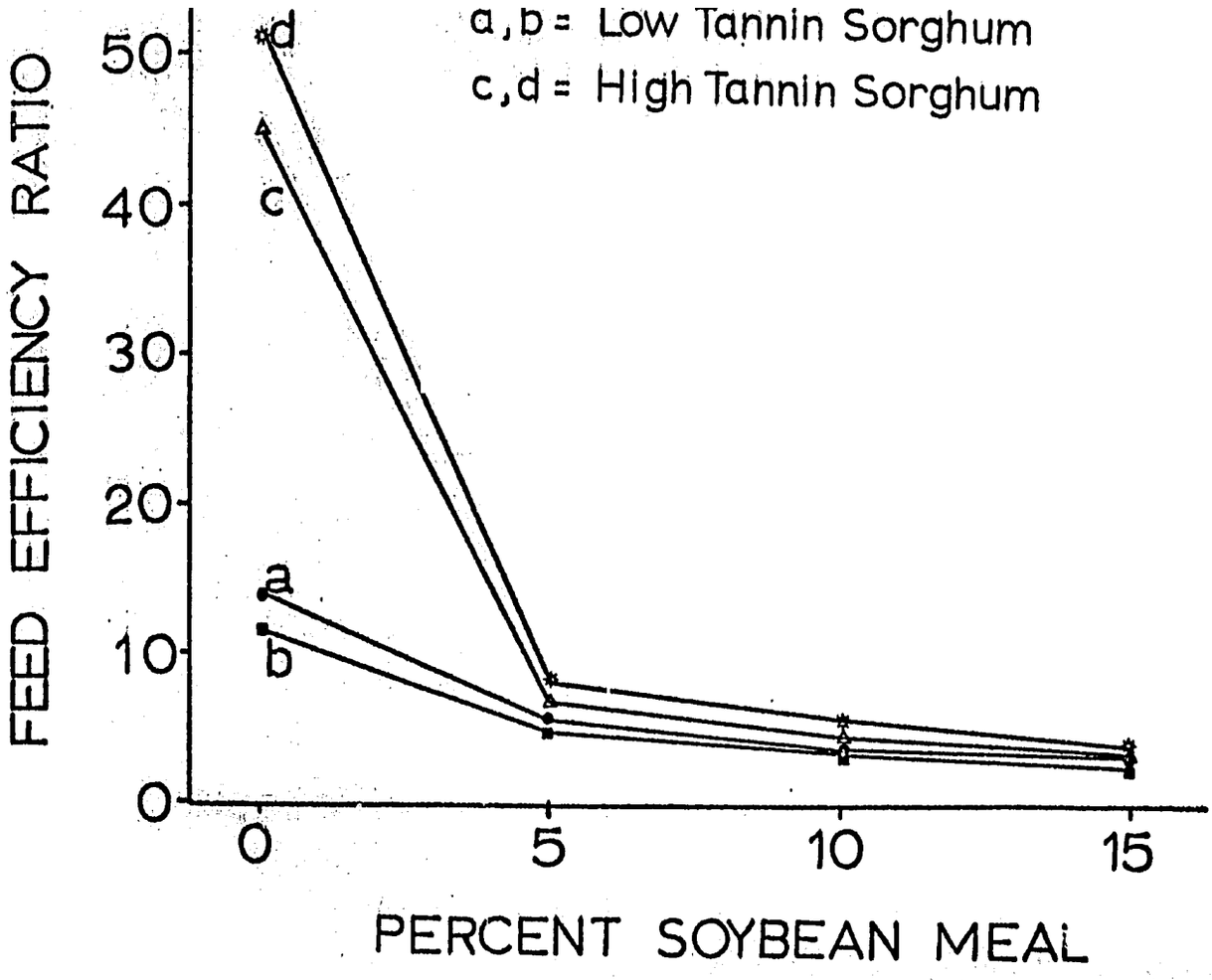

a,b = Low Tannin Sorghum
c,d = High Tannin Sorghum
FEED EFFICIENCY RATIO
50
40
30
20
10
0
d
c
a
b
0
5
10
15
PERCENT SOYBEAN MEAL

FIGURE 9

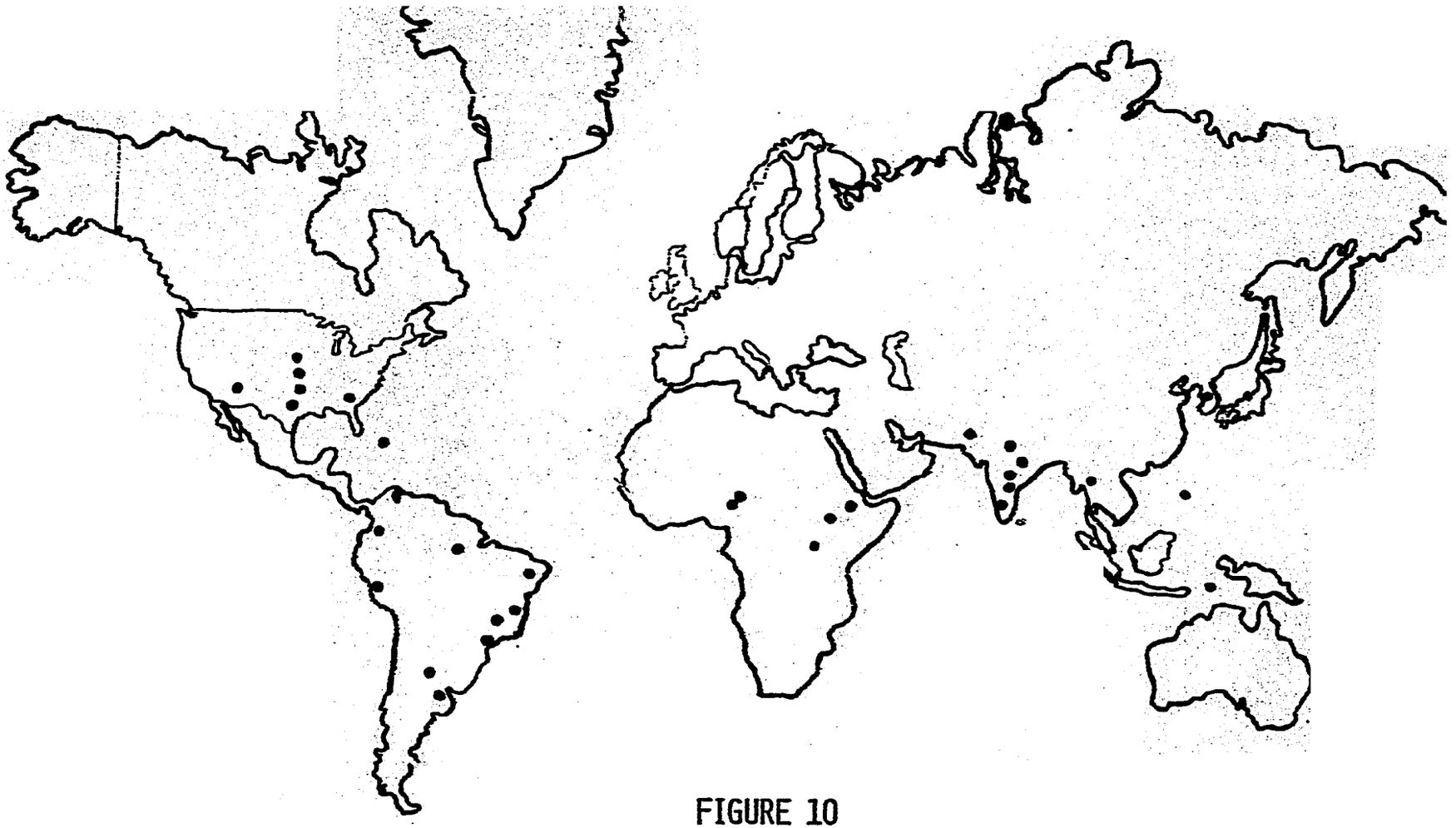


FIGURE 10

PURDUE INTERNATIONAL SORGHUM PROJECT

PROTEIN YIELD TRIALS - 1972

KEY COOPERATORS